ON TAXES, LABOUR MARKET DISTORTIONS AND PRODUCT MARKET IMPERFECTIONS

Nikola Bokan

A Thesis Submitted for the Degree of PhD
at the
University of St Andrews

2010

Full metadata for this item is available in
St Andrews Research Repository
at:
http://research-repository.st-andrews.ac.uk/

Please use this identifier to cite or link to this item:
http://hdl.handle.net/10023/3053

This item is protected by original copyright

On Taxes, Labour Market Distortions and Product Market Imperfections

A thesis presented

by

Nikola Bokan

Submitted for the degree of

Doctor of Philosophy (Economics)

University of St Andrews

United Kingdom

05 January 2010

I, Nikola Bokan, hereby certify that this thesis, which is approximately 50,000 words in length, has been written by me, that it is the record of work carried out by me and that it has not been submitted in any previous application for a higher degree.

I was admitted as a research student in September 2004 and as a candidate for the degree of PhD in Economics in September 2005; the higher study for which this is a record was carried out in the University of St Andrews between 2004 and 2010.

Date 05 January 2010. Signature of candidate

I hereby certify that the candidate has fulfilled the conditions of the Resolution and Regulations appropriate for the degree of PhD in Economics in the University of St Andrews and that the candidate is qualified to submit this thesis in application for that degree.

Date 05 January 2010. Signature of supervisor:

In submitting this thesis to the University of St Andrews we understand that we are giving permission for it to be made available for use in accordance with the regulations of the University Library for the time being in force, subject to any copyright vested in the work not being affected thereby. We also understand that the title and the abstract will be published, and that a copy of the work may be made and supplied to any bona fide library or research worker, that my thesis will be electronically accessible for personal or research use unless exempt by award of an embargo as requested below, and that the library has the right to migrate my thesis into new electronic forms as required to ensure continued access to the thesis. We have obtained any third-party copyright permissions that may be required in order to allow such access and migration, or have requested the appropriate embargo below.

The following is an agreed request by candidate and supervisor regarding the electronic publication of this thesis:

Embargo on both [all or part] of printed copy and electronic copy for the same fixed period of one year on the following ground:

Publication would preclude future publication

Date: 05 January 2010.

Signature of candidate: Signature of supervisor:

Address for correspondence:

Croatian National Bank
Trg hrvatskih velikana 3
10 000, Zagreb
Croatia

Email: nbokan@hnb.hr

For my parents

Abstract

This thesis aims to provide new and useful insights into the effects that various tax, labour and product market reforms have on the overall economic performance. Additionaly, it aims also to provide insights about the optimal monetary and fiscal policy behaviour within the economy characterized with various real labour market frictions.

We analyze the benefits of tax reforms and their effectiveness relative to product or other labour market reforms. A general equilibrium model with imperfect competition, wage bargaining and different forms of tax distortions is applied in order to analyze these issues. We find that structural reforms imply short run costs but long run gains; that the long run gains outweigh the short run costs; and that the financing of such reforms will be the main stumbling block. We also find that the effectiveness of various reform instruments depends on the policy maker's ultimate objective. More precisely, tax reforms are more effective for welfare gains, but market liberalization is more valuable for generating employment.

In order to advance our understanding of the tax and product market reform processes, we then develop a dynamic stochastic general equilibrium model which incorporates search-matching frictions, costly firing and endogenous job destruction decisions, as well as a distortionary progressive wage and a flat payroll tax. We confirm the negative effects of marginal tax distortions on the overall economic performance. We also find a positive effect of an increase in the wage tax progressivity and product market liberalization on employment, output and consumption. Following a positive technology shock, the volatility of employment, output and consumption turns out to be lower in the reformed economy, whereas the impact effect on inflation is more pronounced. Following a positive government spending shock the volatility of employment, output and consumption is again lower in the reformed economy, but the inflation response is stronger over the whole adjustment path. We also find detrimental effects on employment and output of a tax reform which keeps the marginal tax wedge unchanged by partially offsetting a decrease in the payroll tax by an increase in the wage tax rate. If this reform is anticipated one period in advance the negative effects remain all over the transition path.

We investigate the optimal monetary and fiscal policy implication of the New-Keynesian setup enriched with search-matching frictions. We show that the optimal policy features deviation from strict price stability, and that the Ramsey planner uses both inflation and taxes in order to fully exploit the benefits of the productivity increase following a positive productivity shock. We also find that the optimal tax rate and government liabilities inherit the time series properties of the underlying shocks. Moreover, we identify a certain degree of overshooting in inflation and tax rates following a positive productivity shock, and a certain degree of undeshooting following a positive government spending shock as a consequence of the assumed commitment of policy maker.

Acknowledgments

There are many people and institutions I need to thank for their selfless help and advice which made my work on this thesis much less burdensome. First of all, I want to express my gratitude to the Centre for Dynamic Macroeconomic Analysis at the University of St Andrews and the Center for Economic and Business Research at the Copenhagen Business School for generous financial support without which my doctoral studies and the research work on this thesis would not be possible. Special thanks go to my supervisors, Andrew Hughes Hallett and Charles Nolan, for their countless advices, patience, relentless optimism and continuos encouragement. I must also thank Andy for providing me with the opportunity to visit George Mason University in the USA, as well as for the hospitality and enormous help during my stay there.

The School of Economics and Finance proved to be an excellent place to write this thesis. The academic and administrative staff were always extremely helpful and supporting. Among many, I must express particular gratitude to Vladislav Damjanovic for numerous helpful discussions and for all other help provided during my stay in St Andrews. Furthermore, I thank Professor Svend E. Hougaard Jensen for various academic and financial support. The comments received at various stages from seminar participant at the University of St Andrews, the joint CEBR-CEPR 2005 conference, and the 2006 Royal Economic Society Conference are gratefully acknowledged.

Upon returning from the USA I obtained a position at the Croatian National Bank, and the last two years oblige me to give thanks to many of my fellow coworkers. Ivo Krznar and Davor Kunovac made my transition from the academic world to central banking painless and comfortable. Tomislav Galac and Evan Kraft proofread certain parts of the thesis. Among all, Maroje Lang and Ana Maria Ceh deserve special gratitude. Maroje for endless support and encouragement to finalize my PhD thesis, and Ana for infinite discussions and various help provided with respect to proofreading and editing.

Finally, I am deeply grateful to my parents and my friends. Without endless support and encouragement received from my parents this thesis would probably never been completed. There are simply no words enough to express my gratitude towards them. Last but not least, Seka was there for me when I needed her most, for which I am forever grateful.

Contents

Introduction

It is commonly argued that the main cause of differences in economic performance between the EU and North America can be attributed to product market regulations and labour market rigidities. The obvious economic lag of the EU member states relative to their American counterparts made structural reforms a leading policy issue in the Eurozone. As pointed out in Sapir et al. (2004), the removal of barriers to the mobility of goods and services, as well as labour and capital, through the Single Market Programme, aimed to boost competition and productivity, and to accelerate growth. However, growth was at best modest, leading to the deterioration of the European economic performance both in absolute terms and relative to the USA.

Sapir et al. (2004) identify several important causes of poor European performance in the last decades. One of the most important turns out to be the Europeans' poor employment record, which is related to the generous social security system. In the immediate post-war period, rising employment and increases in productivity provided resources sufficient to sustain the welfare state. However, in the last three decades, things changed. The decline in the employment rates and inability to create new employment, relative deterioration of productivity, and increase in the number of dependants required increases in the charges needed to sustain the existing level of benefits. As a result, the tax wedge on labour income had to increase. This led to further employment deterioration.

In addition to the employment effects, stress has been put on the effects of product market regulations on overall economic performance. Specifically, the increase in product market competition and market openness, as well as low entry costs, are viewed to be important stimuli for economic activity, which should have positive effects on overall employment performance. All of these things imply that what is required, but has not yet occurred on a large scale in Europe, is a thorough change in economic institutions and organizations.

However, very little formal analysis has been conducted to evaluate the potential effects of certain reforms. The main aim of this thesis is to shed new light of the effects of various labour and product market reforms on economic behavior. Specifically, we contribute to the existing literature by explicitly considering fiscal issues, such as the effects of various taxes as well as the tax reforms on overall economic performance, that have been largely neglected so far. Additionally, we aim to contribute by considering not only the long run effects of specific reforms, but also their effects on the fluctuations of macroeconomic aggregates. We complete our analysis by considering optimal monetary and fiscal policy in an economy characterized by various product and labour market frictions. We thereby challenge the results obtained by the class of models that abstracted from any real frictions on the labour market side.

The thesis is structured as follows. Chapter 1 provides both an empirical and theoretical literature review and outlines the main motivation behind the research conducted in this thesis. In Chapter 2 we develop a theoretical model of wage bargaining, with imperfect competition in the product markets and different forms of tax distortions, in order to analyze the incentives, costs and potential benefits of structural reform. The results are then used to explain policy makers' behavior, and to derive certain conclusions about which reform measures are the most effective.

Chapter 3 then takes a step towards a deeper understanding of the tax and product market reform processes, and its dynamic impacts, by developing a dynamic stochastic general equilibrium model which incorporates search-matching frictions, costly firing and endogenous job destruction decisions, as well as a distortionary progressive wage and a flat payroll tax. We also analyze the effects of a specific preanounced tax reform which keeps the marginal tax wedge constant. In Chapter 4, we analyze the implications of the search-matching frictions for the optimal conduct of monetary and fiscal policy. Specifically, we are interested in testing the robustness of the conclusions from setups which abstract from real labour market frictions and assume Walrasian labour markets. Finally, Chapter 5 concludes and suggests several possible directions for future research along the lines of the analysis presented in this thesis.

Chapter 1

Literature Review and Motivation

As stated in the Introduction, a thorough change in the European economic institutions is of utmost importance for future European economic performance, but the formal analysis of the structural reform process is scarce. The ultimate goal of this chapter is to summarize the main existing empirical and theoretical literature and to point out the main gaps and drawbacks in it what will provide the motivation for the analysis conducted in the rest of the thesis.

In section 1.1 we begin by reviewing the empirical literature which aims to explain the relatively poor European labour market performance by linking the observed unemployment behavior to the characteristics of labour market institutions. We continue by reviewing the evidence of product market effects on the reform process. Section 1.2 outlines the theoretical consideration in the literature on the effects of various reforms and provides the motivation for our research. It also outlines the main results from our subsequent analysis. Section 1.3 deals with the existing optimal monetary and fiscal policy literature and provides the motivation for the final chapter in this thesis, together with the main findings from it. Section 1.4 concludes.

1.1 Empirical Studies

1.1.1 The Importance of Labour Market Institutions

Since the European unemployment problem goes back a long time, there are many precursors in the academic literature that tried to identify unemployment's major causes. One can broadly identify three prevailing but distinct streams. Back in the 1970s, the discussion of the observed rise in unemployment mainly focused on the role of adverse economic shocks. These shocks can certainly lead to changes in employment, at least for some time, and in the last thirty years one can easily identify many plausible candidates to justify this view. In the 1970s, the focus was reasonably directed towards the oil price increase and the total factor productivity slowdown. As time advanced the list was expanded to the observed shifts in the labour demand and changes in the real interest rates. However, as pointed out in Blanchard and Wolfers (2000), the initial rise in unemployment can be attributed to the adverse common shocks, but explanations of European unemployment rates which solely focus on the effects of the adverse shocks have a serious drawback; they are incapable to explain the cross-country differences evident in the data.

An additional important characteristic of the European labour markets is the persistence of high unemployment rates for more then three decades. This observation raises the question of institutional influences on labour market developments, because it can hardy be disputed that labour market institutions affect the nature of the unemployment and have certain power in generating high unemployment rates. Moreover, it was also hard to accept that the shocks from the 1970s and the 1980s could have had such strong impacts that they would influence unemployment in the 1990s and 2000s. Additionally, the increasing commonality of shocks and the observed heterogeneity in unemployment rates among the European countries made the view resting on shocks as the sole factor behind European unemployment even more implausible. But although the shocks hitting different European economies were similar, the institutional framework across countries was not. This was sufficient to justify the shift in focus from adverse shocks to institutional characteristics in an attempt to explain the European unemployment rates.

In what follows we will present a broad overview of the most influential empirical studies. It is important to point out that although the empirical literature is highly abundant, it is far from being conclusive in every aspect. Layard et. al. (1991) were the first to point to the importance of the institutions for the functioning of labour markets. The 1994 OECD "Jobs Study" was the first and highly influential policy report to put the blame on rigid labour markets as a major cause of high European unemployment.[1] Before proceeding, and in order not to create confusion, it is useful to define what we mean by "institutions". "Institutions" in a broad sense represent certain features of labour markets such as labour taxes, laws and regulations covering employees' rights, trade unions and the structure of wage bargaining, social security system and the treatment of the unemployed,among many other things. These features have occupied the most interest in a wide range of empirical studies.

[1] It could be argued that this view is still largely dominant among policy makers and many academic economists. This can be seen in Sapir's report. But it would be wrong to say that it is universally accepted.

In a comprehensive study, Nickell (1997) and Layard and Nickell (1999) provide detailed analysis of the institutional effects on unemployment as well as on growth rates in a panel of 20 OECD countries. They argue that not every institutional rigidity is bad for the unemployment and growth, and identify the subset of labour market institution on which economic policies should be focused. More precisely, they find some evidence for the overall negative effect of labour taxes on short-run and possibly a long-run unemployment. Furthermore, unions, wage setting and social security systems have additional important effects on unemployment, whereas employment protection and strict labour market regulations are found to have no effect. However, in a similar study, albeit concentrated on the measure of structural instead of actual unemployment, Elmeskov et al. (1998) conclude that an important fraction of the estimated changes in structural unemployment cannot be ascribed to changes in institutions.

Several empirical studies investigated the impact of employment protections, since employment protections are frequently criticized as being the important source of the labour market inflexibility. Despite this widely accepted view, empirical studies have mixed results. Lazear (1990) shows an important effect of employment protection on unemployment. Addisson and Grosso (1996) extend the Lazear (1990), correct for data mistakes and apply the correct estimation procedure, and conclude that there is little to suggest that the contribution of the severance payments to rising unemployment is material. Bentoila and Bertola (1990) develop a dynamic partial equilibrium model and calibrate it to the average European economy. They find that firing costs have a larger effect on firms' propensity to fire than to hire, and a slight positive effect on long-run employment. In contrast, Abraham and Houseman (1993) find a negative effect of employment protection policy on employment and suggest a hiring subsidy to dampened the adverse effects on job creation. Layard and Nickell (1999) also can only identify a very small effect of employment protection on the unemployment rate. However, as in Lazear (1990), the negative effect of employment protection on the employment-population ratio is significant.

The importance of the tax impact on unemployment remains the subject of some debate despite the numerous empirical studies. Again, empirical evidence is inconclusive. Some studies such as Gruber (1994) and Layard and Nickell (1999), indicate that the long run effects of differential taxes on unemployment are absent. On the other hand, Scarpetta (1996) confirms the positive albeit small influence of the tax wedge on the unemployment, a result also obtained in Layard and Nickell (1999). In contrast, Daveri and Tabellini (2000), who undertake an extensive OECD panel study and allow the coefficient on taxes to differ between three group of countries, find significant positive and large effects of the tax wedge on unemployment of the group containing the continental European countries. Nickell et al. (2003) find similar results when controlling for a broader set of the labour market institutions. It is important to point out that most of the studies abstracted from the progressivity of the tax system. When progressivity is included in the analysis, several studies, such as Lockwood and Manning (1993) and Holmlund and Kolm (1995), find positive effects of the increase in progressivity on the employment rate.

The final stream of literature combines the two approaches and investigates whether both the shocks and the institution as well as the interactions of relatively stable institutions and shocks, lies behind observed high unemployment rates in continental Europe.

As emphasized by Blanchard and Wolfers (2000) the explanation relying solely on the institutions is potentially capable to explain the observed cross-country differences in the unemployment rates, but it is not capable to explain the observed evolution over time, since those institutions were much the same in the 1960s as they are today. The main idea in this approach is that although the shocks drive the unemployment, the size of the unemployment consequences of any particular shock is determined by the underlying institutional structure of the economy. This approach is inherently capable of explaining not only the increase in unemployment rates but also the heterogeneity in unemployment dynamics. Bruno and Sachs (1985) first emphasized the importance of both shocks and institutions in explaining unemployment. Their interaction was first presented by Layard et al. (1991), whereas Phelps (1994) was the first to apply panel data analysis to explain the effects of shocks and institution on long run unemployment. The most prominent paper in this line of research is the study by Blanchard and Wolfers (2000). They consider two different panel data specifications; one assuming unobserved but common shocks, and another using artificially constructed country specific shocks such as interest rate, labour demand and total factor productivity shocks. In both specifications, they allow for interaction between institutions (assumed not to be time varying) and the shocks, and find, somewhat surprisingly, that this type of specification can account for both the rise in the unemployment and the observed heterogeneity. Moreover, the magnitudes of the shocks as well as of the institutional effects are empirically plausible.

In a similar study, Belot and Van Ours (2001) start from the argument that the role of each institution depends crucially on the rest of the surrounding institutional framework and analyze the importance of the direct interaction between specific institutions. They find that without controlling for country and time period fixed effects and abstracting from interactions, the unemployment rate is positively related to taxes, the replacement rate and the level of union density whereas employment protection and centralization have significant negative effects. However, when the controls are introduced, the direct effect of every institution on the unemployment rate becomes insignificant, implying that unemployment was caused by the fixed differences across countries and time and not by within country variations in labour market institutions. However, by controlling for the interactions among specific institution, the effects of the tax rate turn out to be significant, the more so the larger is the replacement rate. On the other hand, the effect of employment protection is significant only at the decentralized bargaining level. These results imply a certain importance of interaction effects.

In order to test the Blanchard and Wolfers (2000) critique of the approach based on institutions as the sole cause of the European unemployment, and to determine the amount of the change in long term unemployment that can be explained by changes in the labour market institutions, Nickell et al. (2005) employ a long time series for the set of 20 OECD countries. The proxies for institutions they use are the standard ones as outlined in Oswald (1997), namely taxes, trade union power, benefits and wage inflexibility. They test the null hypothesis of pure institutional capability to explain changes in unemployment against the alternative that explanation of changes in unemployment requires interactions between shocks and relatively stable institutions.

Since the aim is to explain actual unemployment, they include determinants of short run deviation of actual from structural unemployment such as aggregate demand, productivity and wage shocks. They proceed by first analyzing how much of actual unemployment can be explained by pure institutional changes along with the shocks that drive the deviation of actual from structural unemployment. Then they compare those results with the ones obtained from a specification which allows for the interaction between the fixed institutional averages and shocks, captured by time dummies as in Blanchard and Wolfers (2000).[2] The main conclusion is that in the specification without interaction terms, the exclusion of the institutional variables reduces the model fit by 50%.[3] The authors then argue that "given that institutions are generally measured with errors, this level of impact is not bad".[4]

Specifically, employment protection and labour taxes are found to have positive impact on unemployment, with the latter being overturned in the economies with coordinated bargaining. Employment protection mostly operates by increasing the persistence of unemployment. Furthermore, benefits have a large and significant impact on unemployment as well as their duration. In order to determine the contribution of changes in institutions across different countries, the authors conduct an interesting exercise in which they perform dynamics simulation of the model but fix the starting level of the institutions. They find that only in Finland, Germany and New Zealand do changes in the institutions explain

[2] Nickell et .al. (2005) also include country and time dummies as well as country specific trends and lagged dependent variable. It is argued that this inclusion controls for the omitted trend variables in each country or common shocks.

[3] The goodness of fit is meassure in terms of the average squared deviation, and in the model with interaction terms and the institutional variables the average squared deviation equals to 0.32.

[4] Nickell et. al. (2005), p.16.

very little of the changes in unemployment. Furthermore, the combination of benefits and taxes explains two-thirds of the overall change in European unemployment captured by the institutional changes. The authors than conclude that observed changes in labour market institutions are important factors for the explanation of long-term unemployment rates in the OECD countries.[5]

However, when extending the simple institutional change model with institution-shock interactions, the overall fit is by 26% larger relative to the case where only the interaction terms are used, although the model solely based on the interaction terms also performs well.[6] But, the interaction terms turn out to be jointly insignificant, implying no real importance for the explanation of the unemployment shifts. In other words, one can conclude that institutional changes are able to explain overall movements in unemployment, whereas the additional explanatory power of the interaction terms between averaged institutions and the shocks is absent.

1.1.2 The Effect of the Product Markets

It is evident that, by concentrating solely on labour market institutions, previous studies ignored one important aspect of the reform process. As already claimed, one of the widely accepted views is that beside labour market reforms European prospects depend on product market deregulation. Since changes in product market regulations lead to changes in rents,

---

5 Moreover, they argue that increases in data quality would improve the results even further in favour of the institutional importance for the explanation of the unemployment patterns.

6 R^2 in the simple institutional change model with or without institution-shock interactions is 0.98, whereas in the models' specification featuring only interaction terms R^2 is reduced to 0.78.

it is usually conjectured that the deregulation of the product markets should be conducive to higher employment rates.

Before describing the advances on the theoretical side of the literature, let us first summarize several empirical studies. We should point that the empirical work aimed at assessing the impact of product market regulations is surprisingly scarce. As pointed out by Nicoletti and Scarpetta (2005), the main reason is the lack of adequate proxies expressing the intensity of competition, particularly in the cross-section context. Usual proxies such as measures of market power are not widely available and are possibly endogenous to labour market outcomes. Moreover, it can be argued that they are irrelevant for policy.[7] In order to overcome these problems, Boeri et al. (2000) and Nicoletti et al. (2001) use proxies that measure the extent to which product market policies are keen on competition. Specifically, they use a set of cross-country indicators of various regulations in the labour and product markets compiled by the OECD, and by combining those measures of product market competition with broader set of measures of labour market regulations they find positive effects of product market deregulation on employment. In a different study, Griffith and Harrison (2004) analyze the macroeconomics impacts of product market reforms undertaken in the EU over the 1980s and 1990s. Using a two-stage approach, they first estimate the effect of product market reforms on the level of economic rents, and then instrument the markup with the obtained rents. They confirm the view that product market reforms that ease entry, reduce tariff rates and regulatory barriers to trade, as well as elim-

[7] There are at least two reasons why such measures have little policy relevance. The usual proxies such as industry mark-up or industry concentration indices are of little importance for competition agencies, whose interest is concentrated at the level of micro markets. At the same time, they are too specific to be used for aggregate policy implications related to overall product market competition.

inate price controls, have negative effects on economic rents and thereby generate positive effects on employment.

However, by concentrating on the cross-country aspects of product market competition those studies are only partially able to capture the development of labour market policies and their outcomes over time. Moreover, they abstract from various possible interaction effects. In order to provide a deeper understanding of the time effects as well as the interactions between labour and product market policies, Nicoletti and Scarpetta (2005) employ proxies that follow the developments in the regulation of several non-manufacturing industries over the past two decades. They find that deregulation has significantly raised employment rates in the non-manufacturing sector characterized by extensive reforms. Furthermore, they estimate the impact of product market deregulation jointly with the effects of the labour market institutional reforms and find evidence supporting the view of labour and product markets being political complements. Specifically, they find that the product market regulations are relatively more detrimental to the employment in the countries where the bargaining power is high and where the labour market institutions are restrictive. Additionally, they results show that the labour market deregulations are likely to be equally beneficial for employment rates regardless of the level of product market regulation.

What have we learned from those studies? Two things are important to point out. First, there is little dispute that the initial increase in the European unemployment was triggered by adverse and largely common shocks such as supply shocks caused by the oil price increase or the slowdown in the total factor productivity. Second, it is plausible to argue that specific institutional shifts determined subsequent unemployment outcomes. Specifically, initial increases in unemployment has led most governments to implement specific reforms aimed either to ease the unemployment burden or to prevent further negative unemployment movements. These measures ranged from generous unemployment benefits to employment protection measures financed by large tax burdens. However, partial success and the financial pressures, as well as intellectual arguments, generated the need to reconsider and potentially reverse these policies. The aforementioned studies provide important guidance on the potential supply-side effects on one important category, namely unemployment, but remain silent on the potential effects of various reforms on the other important macroeconomic variables, such as output and consumption, that certainly need to be taken into account when addressing the consequences of potential reforms.

1.2 Theoretical Considerations

Although it would be unfair to downplay the importance of the empirical studies, they are certainly only the part of the story. The reason lies in the fact that they can only capture partial equilibrium effects but are unable to capture potentially very important general equilibrium effects. Moreover, they document long run effects, whereas the short run is neglected. Therefore, in order to assess the general equilibrium effects of both product and labour markets on macroeconomic outcomes, deeper theoretical analysis is required. This is the part where we aim to contribute with the analysis provided in this thesis.

1.2.1 The Stock Approach

Several papers have addressed wage and employment determination by explicitly modelling the bargaining process between firms and unions in an imperfectly competitive setup.[8] However, relatively few formal studies consider the joint effects of labour and product market regulations on macroeconomics outcomes. Blanchard and Giavazzi (2003) and Spector (2004) were the only ones to develop a model based on imperfect competition in both product and labour markets to analyze the issue of labour and product market regulations. The main premise is that deregulation fundamentally affects both rents and their distribution and it is therefore likely to have strong distributional and dynamics effects. In other words, short and long run effects might differ. One important factor largely neglected in the literature is the fact that the implementation of structural reforms may be determined and affected by fiscal policy. Moreover, one type of reform that has been largely advocated is the reform of the employment tax system, aimed at reducing the tax burden on employers in order to increase employment and create new jobs without reducing wage levels. Neither Blanchard and Giavazzi nor Spector consider how such reforms are to be financed, how to overcome the potential costs and what might be the effects of potentially important tax reforms.

In Chapter 2. we extend the Blanchard and Giavazzi by including distortionary taxation, which so far has been neglected in the theoretical literature on market reforms. Our hypothesis is that reforms turn out to be costly in terms of performance and in terms of cost of financing – at least in the short term. By extending the model to combine these

[8] See Layard and Nickell (1990), Manning (1993) and for the book treatments of the setup see Layard et. al. (1991).

two types of reform, and then to include the effects of lowering tax distortions, we establish formally that reforms imply significant short run costs as well as long run gains; and that the financing of such reforms will be the main stumbling block. We also find that the composition of the reform package, and the distribution of the tax burden, both matter. Specifically, we find that the short run involves significant costs or losses in employment and welfare, but the long run effects are almost uniformly favourable. Structural reform programmes are therefore likely to be avoided, or abandoned if undertaken, if policy makers become sensitive to their short run costs. Fiscal restraints, such as those imposed by Europe's Stability Pact, exaggerate this effect and thereby make the reforms less likely. Moreover, the choice of reform instrument matters. Tax reform almost always has a larger effect than market liberalization or labour market deregulation.

1.2.2 The Flow Approach and Macroeconomic Fluctuations

The modeling framework used in Chapter 2 is based on the so called stock approach, and as such abstracts from several important empirical regularities to be detailed in what follows. Moreover, the dynamic modeling was rather limited, by allowing the clear cut difference between short and long run induced by entry and exit. In addition, the impact of potentially important expectational effects are neglected. In order to correct for those drawbacks and to be able to analyze economic sensitivity to the particular shocks, we employed a new modelling strategy based on a fully fledged microfounded dynamic stochastic general equilibrium framework enriched with search and matching frictions. Before describing this framework in more detail, let us first discuss the development and the importance of the partial equilibrium search and matching framework and its application for policy analysis.

The Flow Approach

As has been already pointed out, several important empirical facts led to the development of a new and richer framework than was provided by the neoclassical competitive labour market models. This framework is based on based on flows, search, matching and bargaining. First, labour markets are characterized by large flows, that is by high rates of hires by the firms and by large number of separations from firms. Specifically, at the aggregate level, we observe large number of worker and job flows between inactivity and market production. Additionally, at the individual level, workers flows between labour market states, and job creation and job destruction, determine the activity spells present in the data, whose duration is in turn the consequence of the time spent searching for job, filling in a vacancy and working in a particular job. It is obvious that the models based on "stock" approach abstract from these important movements.

This has led to the development of a new stream of literature based on individual search behavior which formed a part of the so-called flow approach. The current search-matching models model unemployment and job spells, as well as wages, as an endogenous outcome of mutually consistent forward looking job creation and job destruction decisions made by workers and firms. In contrast to the previously developed search literature, which concentrated on the individual workers' search, the new equilibrium search and matching framework, as pointed out by Mortensen and Pissarides (1999), "explicitly accounts for and emphasizes the role of employers on the demand side of labour markets".[9] Furthermore, time and uncertainty are explicitly modelled whereby expectations are rational and the gains from trade are privately exploited.

The complexity of the matching process has very important consequences for unemployment. Specifically, since the matching process is costly and complex there will always be workers looking for a job determining unemployment as well as the jobs looking for a worker, determining vacancies. As a consequence, there will always exist some positive unemployment rate which is optimal. Additionally, search and matching frictions generate match specific rents that need to be divided between workers and firms, which in turn requires the specification of the bargaining mechanism to determine the wage. And it is the characteristics of the specified bargaining mechanism which determine actual unemployment, and in turn imply that, although there exists an optimal rate of unemployment, the actual one does not necessarily correspond to it.[10]

The fact that in this framework, unemployment has an explicit economic role allows researchers to analyze the complex labour market implications of institutional changes in a potentially much more detailed and careful way than was possible with the previously available modelling tools. Furthermore, the explicit flow characteristic of this approach allows identification of the complex channels thorough which specific economic policies can affect the labour market. In other words, specific policy affects both unemployment

---

[9] The early search literature was pioneered by Stigler (1961) and McCall (1970). The current search-matching literature goes back to Phelps (1968) who shows the importance of search theory for the analysis of the natural rate of unemployment and the inflation-unemployment trade-off.

[10] Although many possible wage setting mechanisms are allowed within this framework, Nash bargaining is most frequently used.

incidence and unemployment flow, which together with the two sided nature of the model results in multiple channels of influence. For the sake of completeness, let us illustrate the comprehensiveness of the channels captured within this framework. Let us begin by noticing that real world labour markets are characterized by some bargaining power in hands of both workers and firms. Additionally, the outside option of the workers is strengthened by the existence of the unemployment benefits. This unemployment benefit certainly influences both the workers' willingness to work as well as the wage determined in the bargaining process. The wage, on the other hand, determines the firms' willingness to post vacancies and recruit workers, which implies the importance of both parties in determining unemployment duration. Moreover, the wages determine job destruction, which defines additional channel through which benefits affect unemployment. Several additional channels are important to point out. Specifically, workers can threat to leave the job. But finding another job is costly, and the cost increases with increases in the aggregate unemployment rate. At the same time, firms can threaten to fire workers, but finding another worker is also costly, with the cost being higher the lower the unemployment rate. Moreover, the cost of quitting is lower the higher the benefits are, whereas the cost of firing is higher the higher employment protection is. All of this implies that a number of various channels of influence make the framework well equipped for the analysis of various important policy issues.

In an empirical study, Blanchard and Portugal (2001) confirm the validity of several important implications of the basic search and matching framework by analyzing the influence of employment protection. To detail the implications, let us assume that the increase in employment protection is translated into an increase of the cost of worker layoffs. This allows us to determine three important channels of influence. First, this increase by operating via firms' incentives is likely to reduce the number of layoffs and thereby decrease the flow of workers into unemployment. Second, by directly increasing firms' costs, and implictly strengthening workers' bargaining power, this might lead to increases in the bargained wages and thereby to increases in unemployment duration. Third, since steady state unemployment rate is the product of unemployment duration and the flow into unemployment, the effects of changes in the employment protection are a priori ambiguous. What Blanchard and Portugal show is that, at least for the Portuguese case, employment protection works primarily through the reduction in the transitory employment variations and much less through permanent ones, confirming the view that employment protection regulation leads to lower rates of job creation and job destruction.

Application to Labour Market Policy Analysis

Despite the large potential for policy analysis, only a few papers have used the equilibrium search and matching framework to formally analyze the impact of institutional reforms on both the welfare and labour markets. Mortensen (1994b), building on the work by Mortensen and Pissarides (1994), and Millard and Mortensen (1995) performs computational experiment on a model consistently calibrated to the unemployment and policy characteristics of USA. He finds that provision of unemployment benefits has important disincentive effects on job creation as well as on the long run unemployment rate. Moreover, employment protection turns out to have strong negative effects on unemployment incidence and a small positive effect on employment duration, which in aggregate results in a small negative effect on the unemployment rate. He also considers the effect of payroll tax reduction and identifies a small positive effect on the unemployment rate. Coe and Snower (1996) employ a variant of search-matching model to analyze the complementarities among labour market policies. They show that piecewise reforms are ineffective in contrast to more "fundamental" reforms ,where the difference lies in the explicit accounting for the existing complementarities. Moreover, they argue that insufficient appreciation of the importance of the complementarities could be blamed for the absence of effort to implement fundamental labour market reforms.

Several studies have investigated the labour market effects of tax reforms. Pissarides (1998) considers the effects of the employment tax cuts on unemployment and wages in the four different equilibrium models, including the search-matching model. Additionally, Pissarides (1998) analyzes the effect of revenue-neutral reform that makes the taxes more progressive. He finds moderate effects of tax cuts when benefits are indexed to the post-tax wage in competitive and efficiency wage models, but no effect in the unions and search-matching models. But, if unemployment benefits are fixed in real terms, then tax cuts can have substantial effects on unemployment in every model. He also finds a positive effect of revenue neutral tax progression on employment under the union wage bargaining and search-matching models. [11] Additionally, the effect of a revenue neutral switch to progressive taxation under an initially regressive system is larger then the reduction in the marginal tax rate. Sinko (2005) builds on Pissarides (1998) and analyzes the effects

[11] The positive effect of tax progression on employment has been analyzed in Koskela and Vilmunen (1996), who challenge the widely accepted wisdom within conventional labour supply analysis of negative effects of increase in tax progressivity on employment. By using the three most popular trade union models, they show that under plausible assumptions the increase in the progressivity of the tax system lowers wages but is good for employment in all three types of models.

of labour taxation and tax progression in the search-matching model extended to include the endogenous job destruction decisions with three alternative wage setting mechanisms: Nash bargaining, monopoly union and efficiency wages. He confirms the conventional view of negative tax effects on long run employment regardless of the wage setting mechanism. Moreover, within the bargaining setup, the increase in tax progression has positive effects on employment, which is a consequence of the positive tax effect on the emergence of low productive jobs.

Macroeconomic Fluctuations

But all of the aforementioned studies employ partial equilibrium setups and consider the long run consequences of specific reforms on labour market outcomes, thereby fully neglecting their effects on macroeconomic fluctuations. Recently, there has been an upsurge in interest in the business-cycle implications of reallocations in the labour market and the frictions generated by it. This interest has arisen mainly because of the inability of standard real business cycle models to explain the stylized facts observed in the data related to important labour market characteristics. Additionally, the standard real business cycle models produce output dynamics that are nearly identical to the dynamics of the underlying exogenous shock and when the stylized facts related to employment volatility are improved, such as in Hansen (1985) and Rogerson (1988), the persistence of employment and output is worsened. Several studies such as Merz (1995), Andolfatto (1997) and den Haan et al. (2000) extend the standard real business cycle models by including search and matching approach to unemployment. Those studies show that the introduction of the search-matching framework is successful in significantly improving the performance of the real business cycle models and in providing an explanation for largely neglected issues related to involuntary unemployment.

The incorporation of search and matching framework into standard real business cycle models introduced real imperfections on the labour market side, but the product market imperfections as well as the consideration of inflation remained absent. The new generation of monetary dynamic general equilibrium models named New-Keynesian, incorporates product market imperfections as well as nominal rigidities in a Keynesian tradition and is widely used to explain the joint dynamics of inflation, output and employment. Still, it was unable to explain the significant and persistent fluctuations in equilibrium unemployment caused by aggregate shocks, in particular the monetary policy shocks. Additionally, New-Keynesian models have problems in explaining the sluggish response of real wages and inflation together with pronounced and persistent response of output to demand shocks.[12] Walsh (2005) and Trigari (2009) have introduced the search-matching frictions with endogenous job destruction into standard New-Keynesian monetary model with nominal price rigidities. They show that the explicit introduction of the extensive labour adjustment margin together with the imperfections generated by the search-matching process improve the models performance in terms of inflation volatility as well as both output and inflation persistence. Moreover, the model becomes increasingly capable of explaining the overall response of US economy to monetary policy shocks as well as the observed behaviour of employment . The main reason why the model is able to explain the joint movements of output and inflation is a consequence of its ability to explain labour market

[12] For detailed survey of standard New-Keynesian models see Clarida et.al. (1999) and Gali (2002).

dynamics. Trigari (2004b), in a similar model but with exogenous job destruction, additionally shows that search-matching frictions contribute to improve models' performance with respect to wage responses.

Krause and Lubik (2007) have also introduced search-matching friction with endogenous job destruction in a New-Keynesian model, albeit in a different way than the papers discussed above. However, they show that the introduction of search-matching frictions alone is not sufficient to generate the persistent effects of monetary shocks. Moreover, the baseline model is not able to generate the Beveridge curve relationship. However, when the wage is made rigid, as in Hall (2005) the ability of the model to explain labour market facts is improved but the inflation dynamics remains the same as in the baseline case. They identify the explicit dynamics of marginal costs in the presence of search-matching rigidities which lies behind this result. Christoffel and Linzert (2005) extend the Trigari (2004a) approach by including the wage norm as in Hall (2005) and show that wage rigidity together with the right-to-manage assumption of the bargaining process generates persistent movements of aggregate inflation. They also show that the institutional parameters that influence the volatility of wages also influence the persistence of the inflation. Similar conclusions are obtained in the companion paper by Christofell et al. (2005).

As is evident from the previous discussion, either the literature was interested in long run effects of specific reforms within a partial equilibrium setup or in improving the performance of the standard real business cycle or New-Keynesian models by including more elaborate labour markets through the search-matching framework. But surprisingly, only the paper by Zanetti (2009), developed independently from ours in a different model incorporating search-matching, has analyzed the regulatory effects on macroeconomic outcomes as well as on the macroeconomic fluctuations in a general equilibrium context, even though the New-Keynesian setup extended with search-matching seems like a natural framework for this type of analysis. It is important to point out that fiscal issues, and thereby the effects of the tax reforms, were completely neglected.

In Chapter 3 we develop the New-Keynesian model characterized by imperfect competition, costly nominal price adjustment and search-matching frictions with endogenous job destruction in the labour markets, to analyze the effects of product market and labour market regulations on overall economic activity. Specifically, we enrich our model with explicit firing costs as well as explicit fiscal considerations. We introduce two types of distortionary marginal taxes, namely a wage tax paid by employees and the a payroll tax paid by employers. Additionally, we assume the progressivity of the wage tax system. In particular, we are interested in the effect of product market reform aimed at increasing the level of competition, as well as the effects of various tax reforms aimed to reduce the specific tax burden. We also investigate the effect of the specific tax reform aimed at reducing the payroll tax burden but at the same making the necessary adjustment in the wage tax in order for the marginal tax wedge to remain unchanged.

We confirm, within the general equilibrium model with endogenous job destruction, the widely held view of a detrimental effect of marginal tax distortions on overall economic performance. In addition, we find a positive effect of product market reforms on the labour markets and the economy as a whole. Furthermore, we also identify a positive effect of the increase in the degree of progressivity regardless of the initial level. We also find a positive effect of reduction of the tax burden on fluctuations of macroeconomic aggregates. However, we identify the negative influence of tax reform aimed at increasing payroll marginal tax rate but keeping the marginal tax wedge constant. Moreover, we identify the mechanism through which this type of tax reforms works when anticipated one period in advance.

1.3 Optimal Monetary and Fiscal Policy and Labour Market Frictions

The discussion developed in the previous two chapters analyzed aspects of various labour and product market reforms without considering the optimality of policy makers' decision. In the final chapter we aim to complete the story by analyzing the consequences for the optimal monetary and fiscal policy mix of various nominal rigidities as well as real labour market rigidities generated by search-matching frictions so far not analyzed in the literature. Before describing our contribution, we summarize the important developments in this field of analysis.

Most of the standard models used for optimal policy analysis are highly stylized, neglecting many theoretical and policy considerations. One can identify three distinct approaches emerging in the literature. The first, initiated by Lucas and Stokey (1983), analyses optimal monetary and fiscal policy in the context of a perfectly competitive flexible price environment where the government can issued fully state-contingent debt. The government problem in this setup consists of choosing the least disruptive combinations of inflation and tax rates to finance the exogenous stream of government consumption.

Although there is no real rationale for macroeconomic stabilization policy, several things can be learned from this analysis. First, if there is a sufficiently large set of state contingent claims, optimal policy can be made time consistent, although in general the economy will be characterized by time inconsistency. At the same time, if there are nominal claims present even if there are real securities coexisting, the optimal policy in every point of time has the incentive to use inflation to erode the real value of the outstanding debt. The commitment technology that would insure time consistency is required since, by behaving in this way, the government would lose the ability to issue nominal non-state contingent debt, which would in turn require the increased use of taxes and lead to a decrease in welfare. The second important point emerging from this literature is that taxes and government debt inherit the time series properties of the underlying shock.

By contrast, Calvo and Guidotti (1993) and Chari et al.(1991) analyze optimal policy within a similar neoclassical setting but remove the assumption of the availability of state-contingent claims and assume that the government can issue only non-contingent nominal debt. They find that the optimal tax rate is stable over time, and that it also inherits the properties of the underlying shock. The stability of taxes is obtained via the use of unexpected inflation. In this way, by making nominal claims state contingent in real terms, the need to use taxes to finance current and future debt obligations is reduced. In other words, unanticipated inflation serves as a lump-sum tax on financial wealth and allows the government to maintain highly stable tax rates over the business cycle.

While this literature can provide useful policy recommendations, the absence of a real macroeconomic rationale for stabilization policies undermines its usefulness for the understanding of optimal policy behaviuor over the business cycle. More precisely, the assumed neoclassical setting featuring the absence of any kind of nominal or real rigidities is the basic driving mechanism behind some of the results. In other words, costless price adjustment in the Chari et al. (1991) setting allows the policy maker to use inflation to render the real debt state-contingent and thereby keep taxes stable, making inflation volatility and tax stability a feasible and optimal policy.

The second and more recent stream of literature abandons the neoclassical setting and introduces market imperfections and nominal rigidities.[13] Thus, the need for macroeconomic stabilization policy emerges. There are two important differences between the two approaches. First, the neoclassical approach environment features distortionary taxation, while this recent approach assumes either implicitly or explicitly that the government has access to the lump-sum taxes to finance its budget. This in turn removes the need for the use of unanticipated inflation, which acts as the lump-sum tax on financial wealth. Second, although the modelling environment is characterized by imperfect competition, most of the literature assumes the existence of production or employment subsidies that would eliminate the distortions arising from competition imperfections. Major optimal policy implications are that inflation should be set to zero or close to zero in every state and in all times. The reason behind this result is rather intuitive. Costly price change requires a constant price level to minimize inflationary distortions associated with it. Fiscal consequences of shocks play no role in optimal policy determination since the availability of lump-sum taxes can easily deal with them.

[13] For a interesting summary of major advances and implication of this approach see Clarida et. al. (1999) and Woodford (2003).

The methodological contributions of this literature, which combines the technical rigor of the neoclassical setup with up to now somehow neglected, Keynesian views on imperfect price and wage adjustment, are certainly large. Moreover lessons learned from its policy implications constitute an additional dimension of its importance. Yet many features incorporated in those models are far from being realistic and justifiable on other grounds then as the tools generating expositional and technical convenience. Additionally, when compared with the neoclassical literature, this stream of literature provides completely opposite recommendation for the conduct of optimal monetary and fiscal policy.

As a reaction to the differences in policy implication between those two approaches, the third stream of literature emerges, combining crucial featured of both approaches. Specifically, the unrealistic assumption of lump-sum tax availability is removed. Thus, the tax instruments at policy maker disposal become distortionary. Moreover, markets for debt are incomplete and the government can issue only one period nominal non-state contingent debt. Neoclassical assumptions of perfect competition and flexible prices are replaced by monopolistic competition and some form of costly price adjustment. Thereby, Benigno and Woodford (2003) analyze a model in which prices are set in a staggered fashion first introduced by Calvo (1983), whereas producer's price setting in Schmitt-Grohe and Uribe (2004a,2004b) is subject to convex price adjustment cost proposed by Rotemberg (1983). In this setting optimal policy maker faces trade-off between distortions caused by inflation and tax rate volatility in response to unexpected shocks hitting the economy.

Several important implications arise under this modified setting. First, optimal monetary policy features price stability even for a small degree of price rigidity. In other words when prices are sticky, the aforementioned trade-off is overwhelmingly resolved in favour of price stability. The reason behind this result is again the consequence of costly price setting. Second, when prices do not adjust costlessly, tax and debt do not inherit the time series properties of the underlying shock, but are characterized by a near random walk behavior. In the opposite case when price are fully flexible, but markets are still imperfectly competitive, taxes and debt do inherit the time series properties of the underlying shocks. Thus, the optimal inflation process when prices are sticky is more in line with the second stream of literature, which ignores the fiscal consequences of monetary policy actions by assuming the availability of a lump-sum tax instrument. However, tax and debt properties are in line with the optimal neoclassical monetary and fiscal policy literature with real non-state contingent debt as analyzed in Aiyagary et al. (2002).

However, most of the optimal monetary and fiscal policy literature abstract from any real frictions in the labour market. In other words, regardless of whether the analysis is conducted within the neoclassical setup or within more recent New-Keynesian setup, the labour markets are assumed to be Walrasian. By introducing such an assumption, one is neglecting the short run inflation-unemployment trade-offs arising as a consequence of labour market friction and certainly describing the real world economy. In Chapter 3. we construct the model in New-Keynesian tradition characterized by imperfect competition in the goods markets as well as costly price changes. But we depart from mainstream New-Keynesian literature and replace the Walrasian labour markets with a search-matching mechanism. Additionally, we introduce explicit fiscal considerations into our analysis, so far fully neglected in the New-Keynesian models which feature matching characteristics of the labour markets.

We follow public finance literature in the spirit of Lucas and Stokey (1983) and solve the constrained Ramsey problem which takes into account all of the constraints characterizing competitive equilibrium in addition to all of the wedges inherent in the model economy. Thereby we capture the positive aspects of the effects of search-matching externalities. We resort to numerical techniques to illustrate the dynamic implications of our setup. Specifically, we consider the optimal policy responses in cases where the economy is hit either by a positive neutral technological shock or by a positive government spending shock.

We arrive at several important results. First, the increase in the technological level, by leading to an increase in consumption and employment, allows the Ramsey planner to reduce both inflation and the tax rate to fully exploit the benefits of productivity enhancement. This in turn leads to an increase in demand and an increase in firms marginal profits, thereby boosting vacancy posting and increasing employment. Thus, the optimal policy is achieved by deviating from strict price stability, which contrasts with standard New-Keynesian predictions. Second, the presence of unemployment benefits and the expectational dynamic effects of tax rates on wages identify additional channels through which the Ramsey planner can influence efficiency. More precisely, by using taxes, the Ramsey planner can directly reduce inefficiencies stemming from the presence of unemployment benefits as well as the wage, by affecting both current and the expected future tax rates and thereby firms' marginal costs. Third, we find that the optimal tax rate and optimal real government liabilities inherit the time series properties of the underlying shock, and again contrast the results obtained in the standard New-Keynesian literature with sticky prices and Walrasian labour markets. Finally, we also find that optimal policy responses under positive productivity shock show a certain degree of overshooting in inflation and tax rates, whereas under a positive government spending shock inflation and tax rate are characterized by undershooting. This result comes out from the assumed commitment, whereby the policy maker internalizes the effects of its current decisions on future expectations.

1.4 Conclusion

In this chapter we have summarized the main empirical and theoretical literature which analyzes the effects of labour and/or product market reforms. We use this review to identify several important gaps and drawbacks present in the existing literature in order to motivate the research conducted in the remainder of the thesis. Specifically, we identify three existing streams in the empirical literature trying to explain the European unemployment experience and argue that, while the empirical literature provides useful lessons on the reform process, it is only part of the story. The main reason lies in its inability to capture potentially very important general equilibrium effects. Therefore, in order to properly assess the effects of both product and labour markets on macroeconomic outcomes, a deeper theoretical analysis is needed. We also review the major developments in the theoretical field and identify the neglection of several important theoretical and empirical aspects, such as fiscal considerations or the flow characteristics of the labour markets, that need to be taken into account when analyzing reforms' process. Furthermore, we identify the scarceness of the literature analyzing the effects of various reforms on macroeconomic fluctuations.

We have also reviewed the developments in the optimal monetary and fiscal policy literature and identify the absence of any real labour market frictions (which certainly characterize the real world economy) in the analysis. Specifically, the existing optimal monetary and fiscal policy literature assumes the existence of Walrasian labour markets, and by introducing such an assumption one is neglecting the short run inflation-unemployment trade-offs arising from labour market frictions. The analysis which corrects for the aforementioned drawback is certainly important for both the deeper understanding of the reform process as well as for the optimal monetary and fiscal policy conduct.

Chapter 2

The Impact of Tax and Market Distortions on the Phillips Curve and the Natural Rate of Unemployment *

Tax reform, market liberalisation and deregulation in the labour markets are widely seen as the key to improved economic performance - particularly in Europe. As a result, structural reform has become a leading policy issue in both Europe and the OECD. In fact the European Commission has declared the coordination of structural reform to be its top priority (EC, 2008). Yet the academic literature has provided very little formal analysis of the reform process itself; or of how far structural reforms can be expected to improve economic performance. At the same time, many countries have proved extremely reluctant to embrace such reforms despite being keen to advocate their virtues in public. Such inconsistencies require an explanation.

In Europe, arguments for market or institutional reforms have been made, and supported, at the political level under the heading of the Lisbon agenda (Sapir, 2004). Nevertheless, despite these reforms having been advocated widely, governments often fail to carry them out in practice (Dellas and Tavlas, 2005; Hughes Hallett et al., 2005). And where they have been attempted, it has usually been a piecemeal effort and quickly abandoned in the face of opposition. The Hartz IV programme in Germany; or pensions, labour

* Part of this chapter has been released as Bokan and Hughes-Hallett (2006), and published as Bokan and Hughes-Hallett (2008)

market reform and the liberalization of services in France; and the reconstruction of social security in Italy, are three obvious and specific examples. The usual conjecture is that such reforms are costly in terms of economic performance and costly to finance in the short term - a conjecture that we examine below.

Much of this debate has come to focus on reforms in the labour market. That is based (loosely) on the analytic and empirical evidence of a negative link between economic performance and wage rigidities in many countries (Bruno, 1986). Such a link has certainly been observed in the labour and product markets of Europe (Koedijk and Kremers, 1996) where performance is measured in terms of growth and employment; and deregulation is measured in competition policy, merger codes and the liberalisation of employment practices. Yet, however powerful the case for structural reform, previous papers analyzing the reform process have been forced to rely on ad hoc reasoning. The economics literature does not have a model to describe the impact of tax distortions on economic performance, nor the consequences and costs of structural reform (and hence of the incentives for undertaking reforms in the first place). Indeed, a leading OECD survey commented: "...because there is neither a well-established model of the political economy of structural reform, nor an extensive empirical literature on the topic...it is necessary to adopt a pragmatic, ad hoc approach" (Høj et al., 2006). Most analysts have therefore found themselves restricted to studies of the political economy factors that make reforms more likely, or that show institutional or market distortions can go some way to explaining the persistence of unemployment[14].

---

[14] Høj et al. (2006); or Blanchard and Wolfers (2000); Daveri and Tabellini (2000); Nickell et al. (2005).

Second, it is obvious that at least as much effort has also gone into arguing for reforms that reduce the distortionary effects of taxation, as has gone into market deregulation programmes. Yet the literature also contains remarkably little analysis of the benefits (or costs) of tax reform, or of whether it could be more effective than market or institutional reforms. In this paper, we try to redress that deficiency.

To analyse these issues, we need a model of the reform process sufficiently general to encompass the usual reform instruments and the range of structural parameters found in the candidate countries. Starting from a standard model of deregulation, we develop a theoretical model of wage bargaining, with imperfect competition in the product markets and different forms of tax distortions, in order to understand the likely incentives, costs and potential benefits of structural reform. We use the results to explain policy makers' behaviour, and to derive certain conclusions about which reform measures are the most effective.

We then trace out how the implicit inflation-unemployment trade-offs have been affected by different kinds of market distortions, and how far they could be eased by structural reform or deregulation. We also show how different tax or market distortions affect the natural rate of unemployment, and which structural reforms would be the most effective from a welfare or employment perspective.

We find that, contrary to conventional wisdom, it is the removal of tax distortions rather than market distortions which makes the greatest difference. Hence the answer to our first question: those countries that are fiscally constrained, or find themselves unable to finance the consequences of their reforms, are typically the ones that fail to carry them out.

That in turn implies it is essential to provide an analysis that combines fiscal policy and reform instruments. Nevertheless, the crucial conflict remains the inter-temporal trade-off faced by workers: lower real wages (welfare) in the short run vs. lower unemployment and higher real wages in the long run.

2.1 The Model

In order to consider the impact of the tax system on wage bargaining behaviour, and hence the consequences of tax reform, we extend the Blanchard and Giavazzi (2003) model to include distortionary taxation. In addition to distortionary taxes, we consider two deviations from perfect competition to generate the need for product and labour market reforms. The first arises from the assumption of the imperfectly competitive product markets. In this case, we assume the presence of certain number of the monopolistically competitive firms each of them producing a differentiated good. Then, on the labour market side, we introduce an imperfection by assuming a formal wage bargaining process between firms and their workers.

The presence of monopolistically competitive firms leads to the creation of rents in the economy, the size of which is determined by the degree of monopolistic competition. At the same time, the existence of a wage bargaining process leads to a certain distribution of those rents between firms and workers. However, distortionary taxation is necessary to complete the story since any reform programme that needs to be undertaken needs to be financed. And if fiscal expenditures are to be endogenous, potentially, then taxes must ultimately be endogenous too.

We do not model the dynamics of adjustment explicitly in this paper. But in order to allow for differences in the effects over time we will follow Blanchard and Giavazzi by imposing a clear cut distinction between the short term and the long term. This is achieved by fixing the number of producers in the market exogenously in the short run, whereas we allow that number to be determined by a market entry condition in the long run. One can think of this entry condition as a per unit entry cost, c, representing certain regulatory or administrative entry barriers present in the product markets. Although there would be no difference to the equilibrium outcomes if this cost were treated as a shadow cost, it is perhaps better to think of it as real cost which is proportional to output. If this cost were to be a shadow cost, firms present in the market would be able to earn pure profits in the long run; whereas if it is a real cost, firms can earn "excess" profits only in the short run since that excess would eventually be dissipated in the entry cost. Moreover, in order to perform any numerical analysis, the entry costs would need to be treated as real and could be thought as the cost of the time needed to satisfy all of the regulatory requirements plus the cost of setting the firm up and licensing it as a legal entity.

2.1.1 The Consumer's Problem

To model consumption, we assume that the economy contains a fixed number of workers-consumers L, indexed by j, who can choose to either work, or not to work. If the worker decides to work he must supply one unit of labour. If he does not work he is unemployed. Labour is therefore indivisible.

The utility function for worker j is given by following expression

$$U_j = [m^{1-\delta} \sum_{i=1}^{m} C_{i,j}^{\frac{\delta-1}{\delta}}]^{\frac{\delta}{\delta-1}} \tag{2.1}$$

where $C_{i,j}$ represents individual j's consumption of the i-th product; m represents the number of firms or products present in the market; and δ stands for the elasticity of (gross) substitution between products which is defined as ($\delta = \overline{\delta} f(m)$). We assume this elasticity to be an increasing function of number of products with $f'(m) > 0$, and that $\overline{\delta}$ may be fixed by policy. This specification of δ is crucial for disentangling the difference between the short and the long run since, by imposing an exogenous number of firms present in the market, we assume that the elasticity of substitution is constant and exogenous in the short term. But in the long run, it will be endogenous and determined by the number of products that emerge in the final equilibrium.

This specification has three important features. First, assuming that all workers are identical, the utility of the workers will not depend directly on the number of products, but on the level of aggregate consumption instead. Second, an increase in the number of products increases the elasticity of substitution between them and thereby reduces monopoly power of the individual producer. This may have indirect consequences for the utility of the individual worker. Third, with a fixed labour supply, employment generation and reducing unemployment are synonymous.

When making consumption or labour market decisions, each worker maximises (2.1) subject to the following budget constraint:

$$\sum_{i=1}^{m} P_i C_{i,j} = (1 - t_w) w_j N_{i,j} + P w_r(u)[1 - N_{i,j}] \tag{2.2}$$

where $N_{i,j}$ takes the value of one if worker j chooses to work in firm i, or zero if he or she is unemployed; t_w is the average tax rate on wages; and P is the price aggregator defined in Section 2.1.3 below. $w_r(u)$ may therefore be interpreted as the real value of the unemployment benefits, or support received from government in the case of unemployment; or equivalently as the worker's reservation wage.

2.1.2 Unemployment

We now show that the level of social support (unemployment benefits), and hence the reservation wage will increase with government expenditures and decrease with the rate of unemployment in the economy as a whole: that is, $w_r'(u) < 0$.

There are several ways to justify this assertion. Informally $w_r(u)$ may represent the labour market institutions that affect wage bargains: minimum wages, firing costs, the size and duration of unemployment benefits, or the level of social support itself. Increases in any one of those factors would increase the reservation wage when employment is high (unemployment low) since they are funded by the public sector[15]. Or it might be that market reforms create temporary unemployment, but lower the reservation wage since workers know that their old jobs may not be preserved. Again, higher employment would lead to higher wages and higher reservation wages and to lower unemployment since the size of the labour force is fixed (Spector, 2004)[16].

[15] There are no other outside income opportunities for the unemployed in this model.

[16] Spector's argument is that the reservation wage will rise with employment. However if labour supply changes, this result can be overturned: as shown by Fang and Rogerson (2008).

More formally, it can be shown to be the natural outcome of an optimal wage bargain between firms and wage bargainers, as defined by (2.10) below, when the government's (social security) budget remains balanced[17]. Both Spector, and Fiori et al. (2007), show that, in such circumstances, reservation wages will be proportional to the employment rate with a coefficient that depends on the price mark-up, labour's bargaining power, and tax rates. With the labour force fixed, that means the reservation wage will vary inversely with the unemployment rate. We accept that explanation here; the inverse relationship itself being derived explicitly in Section 2.2.2 below.

However this $w_r' < 0$ relationship only defines a direction of change; it does not tie down a level of unemployment. To do that, and in order to be able to show how the employment position is influenced by labour market institutions and employment legislation, it is useful to link the unemployment outcomes to a search model with layoff risks, wage changes once in a job, differential wage offers to insiders vs. outsiders, and wage bargaining (Rogerson et al. (2005)). In those models, the equilibrium (natural) rate of unemployment is given by

$$u_N = \lambda / [\lambda + \alpha_w] \tag{2.3}$$

where $\alpha_w = \alpha_0[1 - F(w_r)]$ describes the probability of receiving an acceptable job offer in the current period, and $F(w)$ is the cumulative probability distribution of all wage offers made in that period. Hence $1 - F(w_r)$ describes the probability of the arrival of *acceptable* job offers.

---

[17] A constraint which has not been imposed in earlier tax reform studies: Bayoumi at al.(2004); Coenen et al. (2008). Imposing it here means that the budget will remain in balance throughout our analysis.

In this formulation α_0 is the contact rate, reflecting the probability of contact between employers and employees. In that case, α_w describes the arrival rate of offers that actually lead to employment. And λ reflects the layoff risk; that is, the separation rate implied by the probability that a job will be terminated in the current period. Both probability distributions remain unspecified in this paper, but are often taken to be independent Poisson distributions in which case α_0 and α_w become constants which describe the *average* rates of contact and employment per period.

Given this, the short run movements in the rate of unemployment will be determined by the difference between current separations and new hires:

$$\partial u/\partial t = \lambda(1-u) - \alpha_0[1-F(w_r)]u \tag{2.4}$$

which, over time, converges to u_N. This formula therefore ties down the speed at which unemployment converges on u_N.

2.1.3 Welfare Indicators

Finally P stands for the price aggregator obtained after solving the consumer's optimization problem. It is given by:

$$P = [\frac{1}{m}\sum_{i=1}^{m} P_i^{1-\delta}]^{\frac{1}{1-\delta}} \tag{2.5}$$

This expression is slightly different from the standard Dixit-Stiglitz aggregator as a consequence of the assumed form of the utility function at (2.1). Solving the consumer's optimization problem, and using the fact that the problem is symmetric across all consumers, we can obtain an expression for the consumption that would maximise utility for the individual consumer. It is given by

$$[(1-t_w)\frac{w_j}{P} - w_r(u)]N_{i,j} + w_r(u) \tag{2.6}$$

This expression is proportional to the individual's maximised utility level and can be used to make welfare comparisons in what follows. All welfare comparisons that follow will therefore be in terms of consumption equivalents.

2.1.4 The Firms' Problem

We assume that each firm produces a differentiated product indexed by i using the same production technology which is linear in labour. Output is therefore given by[18]

$$Y_i = N_i \tag{2.7}$$

where $N_i = \sum_j N_{i,j}$ represents total employment in firm i. Since both individual and aggregate demands are determined by the consumer's optimization problem, the firms' problem consists of determining prices taking costs and demand as given. This allows us to obtain the partial equilibrium demand function for each product market. It is given by:

$$Y_i = \frac{Y}{m}(\frac{P_i}{P})^{-\delta} \tag{2.8}$$

[18] Alternatively one can think of (2.7) as a production technology in which capital is fixed and normalized to one. Interestingly, Spector (2004) claims that capital plays a key role in the outcomes of deregulation in the product and labour markets because unions and employers bargain over the rents created by the irreversibility of capital investment, as well as over the rents derived from imperfect competition. However, in a discussion paper version of this paper (Bokan and Hughes Hallett, 2006), we show that the introduction of capital (via a Cobb-Douglas production function) complicates the analysis but does not change the results. Hence it makes no difference if we include capital or treat it as fixed.

2.1.5 Wage Bargaining and the Government

Before describing wage bargaining problem, we need to introduce the tax system. We assume first that both workers and producers are obliged to pay certain taxes. Workers need to pay a tax on the wages they earn. In our model, it is assumed that a common average tax rate will be imposed on every working worker's wage. We also assume that unemployment benefits are not taxed.

Next, producers need to pay payroll taxes[19], t_p, defined as a certain fixed percentage of the workers gross wage. Both of these taxes are assumed to be flat taxes. Extensions to a progressive tax system are possible, but lead to very complicated expressions which limit any insight into the scope for reform[20]. Our flat tax specification meanwhile implies the following government budget constraint, over and above any fixed or lump sum elements in taxation or expenditures:

$$B = (t_w + t_p) w_i \sum N_i - P w_r(u) [\frac{L}{m} - \sum N_i] \tag{2.9}$$

We treat B as being constrained by a ceiling on government debt. That means any increases in expenditures, or reductions in tax rates, must be matched by increases in tax revenues elsewhere in the system. This is just an artificial device which allows us to focus on the cost of financing any reforms. However, deficits do have to be financed by interest payments or tax revenues. So B will always be limited in practice.

---

[19] Or training costs, firing costs; or any profit or corporate taxes that vary in line with production costs.

[20] Lockwood and Manning (1993) allow progressive taxes and then show that changes in the marginal and average tax rates may have different effects. That is ruled out here. Note also that (2.9) implies equal tax bases so we pick up none of the Koskela and Schoeb (1999) effects on wages when tax bases vary.

Meanwhile each firm bargains with L/m workers over wages and employment in that industry, in both the short and the long run. Intuitively, a fraction L/m of the workers forms a union. That union then bargains with the firm over wages and the level of employment. Indivisibility of labour implies that workers can either be employed in the firm or be unemployed.

In what follows, we consider a world of Nash efficient bargaining solutions. There are three reasons for this. First, the efficient bargaining concept allows wages to be bargained off the labour demand curve, which implies that an increase in wages could be achieved without an immediate decrease in employment ("stronger workers may obtain higher wages without a decrease in employment"). Second, empirical studies (Dobbelaere, 2004) have rejected *The Right to Manage Model* in favour of an efficient bargaining model as the appropriate explanation of wage bargaining in many European countries. Since the case for structural reform is particularly strong in Europe, it is important to have a model that can capture that feature. Third, this assumption ensures incentive compatibility on both sides of the labour market[21].

Assuming risk neutrality for the unions, the wage bargaining problem can be written as:

$$\max_{w_i, N_j}\{\beta \log[(1-t_w)w_i - Pw_r(u)]N_i + (1-\beta)\log[P_i - (1+t_p)w_i]N_j\} \tag{2.10}$$

where β is an exogenously determined index of union bargaining power; and where t_w and t_p represent the average tax rates paid by employees and employers respectively ($0 \leq$

[21] Since the empirical evidence in favour of efficient bargaining is not conclusive, it is might be better to rely on the first and third of these reasons for adopting a Nash bargaining approach. However Spector (2004) and Fiori et al. (2007) have stressed that essentially the same results emerge from the Right to Manage model. So this distinction is actually unimportant here.

$t_w, t_p < 1$). This formulation implies that unions will choose w_i to maximize the *net* wage surplus from employment, the first term within the brackets, while firms will choose N_i to maximize their net profit (the second term).

2.1.6 Regulatory Instruments

Several important consequences of market regulation now follow. On the product market side we have c and $\delta = \overline{\delta} f(m)$. Reductions in the entry cost, c, can be thought as the removal of administrative restrictions; or the replacement of some state owned monopolies by market firms. The degree of product substitutability in the markets is broken into two parts. First, a policy component ($\overline{\delta}$) whose increase could represent some market liberalisation measure, or a reduction in some domestic/external trade barrier which has the effect of increasing product substitutability. These are matters which lie within government control. The second element, $f(m)$, is an index of market competition which increases with the number of firms. If we change δ by policy, we change $\overline{\delta}$. But m may then change. So, in practice we speak of a *net* change to δ.

Finally, in the labour markets, we have β representing bargaining power whose increase can be interpreted as the increase in the degree of the workers' power over wage and employment decisions ranging from rights to strike, employment protection legislation, severance conditions, firing costs, or other collective matters. In addition both types of taxes represent regulatory instruments under direct government control.

2.2 Solving for Equilibrium Outcomes

In order to proceed, we solve the model in three steps. First we solve for short run partial equilibrium values for relative prices and real wages. These will then be used to obtain the short run general equilibrium prices and wages. After obtaining those values, we can solve for the corresponding long run equilibrium values.

2.2.1 Short Run Partial Equilibrium Relationships

Equilibrium demand for each product, and hence employment, will be determined by (2.8). Since workers and firms bargain over both wages and employment, and since employment is already determined as a function of output, our bargaining problem can be resolved by substituting (2.7) and (2.8) into (2.10), and then allowing workers and firms to bargain over wages and prices. The solution to that problem is given by:

$$\frac{P_i}{P} = \frac{\delta(1+t_p)w_r(u)}{(\delta-1)(1-t_w)} \tag{2.11}$$

which follows from the first order conditions for relative prices and real wages:

$$\frac{P_i}{P} = \left(\frac{\delta+\beta-1}{\delta(1+t_p)}\right)\frac{w_i}{P} \; and \tag{2.12}$$

$$\frac{w_i}{P} = \left(\frac{\beta}{1+t_p}\right)\frac{P_i}{P} + \left(\frac{1-\beta}{1-t_w}\right)w_r(u) \tag{2.13}$$

Using the expressions above, we can solve for short run partial equilibrium real wages and relative prices as functions of the regulatory parameters in the model. In fact:

$$\frac{P_i}{P} = [1+\mu]w_r(u) \text{ and} \tag{2.14}$$

$$\frac{w_i}{P} = \left[\frac{1 + \beta\mu(1 - t_w) - \beta(t_w + t_p) + t_p}{(1 + t_p)(1 - t_p)}\right] w_r(u) \tag{2.15}$$

where μ represents the mark-up in relative prices[22], defined as

$$\mu = \frac{\delta(t_w + t_p)}{(\delta - 1)(1 - t_w)} + \frac{1}{\delta - 1}. \tag{2.16}$$

It is easy to see that this mark-up is an increasing function of both taxes on wages paid by employees, and the payroll tax paid by employers. That is,

$$\frac{\partial\mu}{\partial t_p} = \frac{\delta}{(\delta - 1)(1 - t_w)} > 0, \quad \frac{\partial\mu}{\partial t_w} = \frac{\delta(1 + t_p)}{(\delta - 1)(1 - t_w)^2} > 0 \quad \textit{and} \quad \frac{\partial\mu}{\partial t_w} > \frac{\partial\mu}{\partial t_p} > 1 \tag{2.17}$$

when $\delta > 1$. This result is to be expected since, in the case of increases in payroll taxes, it is optimal for producers to bargain for higher prices; whereas in the case of an increase in the taxes paid by employees, the latter will demand higher wages. However, the latter would lead producers to require an even higher mark-up in order to prevent profit margins from changing too much – their ability to do so being limited only by the degree of inter-product substitutability.

These results also show that μ represents a mark-up in *relative* prices, reflecting the combined rents to the firm and the derived rents to the work force. However we can be sure that $\mu > (t_w + t_p)/(1 - t_w)$ holds for all $\delta \geq 1$; and that μ is a decreasing function of δ which reaches its minimum at $\theta = (t_w + t_p)/(1 - t_w)$ when $\delta \to \infty$; a minimum value which increases with t_p and t_w. Hence we can think of $\mu - (t_w + t_p)/(1 - t_w)$ as the degree

[22] This expression shows the composition of the mark-up. Note that (2.14) and (2.11) show that this model solves for relative prices, not the price level, and requires the usual elasticity restriction $\delta \geq 1$ to hold.

of market distortion due to imperfect competition; and $(t_w + t_p)/(1 - t_w)$ as the degree of distortion due to the tax regime.

Thus there will always be some distortions, even under perfect competition, so long as there are taxes. We are restricted to a second best world. Finally $\delta \geq 1$ is indeed required, by (2.11), since otherwise prices will turn negative.

2.2.2 Short Run General Equilibrium

Since in a symmetric equilibrium all producers need to charge the same price, and since not all of them can have relative prices larger than one in a general equilibrium, all relative prices must be equal to one in the general equilibrium setting. Substituting that into (2.14) provides us with the following condition for the reservation wage:

$$w_r(u) = \frac{1}{1+\mu} \tag{2.18}$$

Taking tax rates as temporarily fixed, this expression implicitly determines the short run unemployment rate which is a consequence of the assumed fixed short run coefficient of the elasticity of substitution. Substituting (2.18) into (2.15) we obtain an expression for the short run general equilibrium real wage in terms of μ:

$$\frac{w_i}{P} = \frac{1 + \beta\mu(1 - t_w) - \beta(t_w + t_p) + t_p}{(1 + t_p)(1 - t_w)(1 + \mu)} \tag{2.19}$$

But real wages are proportional to the reservation wage: (2.15) and (2.19) both imply

$$\frac{w_i}{P} = \left[\frac{1 + \beta[\mu(1 - t_w) - t_w] + (1 - \beta)t_p}{(1 + t_p)(1 - t_w)}\right] w_r = A w_r \tag{2.20}$$

where $A > 0$. So, if the social security budget is kept in balance, (2.9) with $B = 0$ becomes

$$(t_w + t_p)\ell A w_r = (1 - \ell)w_r, \; or \ell[1 + (t_w + t_p)A] = 1$$

where $\ell = \sum N_i/L$ is the employment *rate* for the economy as a whole. Hence,

$$w_r = \frac{[1 + (t_w + t_p)A]}{(1 + \mu)}\ell \text{ and } w_r'(u) = -\frac{[1 + (t_w + t_p)A]}{(1 + \mu)} < 0$$

since $\ell = 1 - u$. This is the negative relationship introduced in Section 2.1.2[23]. Hence a higher reservation wage, or a higher level of social support, will automatically lead to lower unemployment, and vice versa (higher unemployment implies lower reservation wages), both in the long and the short run – as claimed.

2.2.3 Comparative Statics in the Short Run

Proposition 1 *Short run real wages are an increasing function of labour's bargaining power if and only if the mark-up, broadly defined, is greater than the share of the total tax burden on the per unit net wage received by employees: or, equivalently, as long as the following condition (market distortions exist) is satisfied:*

$$\mu > \frac{t_w + t_p}{1 - t_w} \tag{2.21}$$

Proof. The first derivative of short run equilibrium real wage is positive if (2.21) holds, since then $\frac{\partial \frac{w_i}{P}}{\partial \beta} = \frac{\mu(1-t_w)-t_p-t_w}{(1-t_w)(1+t_p)(1+\mu)} > 0$ holds, given that $\delta \geq 1$ implies $\mu \geq 0$. ■

Notice that, whatever the tax system, (2.21) will hold as long as $\delta < \infty$. But if $\delta \to \infty$, and product market competition increases, then (2.21) will become an equality

23 An extension to allow budget imbalances, $B \neq 0$, can easily be incorporated at some cost to the algebra.

and labour's bargaining power will have no impact on real wages. This conclusion is new and shows that the composition of the mark-up matters. In addition, it conflicts with Spector's (2004) analysis which finds the effect of increasing competition to be ambiguous for the reasons discussed in Section 2.2.5 below.

Next we consider the consequences of a change in the two types of taxes:

Proposition 2 *The short run equilibrium real wage is always a strictly decreasing function of payroll taxes, whereas it is unaffected by changes in wage taxes.*

Proof. Substitute the broad mark-up, (2.16), into the solution for short run equilibrium real wages, and take first order derivatives with respect to t_p and t_w. ■

The intuition behind this conclusion comes from the effect of tax changes on the mark-up. Evidently the mark-up is *less* responsive to changes in the payroll tax than it is to changes in taxes paid on wages (see (2.17); $t_w < 1$). Thus, in the case of an increase in payroll taxes, real wages must fall because firms can always increase their mark-up by more than enough to compensate for the increase in the payroll tax: see again (2.17). The burden is therefore partly transferred to the workers. But if there is an increase in wage taxes, workers will demand higher wages. Firms are able to compensate for this increase by raising their mark-up by more than they could have done in the payroll tax case. But that results in an increase in the general price level such that real wages remain unaffected.

Proposition 3 *The short run equilibrium reservation wage is always a strictly decreasing function of both types of taxes.*

Proof. (2.18) and (2.17) together imply the result. ■

This result is also intuitive since the equilibrium reservation wage is inversely related to the mark-up, and the mark-up is increasing in both types of taxes.

Corollary 1 *Proposition 3 therefore implies that the equilibrium unemployment rate will increase with increases in both types of taxes, in contrast to the competition effect which causes the unemployment rate to fall (Spector, 2004). But the size of the impact on reservation wages, and hence on the unemployment rate, will differ depending on which tax rate has been changed: (2.17) implies* $\partial\mu/\partial t_w > \partial\mu/\partial t_p$ *in (2.18).*

2.2.4 The Long Run: Entry and Exit

In the long run, firms can restructure or enter new markets. We assume that firms need to pay a fixed entry cost which is a fraction of the price per unit of output. This means that firms will enter the market so long as rents cover those entry costs.

Since firms get a share $1-\beta$ of the total rents from which taxes need to be paid, we can define the share of *net* rents available to cover per unit entry costs as follows[24]:

$$(1-\beta)[1-(1+t_p)w_r(u)] \tag{2.22}$$

[24] This expression defines the net rents going to firms from *all* sources: from price setting, wage setting and tax distortions, over and above what they would receive with perfect competition in all markets and no distortions. In that case, real wages would equal $w_r(u)$ as can be seen from (2.27) and (2.28) below. Hence (2.22) represents net rents per unit, in excess of "normal profits", and the scale factor (Y) plays no role once excess profits per unit of output are determined since the production function is monotonic.

Substituting (2.18) for , we can now express the maximum acceptable entry cost as a function of the mark-up, bargaining power and taxes. It is given by

$$c = (1-\beta)\left(\frac{\mu - t_p}{1+\mu}\right) \tag{2.23}$$

However the mark-up itself is no longer exogenous since the elasticity of substitution coefficient will change because the number of firms, and the number and varieties of goods, will change when firms enter and exit the market. In fact, the number of firms and the degree of substitution between goods will adjust through entry and exit until the rents, (2.22), are fully consumed by the entry costs (2.23). In other words the number of firms, and thereby the degree of competition, must be such as to totally dissipate any excess profits/rents over entry cost. Recall that we require $\delta \geq 1$. Hence:

Proposition 4 *The number of firms, goods and employment will rise in the transition from short to long run if tax rates of either type are increased; or if market regulation lowers the degree of substitutability (or the degree of competition) between goods and between producers.*

Proof. The first derivative of the maximum acceptable entry cost is positive:

$$\frac{\partial c}{\partial \mu} = (1-\beta)\frac{(1+t_p)}{(1+\mu)^2} \tag{2.24}$$

Combining (2.24) with (2.17), or with $\partial\mu/\partial\delta < 0$ from (2.16), gives the result. ■

Non-Monotonicity: It is important to see what is going on here. Increasing the tax rates of either type increases the mark-up that firms can impose, and hence the costs (and rents) they are prepared to pay in order to enter the market. Moreover, that mark-up will have increased by *more* than the original increase in tax rates. That follows from (2.17).

Hence, the number of firms and degree of competition has to fall in the medium term (the first phase of the long term), although profits and rents will rise as (2.24) shows. But if rents rise, then new firms will enter the market and, in the longer term, the number of firms and goods produced will rise again. In other words, there is a non-monotonic response.

Corollary 2 *More firms (goods, employment[25]) enter the market in the transition from short to long run than leave in the short term.*

Proof. The changes in the short term mark-up, $\partial\mu/\partial j = \mu_j$, are given by (2.17); and the subsequent long term adjustments by the partial derivatives from (2.24), (2.26) below, and from (2.16), once the new degree of substitutability has been established. Putting these together, the total change is

$$d\mu = \left[1 + \frac{\partial\mu}{\partial\delta}\cdot\frac{\partial\delta}{\partial c}\cdot\frac{\partial c}{\partial\mu}\right]\mu_j dj, \quad \text{for } j = t_w, t_p, \delta \tag{2.25}$$

where the second term on the right represents long run changes. But, using (2.24), (2.26) and (2.16), the product of the three partials in the bracket is negative. Given (2.17), that result confirms Proposition 4. Since μ falls if either tax rate falls or $\bar{\delta}$rises,entry cost fall and δ rises compared to the status quo ante, (2.23)-(2.26), which implies more firms and more goods. ■

Corollary 3 *In the long run, a policy of reducing wage taxes will be more effective than reducing payroll taxes for increasing the number of firms, goods or employ-*

25 There is a possible exception here. If t_w falls, unemployment is unaffected: (2.27). But if the participation rate rises, requiring the participation ratio of $<100\%$ to ensure A>1, then employment will still rise.

ment. However, a policy of market liberalisation that raises the level of competition between producers will be more effective than either at low levels of competition (defined by $\delta(\delta - 1) < 1 - t_w$); but less effective if competition or taxation are already high.

Proof. Competition, and the number of goods and firms all increase if the allowable level of entry costs increases. By (2.24), that requires the mark-up μ to rise. The result now follows by comparing the partial derivatives in (2.17) with each other, and with $\partial\mu/\partial\delta$ from (2.16). Note that (2.24) implies that the number of firms increases with the entry costs they are prepared to pay in order to enter a new market, and with the ease with which their goods can be substituted for others (δ). And employment increases because $\partial w_r(u)/\partial c < 0$ follows from (2.27) below. ■

Finally, by substituting (2.16) into (2.23) and rearranging, we can solve for the long run elasticity of substitution as a function of the regulatory parameters. That solution is:

$$\delta = \frac{(1-\beta)(1-t_w)}{c-(1-\beta)t_w} \tag{2.26}$$

Using (2.23) and (2.18) in (2.18) and (2.19), we can now solve for the long run reservation wage and the long run real wage. Their equilibrium values are given by:

$$w_r(u) = \frac{1-c-\beta}{(1-\beta)(1+t_p)} \text{ and} \tag{2.27}$$

$$\frac{w_i}{P} = \frac{1-c-\beta t_w}{(1+t_p)(1-t_w)} \tag{2.28}$$

The introduction of taxation in this model has therefore increased the complexity of the solution, but it is straightforward to see the effects of the regulatory parameters on the equilibrium reservation wage, real wages and employment.

2.2.5 Comparative Statics in the Long Run

Proposition 5 *Long run equilibrium reservation wage (unemployment rate) is always a decreasing (increasing) function of labour's bargaining power.*

Proof. The first derivative of $w_r(u)$ with respect to labour's bargaining power is always negative:

$$-\frac{c}{(1-\beta)(1+t_p)} < 0 \tag{2.29}$$

■

Proposition 6 *Long run equilibrium real wages are always a decreasing function of bargaining power.*

Proof. Taking first order derivatives in (2.28), we obtain $-t_w/[(1+t_p)(1-t_w)]$ which is also negative. ■

To explain Propositions 5 and 6, consider a permanent increase in labour's bargaining power. In the short run, this leads to a rise in real wages since the share of the profits (rents) going to the workers will have increased. But that means the profits available to firms will be reduced and it will become harder to satisfy the requirement imposed by the entry condition . the more so, the greater is β. Therefore the number of the firms present in the market will decrease. A decrease in the number of firms implies a decrease in the elasticity of substitution faced by the remaining firms. That means that firms will charge higher prices. Workers will demand higher wages to compensate. But, because firms have market power (and because taxation increases the mark-up that this implies; and also because the tax wedge increases the nominal wage claim workers have to make in order to preserve their take home pay), these wage increases will be passed on in price increases. That leads to a reduction in the real wage finally received by the workers. If taxation were to go to zero, this effect would vanish as (2.28) would be independent of β. It would also vanish even if markets were to become fully competitive since $\delta \to \infty$ implies $c \approx (1-\beta)t_w$ in (2.26), which makes w_i/P independent of β in (2.28). Hence, either distortionary taxes or imperfect competition, or both, is responsible for the decreasing value of bargaining power.

Finally we consider the effects of a change in taxes on reservation and real wages.

Proposition 7 *The long run reservation wage is not affected by changes in the taxes paid by employees, but is a decreasing function of the taxes paid by employers. By contrast, the long run equilibrium wage is an increasing function of the taxes paid by employees and a decreasing function of the taxes paid by employers.*

Proof. The first derivative of $w_r(u)$ with respect to t_w is zero, and with respect to t_p is

$$-\frac{1-c-\beta}{(1-\beta)(1+t_p)^2} \tag{2.30}$$

which is negative so long as $c+\beta<1$. Similarly the first derivative of the long run real wage with respect to t_w is

$$\frac{1-c-\beta}{(1+t_p)(1-t_w)^2} \tag{2.31}$$

whereas the first derivative with respect to t_p is given by

$$-\frac{1-c-\beta t_w}{(1+t_p)^2(1-t_w)} \tag{2.32}$$

Of these two expressions, the first is always positive and the second always negative so long as $c+\beta<1$. However, it is easy to check that $c+\beta<1$ always holds if $\delta \geq 1$ (implying $\mu \geq 0$) since $t_p \geq 0$[26]. ■

2.2.6 Business Tax Reform: An Example

A much discussed area of economic reform is to reduce tax distortions. Consider a scenario in which a government plans to reduce the taxes faced by employers. Let us also assume that the government is either required to keep the budget balanced, or needs to keep the deficit within some strict upper bound such as demanded by the Stability and Growth Pact. Wage taxes would have to rise to compensate. What are the short and long run effects of this policy?

According to Proposition 2, the short run increase in the wage taxes needed to keep the budget in balance will not affect real wages, whereas the planned reduction in payroll taxes would lead to an increase in the real wage through its favourable (lower) effect on the mark-up. But the extra taxes paid by employees will have the opposite effect, increasing the mark-up where the lower payroll taxes reduce it. This combination of tax changes would therefore lead to a short run decrease in employment since the negative wage tax ef-

[26] From Proposition 7, and its short run counterparts (Propositions 2 and 3), we can see that the ambiguous effect of increasing competition on wages noted by Spector (2004) is in fact a temporal effect; not a capital-labour conflict since capital is not needed to obtain the result. In the short run wages fall due to myopia in the wage bargains struck by workers. In the long run wages rise because competition in the product markets reduces mark-ups and therefore increases consumption and employment.

fect will be larger than the positive payroll tax effect on $w_r(u)$ (see Corollary 1). Thus the short term impact of this type of policy would increase unemployment. It might have been better to have just reduced wage taxes; or to have removed the short term requirement to keep the budget balanced. In either case, these are disincentives which may block this kind of structural reform programme. It entails a short run loss in economic performance, political loss of face, and counter-productive outcomes if budget balance is enforced – although abandoning the fiscal restraint altogether might have risked destabilising the budget.

But in the long term, the sequence of events is quite different. Indeed, the direction of impact is reversed. By Proposition 7, the *net* long run effect of an increase in the wage taxes needed to compensate for our reduction in payroll taxes, would lead to a reinforcing increase in long run real wages; and to a decrease in the unemployment rate since the reservation wage, which also increases, is negatively related to unemployment. This outcome follows because a rise in wage taxes will not affect the reservation wage (Proposition 7). But the compensating fall in payroll taxes will increase the reservation wage, reflecting a fall in unemployment, even if t_w has had no effect. The final outcome is a fall in unemployment therefore.

The outcome of this example is therefore summarised in Table 2.1. It highlights the non-monotonicity property in Proposition 4, which arises here because the increase in wage taxes has had a larger effect in increasing the mark-up [and hence real wages and the reservation wage], than the decrease in payroll taxes has had in decreasing it.

Table 2.1. The Implications of Lowering Business Taxes

a) *In the short run (by Propositions 2 and 3)*

$$\frac{\partial w_i/P}{\partial t_w} = 0, \quad \frac{\partial w_i/P}{\partial t_p} < 0 \quad and \quad \frac{\partial w_r(u)}{\partial t_w} < 0, \quad \frac{\partial w_r(u)}{\partial t_p} < 0$$

So $t_p \downarrow$ implies $w_i/P \uparrow$, but also $w_r(u) \uparrow$ so $u \downarrow$. But $t_w \uparrow$ implies no change in w_i/P, while $w_r(u) \downarrow$ so $u \uparrow$. And of the two, t_w has the stronger effect. Hence u rises overall.

b) *In the long run (by Proposition 7)*

$$\frac{\partial w_i/P}{\partial t_w} > 0, \quad \frac{\partial w_i/P}{\partial t_p} < 0 \quad and \quad \frac{\partial w_r(u)}{\partial t_w} = 0, \quad \frac{\partial w_r(u)}{\partial t_p} < 0$$

So $t_p \downarrow$ implies $w_i/P \uparrow$, and $w_r(u) \uparrow$ so $u \downarrow$ as before. But $t_w \uparrow$ now implies $w_i/P \uparrow$, and no change in $w_r(u)$, which leaves u unchanged. And, as before, t_w has the stronger effect (although we don't need that). This time u falls unambiguously.

In other words, there is a demand side effect here despite the neutral budget changes, and the distribution of the burden of taxation matters a great deal. This result therefore rationalizes what the Scandinavians call their "flexicurity" approach to fiscal reform.

Comment: This example confirms a widely accepted premise that structural reforms (an easing of business taxes in this case) would be beneficial in the long run; but would induce short run costs, both in terms of economic performance (indicated here by the increase in the short run unemployment rate) and in their political implications. This short run-long run conflict has been made all the sharper by the presence of the budget restraint and that in itself might be enough to block the reform efforts altogether. But the long term effects are entirely positive, as indicated by the falling unemployment. The question therefore is whether the *discounted* long run benefits will outweigh the short run costs. To make that determination, we need a model with explicit dynamics. That is a topic for further research. At this point we have only a comparative statics answer to that question.

2.3 Unemployment, the Natural Rate and the Phillips Curve

The next step is to consider how structural reforms affect unemployment.

For a decade now, economists have been arguing that the traditional Phillips curve has become flatter or has shifted its position, and they have offered a remarkable variety of explanations for why this might happen. It could be the result of transnational wage bargaining; or the effect of locational competition and globalization on the slope and position of the Phillips curve (Demertzis and Hughes Hallett, 1998; Bean, 2006; Pain et al., 2006). Or, as Razin and Binyamini (2007) show, it could be the result of trade, increased competition and migration as product markets integrate. But equally it could be the result of reduced market frictions (Smets and Wouters, 2007); or of greater credibility and effectiveness in monetary policy (Roberts 2006, Boivin and Giannoni, 2006), especially as expectations become anchored (Williams, 2006). The next obvious question is: could structural reforms not have a similar flattening or shifting effect on the Phillips curve? In this section, we find that slope changes in the Phillips curve could be the result of reducing business taxes, or wage taxes if the price margins of the imperfectly competitive firms are sufficiently sensitive. By contrast, reducing wage bargaining power, or employment protection, or hiring and firing costs, have little effect on the slope as opposed to the position of the Phillips curve.

To summarise what we have so far:

In the short run: Proposition 1 does not extend to reservation wages or unemployment since μ is invariant to β in the short term: $\partial w_r / \partial \beta = 0$ in (2.19). But w_r and u do change with both tax rates. Proposition 3 implies that short term unemployment will rise with both kinds of taxes, but more so with wage taxes than business taxes. These are the reforms which could be used to improve the short run Phillips curve trade-off.

In the long run: Section 2.2.4 shows that w_r and u change with δ, when the latter starts to change with the entry of new firms. So taxes, competition policy and labour market deregulation will all affect unemployment in the long run. Proposition 7 shows that u_N is unaffected by wage taxes t_w, but increases with business taxes t_p. Proposition 5 shows that u_N is also increasing in labour's bargaining power β. These are structural reforms that influence the natural rate of unemployment by shifting the long run Phillips curve to the left and to a lower u_N value. Changing $\overline{\delta}$ will have the same effect.

Product market liberalisation: It is open to the government to increase δ by increasing $\overline{\delta}$ through competition policy or market deregulation. In that case the following hold:

$$\frac{\partial \mu}{\partial \delta} = \frac{-(1+t_p)}{(\delta-1)^2(1-t_w)} < 0 \text{ from } (2.17)$$

and

$$\frac{\partial w_r}{\partial \delta} = \frac{1}{\delta^2(1+t_p)} > 0 \text{ using } (2.27), (2.24), (2.17).$$

Thus, unemployment will fall in the short run if either tax rate is reduced: but by more if wage taxes fall. It also falls if competition policy, $\overline{\delta}$, is applied more vigorously (recall that the government cannot affect the $f(m)$ component of δ in the short run). And in the long run, unemployment will fall with deregulation in the labour markets, β; with business taxes t_p (but not wage taxes); and with market liberalisation δ.

The Effects on the Phillips Curve and the Natural Rate of Unemployment: How does this affect unemployment and its natural rate? In this standard framework, three things can happen. The slope of the short run Phillips curve's might change or be flattened; or the curve might be displaced downwards; or the (vertical) long run curve might shift to the left.

The first possibility implies an improvement in the short run Phillips curve trade off: the inflationary implications of any expansionary policy or events are reduced, even if the unemployment consequences of a monetary contraction become more severe. The second and third possibilities imply short and long run gains in that *any given* rate of monetary expansion/inflation will generate lower rates of unemployment in both the short and long run. Conversely, targeting a lower rate of unemployment would trigger less inflation in the short run; and also in the long run if that the underlying rate of monetary expansion is reduced at the same time.

The implications of structural reform for the natural rate of unemployment and the Phillips curve are now clear. In the short term, the slope of the Phillips curve is given by $d\dot{P}/du$ where $\dot{P}$ denotes the rate of price inflation. Since $\dot{P}$ is not determined in the model, we will assume the underlying rate of monetary growth remains constant: $\dot{m}$ say. Then $\dot{P} = \dot{\mu}+\dot{m}$; and the mark-up falls with either tax rate, or if δ increases. But the mark-up can only change *while* the tax rates or $\overline{\delta}$ are changing. Thus there will be a temporary decrease in inflation while the reforms are being introduced. Thereafter it reverts to its previous level.

Now to determine du. Notice that $du = (du/dw_r)/dw_r/dx$ where x can be t_p, t_w or $\overline{\delta}$ depending on the reform type chosen. Notice also that du/dw_r is independent of the reform measure. Using the expressions above, (2.19) and (2.18), we find:

$$\frac{\partial w_r}{\partial t_p} = \frac{-1}{(1+\mu)^2} \frac{\delta}{(\delta-1)(1-t_w)}, \; \frac{\partial w_r}{\partial t_w} = \frac{-1}{(1+\mu)^2} \frac{\delta(1+t_p)}{(\delta-1)(1-t_w)^2},$$

$$\text{or} \quad \frac{\partial w_r}{\partial \overline{\delta}} = \frac{f(m)}{\delta^2(1+t_p)}$$

respectively. Consequently du will become larger (in absolute value) if t_p is reduced since μ has become smaller and the rest remains unchanged. Similarly du will become smaller if $\overline{\delta}$ is increased. But, and by contrast, du will become either larger or smaller if t_w is reduced, depending on whether the μ effect (larger) or the t_w effect (smaller) turns out to dominate.

Overall then, a temporary flattening effect on the short run Phillips curve is possible. But after that it is hard to make a general statement because the outcome depends on the reform instrument used. If business taxes are lowered, the short run Phillips curve gets flatter unambiguously. If competition policy is increased, it gets steeper. And if wage taxes are reduced, the outcome is ambiguous and will vary from economy to economy. Meanwhile the wage bargaining arrangements have no short run effect.

In the longer term, the effect of these market based reforms is straight forward. A reduction in either tax rate will reduce the natural rate of unemployment, both shifting the short run Phillips curve down and shifting the long run curve to the left. At the same time, the short run curve will be flattened if the instrument is business taxes; possibly also if it is wage taxes. And it will certainly be steeper if competition policy is used. In addition, deregulating wage bargains and also the dynamic effects of the measures cited above will reduce the natural rate by shifting the long run curve to the left.

Sensitivity and Robustness: From (2.30) we can infer that u_N will improve under lower business taxes by more in those countries where t_p is low, or where c is low or δ large; that is in countries that already have low business taxes, low entry costs and competitive product markets. So it is the deregulated economies which have most to lose from a lack of reform; and who would gain the most, at least in employment, from a reform of business taxes. Trade union or wage bargaining power plays no role in that comparison.

Similarly, starting from (2.29), deregulating the labour market will reduce u_N by more in those countries with competitive goods markets, but strong wage bargaining power or regulated labour markets: entry costs do not play a role in this comparison. Lastly, liberalising the product markets will have a greater effect in reducing u_N in those economies where competition or taxes of either kind are low.

2.4 Which Reforms Will be Most Effective?

a) From a Welfare Perspective: It is natural to ask which reform strategy would be the most effective in terms of increasing the number of goods and employment in an economy. We define effective to mean getting the mark-up or acceptable cost of entry to fall as taxes, or labour and product market regulation falls because, if a measure is effective in that sense, then it will raise real wages and the reservation wage at the same time (by (2.27) and (2.28)). That implies an increase in welfare and a decrease in unemployment. Hence one way to determine which reforms are most effective is to determine which instrument has the largest impact on real wages and welfare.

From Corollary 3, we already know that a reform of wage taxes, t_w, will be the more effective of the two tax instruments. We also know that deregulation of the product markets will be better than tax reform if $\delta(\delta-1) < 1-t_w$; from which we can calculate the maximum value of δ, δ_{max}, such that market liberalisation would be the preferred option, given the tax rate on wages. Following a similar approach, we can compare the size of the partial derivatives of w_i/P with respect to β, δ and t_w to determine the thresholds for the most efficient instrument. After some algebra, this yields:

Corollary 4 *(a) Product market liberalisation is more effective (welfare enhancing) as a reform programme than deregulating the labour market if*

$$\delta < 1 + \sqrt{(1-\beta)(1-t_w) - t_w} \leq 2, \tag{2.33}$$

or if $\delta > 1 + 1/\theta$ where θ is the measure of tax distortion defined in Section 2.2. (b) Labour market deregulation is more effective than tax reform if

$$t_w < (1-\beta)(\delta - 1)/\delta \tag{2.34}$$

Proof. Compare $\partial(w_i/P)/\partial\delta$, $\partial(w_i/P)/\partial\beta$ and $\partial(w_i/P)/\partial t_w$ in absolute size. ■

Corollaries 3 and 4 therefore provide a set of simple sufficient conditions to assess the relative efficiency of each type of reform programme, each condition being expressed as the maximum δ value that can hold if the given instrument is to be more effective for increasing welfare.

b) From an Employment Perspective: The corresponding results for which reform strategy is most effective for reducing unemployment are rather different. Because the structural and institutional reforms that affect employment take some time, we will only consider the long run consequences of the different measures on u_N. We also only consider the case in which the relationship between w_r and u is not changed: so the source of reform does not alter the relationship between reservation wages and the rate of unemployment. That may not always be true, but the results easily generalise.

From Proposition 7, business taxes t_p are clearly a more effective reform instrument than wage taxes t_w as far as employment generation is concerned. Given that, we have:

Corollary 5 *(a)Product market reforms are more effective than business tax reforms as an instrument for generating employment if*

$$\delta < \left\{1 + \sqrt{1 + 4\Psi}\right\}/2 \quad where \quad \Psi = (1 + t_p)/(1 - t_w)^2 \tag{2.35}$$

(b) But business tax reforms are more effective for generating employment than labour market deregulation if

$$\delta < (2 + t_p)/(1 + t_p) \tag{2.36}$$

(c) Liberalising product markets is more effective than deregulating labour markets if

$$\delta < (1 - \beta)\sqrt{(1 - t_w)/c} \tag{2.37}$$

Proof. Compare $\partial w_r/\partial t_p$, $\partial w_r/\partial \delta$ and $\partial w_r/\partial \beta$ in absolute size, using the results of Sections 2.2.4 and 2.2.5. Note that (2.35) and (2.36) are sufficient conditions. ■

There is a clear ranking here if δ is small. In the long run, unemployment is best reduced and employment generated by liberalising the product markets; then by reducing business taxes; and finally by deregulating the labour markets. That is for economies with imperfectly competitive markets. Reducing wage taxes would have no effect, either positive or negative, except as a short term measure.

But in economies with competitive markets, the ranking will become reversed: deregulating the labour markets will be most effective, then reforming business taxes, and then product market liberalisation.

Evidently the inequalities in (2.35), (2.36) and (2.37) are the crucial terms for determining which ranking applies in practice. It seems likely that the second ranking will apply to the developed economies since, even with tax rates as high as $t_w = 0.5$ and $t_p = 0.5$, and with unit entry costs as low as $c = 0.1$, the upper bounds on δ will remain below 2 or 3. And that is what the data in our sample of OECD/EU economies shows (Table 2.4).

Corollary 6 *The reform measures that are effective for reducing unemployment (generating employment) will, in general, be different from those that are most effective for increasing welfare.*

Proof. Compare Corollaries 5 and 4; they produce different rankings by effectiveness for each objective, except for when δ is very small. ■

Thus in core Europe, and in contrast to the welfare comparisons, the effective reforms for job creation will lie in deregulating the labour markets; then in reduced business taxes; and then in market liberalisation. Could Mrs. Thatcher have been right after all?

2.5 Empirical Results

To evaluate the practical significance of our results, we have used the OECD's *Tax Data Base* and unemployment figures from the OECD's *Main Economic Indicators*. The former supplies t_w and t_p defined as "all in" average tax rates on manufacturing wages and corporate incomes, inclusive of social security contributions; the latter, unemployment rates on a standard definition[27]. For the remaining parameters, we set β (the wage bargaining parameter) at 0.25, being the mid-range estimate from the Layard, Nickell and Jackman (1991) study, and then consider $\beta = 0$ and $\beta = 0.5$ – decentralised and centralised wage bargaining respectively – as alternatives.

Finally, and perhaps more controversially, we set δ at 3.5 for the short run substitutability between products[28], and $\delta = 10$ for the long run substitutability. These figures are based on the few within-period product substitutability studies in the literature and may be compared to $\delta = \infty$ for perfectly competitive markets[29]. All data are for 2005.

Table 2.2 records the tax and price distortions, as they stood in 2005, for the 24 OECD economies and the EU as a whole. There is considerable variation, but three features stand out.

---

[27] The OECD figures agree with Eurostat's ESA95 data, except that the latter does not separate employer from employee social security contributions. As a result, we don't have consistent data for the smaller states of the EU (Estonia, Cyprus, Latvia, Lithuania, Malta, and Slovenia) who are not yet members of the OECD. Splitting those contributions 50-50 between employers and employees gives us rough estimates of the figures in Tables 2.2 to 2.4 for those countries. Their figures are available on request.

[28] We impose $\delta = 3.5$ to give a 20% mark-up on average, following Rotemberg and Woodford (1992).

[29] Ogaki and Reinhart (1998a,b) suggest $2.9 - 3.9$ for the US, while developing countries have lower figures which again suggests $2.9 - 3.9$ would be about right for the OECD economies. Ravn et al. (2004) prefer 2.0; Papadaki et al (2004) $3.0 - 5.0$; and Gali et al. (2003) calculate mark-ups which imply $\delta = 3.3$ for the EU. Long run figures correspond to the midpoint US estimates in Duca and VanHoose (2000).

First, all of Europe suffers greater tax and price distortions than the US. Ireland is an exception. But outside Europe, only Canada does. Similarly, core Europe (Belgium, France, Italy, Germany, and Sweden in this instance) are noticeably more distorted than the EU as a whole. And the Netherlands, Czech Republic, Hungary, Poland and Finland come close. In most cases European tax distortions and price distortions are equally serious. But in the Netherlands, Poland, Finland and Denmark, it is the price distortions which are more serious (implied by the high values of c, reflecting above average mark-ups), while tax distortions are more serious in France and Italy. There is therefore a small vs. large economy distinction in terms of competitive markets.

Second, countries can be grouped by the strength of their overall market distortions:

(i) Core Europe: Belgium, Germany, France, Italy Sweden and the EU-25 ($\mu > 1.5$).

(ii) The Hapsburgs: Czech Republic, Hungary, Poland, Slovakia, Finland, Netherlands, Austria, Denmark ($1.5 > \mu > 1.35$)[30].

(iii) Periphery Europe: Greece, Spain, Norway, Portugal ($1.35 > \mu > 1.07$)

(iv) The Anglo-Saxons: the US, the UK, Switzerland, Canada, and Australia where $1.07 > \mu > 0.95$; and

(v) Recovery Economies: Japan, Ireland ($\mu < 0.95$). The smaller transition economies (not shown here) also fit into this group.

This grouping, while arbitrary, remains unchanged for different values of δ and β.

---

30 With surprisingly little violence to history: the Netherlands was under Hapsburg rule for a limited period, and Poland only partly, but Finland and Denmark never were.

Table 2.2. Price and Tax Distortions, by Country, with $\beta = 0.25, \delta = 3.5$ and Variations

Country	tax distortion: $\theta = \frac{t_w + t_p}{1 - t_w}$	$\beta = 0.25\,\delta = 3.5$ price distortiton			$\beta = 0.25\,\delta = 10.0$ price distortiton			$\beta = 0.25\,\delta = \infty$ price distortiton		
		μ	$\mu - \theta$	c	μ	$\mu - \theta$	c	μ	$\mu - \theta$	c
Belgium	1.183	2.050	0.873	0.431	1.426	0.243	0.348	1.183	0	0.304
Germany	1.032	1.845	0.813	0.431	1.258	0.226	0.348	1.032	0	0.304
France	0.899	1.659	0.760	0.357	1.110	0.211	0.355	0.899	0	0.273
Italy	1.018	1.825	0.807	0.363	1.242	0.224	0.263	1.018	0	0.208
Netherlands	0.773	1.482	0.709	0.399	0.970	0.197	0.307	0.773	0	0.258
Austria	0.708	1.391	0.683	0.368	0.898	0.190	0.269	0.708	0	0.216
Spain	0.612	1.257	0.645	0.316	0.791	0.179	0.203	0.612	0	0.176
Ireland	0.314	0.840	0.526	0.298	0.460	0.146	0.181	0.314	0	0.119
Portugal	0.484	1.078	0.594	0.303	0.649	0.165	0.187	0.484	0	0.124
Finland	0.779	1.491	0.712	0.377	0.977	0.198	0.280	0.779	0	0.303
Greece	0.536	1.150	0.614	0.303	0.696	0.170	0.184	0.536	0	0.125
Denmark	0.709	1.393	0.684	0.435	0.899	0.190	0.353	0.709	0	0.309
Sweden	0.923	1.692	0.769	0.380	1.137	0.214	0.284	0.923	0	0.232
UK	0.453	1.035	0.582	0.344	0.610	0.160	0.240	0.453	0	0.191
Czech Rep	0.774	1.484	0.709	0.342	0.971	0.197	0.236	0.774	0	0.179
Hungary	0.781	1.494	0.713	0.353	0.979	0.198	0.250	0.781	0	0.194
Poland	0.757	1.461	0.704	0.383	0.953	0.195	0.288	0.757	0	0.236
Slovakia	0.723	1.412	0.689	0.382	0.914	0.191	0.219	0.723	0	0.160
EU-25	0.811	1.535	0.724	0.376	1.014	0.201	0.279	0.811	0	0.226
US	0.421	0.989	0.568	0.343	0.573	0.158	0.238	0.421	0	0.182
Japan	0.362	0.907	0.544	0.308	0.513	0.151	0.192	0.362	0	0.131
Canada	0.477	1.067	0.590	0.347	0.641	0.164	0.242	0.477	0	0.185
Australia	0.400	0.960	0.560	0.344	0.556	0.156	0.239	0.400	0	0.182
Switzerland	0.405	0.966	0.561	0.326	0.561	0.156	0.216	0.405	0	0.154
Norway	0.584	1.219	0.638	0.368	0.761	0.176	0.269	0.584	0	0.215

Notes: a) $\delta = 3.25$ represents a consensus estimate of the average short run inter-product substitutability in the advanced OECD economies, derived from the references given in the text. It corresponds to price mark-ups which range from about 5% in the US or UK, to 55% in the EU-25, and $60\% - 85\%$ in France, Germany or Italy. $\delta = 10$ is a consensus estimate of the likely long run degree of within period substitutability, taken from estimates for the US economy (Duca and van Hoose 2000, 2006). Finally, $\delta = \infty$ represents perfect competition. b) Further results for $\beta = 0$ and $\beta = 0.5$, representing decentralised and centralised wage bargaining respectively, are available upon request. But those variations make little difference to our comparisons and are not reported here.

Third, tax distortions are larger than price distortions in Belgium, the Czech Republic, Denmark, Germany, France, Italy, Netherlands Sweden, Austria, Finland, Poland, Hungary and Slovakia. But price distortions are more important in Spain, Greece, Ireland, Portugal, the UK and the non-EU economies. That may reflect the size of the domestic markets; but more likely a generally lower incidence of taxation.

Tables 2.3 and 2.4 meanwhile give the upper bounds on δ, or the degree of competition in the markets, to show which different reform measures would be the most effective for generating either welfare improvements or new employment opportunities.

In fact, Table 2.3 shows that tax reform is almost always the most effective instrument for welfare purposes unless the labour market is very distorted. For the OECD and EU members displayed in Table 2.3, we find:

i) Product market liberalisation is more effective than tax reform if $\delta \leq 1.5$.

ii) Product market liberalisation is more effective than labour market deregulation when $\delta \leq 2$ (if $\beta \approx 0$), or when $\delta \leq 1.5$ (if $\beta \approx 0.25$).

iii) Tax reform is better than labour market deregulation unless $\delta \leq 1.3$ ($\beta \approx 0$); or unless $\delta \leq 1.5$ (when $\beta \approx 0.25$), and for δ values above 4 or 5 if $\beta = 0.5$.

Thus tax reform is always the most effective type of reform unless δ is *very* small, which is unlikely in any of the advanced OECD economies[31]. An exception would be in an economy with severe labour market distortions ($\beta \geq 0.5$). In that case, labour market deregulation is likely to be the most effective instrument.

By contrast, Table 2.4 shows that market liberalisation will be the most effective instrument for generating new employment, followed by business tax reforms, and then labour market regulation – except in the case of core Europe (which, in this case, comprises France, Germany, Belgium, Netherlands, Italy, Austria, Finland, Denmark, Sweden, Czech

[31] But governments are still free to use combinations of instruments to boost their reform packages.

Table 2.3. Threshold Values for Policy Effectiveness for Improving Welfare, δ_{max} values:

Country	Market liberalisation better than tax reform if $\delta < \delta_{max}$, for any β value	Market liberalisation beats labour reform if $\delta < \delta_{max}$			Tax reform beats labour reform if $\delta < \delta_{max}$		
		a)	b)	c)	a)	b)	c)
Belgium	1.42	2.00	1.20	never	1.68	2.17	5.26
Germany	1.54	2.00	1.68	never	1.20	1.28	1.50
France	1.49	2.00	1.53	never	1.36	1.55	2.15
Italy	1.49	2.00	1.51	never	1.39	1.59	2.25
Netherlands	1.45	2.00	1.38	never	1.50	1.85	3.21
Austria	1.48	2.00	1.49	never	1.40	1.62	2.36
Spain	1.53	2.00	1.65	never	1.23	1.34	1.61
Ireland	1.55	2.00	1.69	never	1.19	1.26	1.46
Portugal	1.54	2.00	1.68	never	1.20	1.28	1.50
Finland	1.47	2.00	1.47	never	1.43	1.68	2.54
Greece	1.54	2.00	1.68	never	1.20	1.28	1.50
Denmark	1.42	2.00	1.17	never	1.70	2.22	5.68
Sweden	1.47	2.00	1.45	never	1.45	1.70	2.63
UK	1.50	2.00	1.57	never	1.32	1.48	1.95
Czech Rep	1.51	2.00	1.57	never	1.31	1.47	1.92
Hungary	1.50	2.00	1.54	never	1.35	1.53	2.07
Poland	1.47	2.00	1.45	never	1.46	1.72	2.70
Slovakia	1.52	2.00	1.61	never	1.27	1.40	1.74
EU-25	1.47	2.00	1.47	never	1.43	1.67	2.52
US	1.50	2.00	1.57	never	1.32	1.48	1.94
Japan	1.54	2.00	1.45	never	1.21	1.30	1.53
Canada	1.50	2.00	1.56	never	1.33	1.49	1.98
Australia	1.50	2.00	1.57	never	1.32	1.48	1.94
Switzerland	1.52	2.00	1.62	never	1.26	1.39	1.72
Norway	1.48	2.00	1.50	never	1.40	1.62	2.35

Notes: a) with $\beta = 0$; b) $\beta = 0.25$; and c) $\beta = 0.5$ ("never" means δ_{max} is complex).

Table 2.4. Threshold Values for Policy Effectiveness in Lowering Unemployment, δ_{max}.

Country	Tax reform is less effective than market liberalisation if $\delta < \delta_{max}$, for any β value	Tax reform is more important than deregulating labour markets if $\delta < \delta_{max}$, for any β value	Market liberalisation beats deregulating labour markets if $\delta < \delta_{max}$		
			a)	b)	c)
Belgium	2.48	19.81	1.18	never	never
Germany	2.41	12.48	1.18	never	never
France	2.19	4.85	1.43	1.08	never
Italy	2.24	5.60	1.41	1.06	never
Netherlands	2.22	5.55	1.28	never	never
Austria	2.13	4.36	1.39	1.04	never
Spain	1.91	3.32	1.60	1.20	never
Ireland	1.84	2.65	1.68	1.26	never
Portugal	1.92	2.97	1.66	never	never
Finland	2.17	4.86	1.36	1.02	never
Greece	1.94	3.06	1.66	1.24	never
Denmark	2.28	6.77	1.16	never	never
Sweden	2.42	5.71	1.35	1.01	never
UK	1.97	3.25	1.48	1.11	never
Czech Rep	2.11	4.08	1.49	1.12	never
Hungary	2.13	3.13	1.45	1.14	never
Poland	1.92	4.93	1.34	never	never
Slovakia	2.06	3.72	1.55	1.16	never
EU-25	2.19	4.99	1.36	1.02	never
US	1.96	3.17	1.48	1.12	never
Japan	1.89	2.79	1.64	1.23	never
Canada	1.99	3.33	1.47	1.10	never
Australia	1.95	3.12	1.48	1.11	never
Switzerland	1.92	2.99	1.56	1.17	never
Norway	2.07	3.90	1.39	1.04	never

Notes: a) with $\beta = 0$; b) $\beta = 0.25$; and c) $\beta = 0.5$; where "never" implies $\delta_{max} < 1$.

Republic and Poland) where labour market reform would be more important than lowering business taxes.

2.6 Concluding Remarks

We have taken a standard model of the labour market in an economy with imperfect competition in the product and labour markets, and extended it to allow for the endogenous entry of firms, the implications for unemployment, distortionary taxation, and to show the composition of the price mark-up. The main contributions have been to show how tax reforms can contribute to the reform process; how the composition of the price mark-up determines the long run effects of structural reform; and how the effectiveness of different reform instruments varies depending on whether welfare or employment creation is the ultimate objective.

From the general equilibrium outcomes of this model, we find:

a) There is a difference between the short run and long run consequences of reform. The short run involves significant costs or losses in employment and welfare, but the long run effects are almost uniformly favourable. Structural reform programmes are therefore likely to be avoided, or abandoned if undertaken, if policy makers become sensitive to their short run costs.

b) Fiscal restraints, such as those imposed by Europe's Stability and Growth Pact, exaggerate this effect and make it less likely that such reforms will be carried out.

c) The choice of reform instrument matters. Tax reforms tend to be most effective for raising welfare; whereas labour market deregulation will be best for creating employment if product markets are competitive, but product market liberalisation if they are not. Thus reforms for welfare and for generating employment would not be the same.

d) These instrument rankings are only intended to demonstrate comparative advantage for different objectives. They do not rule out the possibility of creating optimal reform packages for different objectives. But deregulating the labour market is only effective where wage bargaining distortions are large.

e) Business and wage taxes do not have the same effects on wages, output or employment as is often assumed in the public finance literature[32].

[32] This result explains Prescott's (2004) claim that payroll taxes are the prime cause of poor growth and high unemployment. This is true if business taxes are the only candidate for reform; but product/labour market liberalisation would be better if employment generation and output growth is the objective.

Chapter 3

The Effects of Tax and Product Market Reforms on Macroeconomic Performance

Product market regulation and labour market rigidities are widely blamed for the relatively poor economic performance in Europe. As a result, structural reform has become the leading economic policy issue in the European Union. Since the European Economies appear to be less reformed and less flexible than their American counterparts, efforts to restore economic performance vis-a-vis the US economy have been associated, in particular, with the need for higher productivity, lower costs and more flexible (or more competitive) labour markets. In addition to the general institutional framework, particularly taxes, as argued by Prescott (2004), are to be blamed for the relatively poor European economic performance. Moreover, as documented by Stock and Watson (2005) the reduction in labour and product market regulations are widely accepted to be an important component of the reduction in the volatility of the business cycles.

In general, when designing reform policies, policy makers are constrained by various trade-offs generated by a number of different objectives to be fulfilled. Those trade-offs certainly depend on the institutional characteristics as well as on the equilibrium levels of key macroeconomics variables. Specifically, tax reform aimed at promoting employment alters the long run level of some key macroeconomic variables, such as wages and output, and changes the dynamic sensitivity of the economy to exogenous shocks. Furthermore, in the presence of a costly price setting mechanism, the effects of structural reforms on price setting conditions affect the way in which real quantities fluctuate.

Surprisingly, very little formal general equilibrium analysis has studied the effect of either labour or product market reforms.[33] Most of the papers analyze the effects of the structural reforms either in a partial equilibrium setup characterized by certain real labour market frictions, such as efficiency wages or search and matching inefficiencies, but abstract from dynamic consequences, or in a dynamic general equilibrium setup with Walrasian labour markets. The partial equilibrium setup obviously abstracts from general equilibrium effects, whereas the peculiarity of the Walrasian market setup is the absence of explicit modelling of employment choices, or in other words neglect of the extensive margin and thereby "real" or involuntary unemployment. Furthermore, even in this restricted general equilibrium setup no papers have analyzed the effects of labour and product market reforms on aggregate macroeconomic fluctuations and hardly any papers have analyzed the specific effects of the tax reforms.[34]

The purpose of this paper is twofold. First, we wish to analyze the effects of various tax reforms on the labour market characteristics and overall economic performance. Since the focus of most of the previous studies was the analysis of the effects of tax reforms solely on the labour market behavior, we aim to investigate the effects of both the tax as well as product market reforms on the labour markets as well as on the other macroeconomic aggregates such as inflation, consumption and output. Second, we analyze the effect of the aforementioned reforms on aggregate fluctuations.

[33] Several notable and very recent exceptions are the papers Vanhalla (2006) and Zanetti (2009).

[34] An exception is Coenen et.al. (2008).

In order to fulfill our goal we construct a New-Keynesian model characterized by imperfect competition and costly nominal price adjustment. We enrich the standard model by introducing explicit fiscal and monetary considerations and most importantly replace the assumption of Walrasian labour market with more realistic setup described by a matching mechanism. This allows us to explicitly consider the effects of the reforms on employment and on the dynamics of nominal as well as real variables.

Particular emphasis has been given to the quantification of the long run effects of the labour market reforms originating in the specific tax structures. Specifically, we focus on long run effects of three tax instruments, notably the marginal wage tax rate, employers social security contributions determining the payroll tax rate, and the degree of tax progression. How a specific tax reform, aiming to reduce the tax burden, will exactly affect the labour market's characteristics and overall economic performance, crucially depends on the prevailing characteristics of both labour and product markets determined by the wage and price setting mechanism, but also on the way that the implied loses in government revenues are financed. We believe that the reasonably general model developed in this paper, should provide us with the new insights regarding the effects of various tax and product market reforms on the overall economic performance.

We confirm that in the context of a general equilibrium model with endogenous job destruction, a widely held view that the reduction in the marginal tax distortions is beneficial both for the labour markets and the overall economic performance holds. This is consistent with the results obtained in Coenen et al. although in the different setup with Walrasian labour markets and without explicitly determined unemployment. In addition we find that the increase in the product markets degree of competition is also beneficial for the labour market and the economy as a whole.

Furthermore, we find that the increase in the degree of average tax progressivity is beneficial from the long run perspective for labour markets, consumption and output, regardless of the initial progressivity level. The effects of the tax systems' progressivity have already been analyzed in the literature, but mostly in the partial equilibrium setup. However, the existing literature is all but conclusive on its effects. Thus, Koskela and Vilmunen (1996) find that the increase in the degree of progressivity increases employment but reduces wages. Pissarides (1998) also finds a positive effect of the increase in progressivity on employment when wages are determined by bargaining. Sinko (2005) generalizes the Pissarides setup by endogenizing job destruction and obtains similar results. Furthermore, Vanhala (2006) identifies the dependence of the tax progression effect on the initial degree of progression in the context of a general equilibrium model with matching frictions. All of the aforementioned papers consider revenue neutral tax reforms such that tax instrument pairs are changed correspondingly so to keep the government's budget balanced in each period. In our setup we depart from this type of analysis justified by the fact that it is unrealistic to expect the policy maker to have all of the necessary information needed to determine the complex effects of the tax change on the tax base, such that the corresponding tax instrument could be easily adjusted in order to keep the government budget balanced. In our setup the implied changes in government revenues are financed by the adjustment of lump sum transfers (taxes) so to keep the calibrated government spending-to-GDP and debt-to-GDP ratio unchanged in the steady state.

Regarding the dynamic implications of the aforementioned reforms we find that each reduction in the particular marginal tax instrument leads to a decrease in the volatility of output, consumption and employment. On the other hand, the increase in the degree of tax progression generates the same results. Following a positive technology shock the response of inflation in a reformed economy is relatively large only on impact, whereas following a positive government spending shock the inflation response in the reformed economy is larger along the whole adjustment path. These results hold for both the tax as well as for the product market reforms although they work through different channels.

Recently, several OECD countries have reduced payroll taxes, while because of budgetary considerations, increasing the wage tax rate. We complete the analysis by considering a specific reform which implements a reduction in the payroll tax rate with a corresponding increase in the wage tax rate, such that the marginal tax wedge remains constant. In addition, we retain the assumption of lump sum transfers adjustment such that the government spending and debt to GDP ratios are consistent with the Maastricht convergence criteria. Our results indicate that this type of reform would be detrimental for labour markets and the overall economic performance in the long run, since the negative effects of the wage tax increase offset the positive effects of the reduction in the payroll tax rate for reasonable calibration of our model. This result runs counter to those obtained in Heijdra and Ligthart (2009) and call into question the conventional view of the payroll tax cut. Furthermore, our results are consistent with empirical studies, such as Gruber (1997), Bauer and Riphahn (2000), which suggest small or negligible effects of the payroll tax cuts on the employment. Finally, we show that if such reform is anticipated one period in advance short run positive effect are also absent.

The rest of the chapter is organized as follows. In Section 3.1, we detail the description of our model. Section 3.2 identifies potential channels throughout which the tax and product market reforms might impact the economic behavior. In Section 3.3, we define the functional forms and describe the calibration exercise. The long run effects of various reforms are analyzed in Section 3.4, whereas the dynamic responses are considered in Section 3.5. Long run effects of specific tax reform with the corresponding transition dynamics are described in Section 3.6 and the Section 3.7 concludes.

3.1 The Model Economy

Extending the approach developed in Walsh (2005), Trigari (2009) and Lubik and Krause (2007) we develop a New Keynesian model characterized by numerous frictions in both the labour and product markets. Broadly speaking, we depart from the widely adopted Walrasian labour market assumption and introduce labour market frictions in the Mortensen and Pissarides (1994) style, through application of the search and matching mechanism. Furthermore, frictions in the product markets are modelled by introducing the monopolistic competition in a Dixit and Stiglitz (1977) fashion. In this section we describe our model economy by specifying tastes, technology and the behavior in the labour markets, and derive the agents optimal decision rules. After the decision rules are obtained we solve for the steady state of the economy and linearize our model around the obtained steady state. Following the calibration we consider the effects of various shocks.

3.1.1 Households

Following Merz (1995) and Andolfatto (1997) we assume continuum of infinitely lived families ι of mass one populating our model economy. The families are assumed to be uniformly distributed over unit interval and to have the ability to perfectly insure each member against the potential fluctuations in its income. This assumption, which effectively introduces complete consumption insurance among the family members, is needed to avoid potential distributional complications arising from agent heterogeneity. As a result, the equality of the marginal utility of wealth and consumption of the ex ante identical consumers implies ex post equal consumption, and allows us to set up the problem in terms of the representative family construct and ignore the index ι denoting the family type.

Specifically, every family consists of the workers employed across various firms as well as of the unemployed workers representing population at large. Moreover, all families have identical preferences over real consumption bundle C_t and real money balances $\frac{M_t}{P_t}$, where M_t denotes nominal money holdings and P_t stands for the aggregate price level. We also assume that the families form the habits over real consumption bundle and describe preferences by discount factor β and utility functions $U(C_t, H_t)$ and $\Lambda(\frac{M_t}{P_t})$, where H_t denotes the habit stock. For simplicity, we consider simple time additive and non-persistent habit specification proposed by Abbel (1990), Constantinides (1990), Campbell and Cochrane (1999), familiar as the "external" habits. In this case, habit stocks are proportional to the aggregate consumption in the last period C_{t-1} which defines H_t as hC_{t-1}

To determine optimal decision regarding consumption bundle C_t, nominal money M_t and bonds B_t holdings, representative family pools its members income and maximizes expected present discounted value of a lifetime utility. Formally, the maximization problem reads as:

$$\max_{\{C_t, M_t, B_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left\{ U(C_t, H_t) + \Lambda(\frac{M_t}{P_t}) \right\} \tag{3.1}$$

subject to budget constraint defined in real terms as

$$C_t + \frac{M_t}{P_t} + \frac{B_t}{P_t} = (1 - \tau^w) W_t + \frac{M_{t-1}}{P_t} + R_{t-1} \frac{B_{t-1}}{P_t} + b(h, w) u_t + \Pi_t - \tau_t^L \tag{3.2}$$

W_t stands for aggregate wage obtained by the representative family which will be precisely defined in what follows whereas τ^w denotes wage tax rate paid by employed family members. R_t is the gross one period nominal risk-free interest rate paid to the bond holders at the beginning of the period t and $b(h, w)u_t$ is the aggregate unemployment income received by the unemployed family members u_t such that $b(h, w) > 0$. Beside wage, assets and unemployment income, representative family receives aggregate profits Π_t based on the diversified ownership stake in the firms. Moreover, the representative family also receives pure government transfers (taxes) in a lump sum fashion which we denote by τ_t. In what follows we abstract from participation decisions and assume that the representative family's labour is supplied inelastically and normalize the labour force to one.

As is standard in a Dixit-Stiglitz set up, the consumption bundle is represented by the CES aggregate of the differentiated products

$$C_t = \left[\int_0^1 c_{it}^{\frac{\varepsilon - 1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon - 1}} \tag{3.3}$$

where $\varepsilon > 1$ denotes elasticity of substitution of various types of goods indexed by $i \in [0, 1]$. When optimizing, the representative family proceeds in two steps. First it determines the optimal demand schedules for every single type of differentiated product by minimizing the costs of bundle purchases

$$\min_{c_{it}} \int_0^1 p_{it} c_{it} di := P_t C_t \tag{3.4}$$

subject to (3.3) where c_{it} denotes consumption level of the single differentiated product of type i. Solution of the previous minimization problem results in a demand function for the single product variety given by:

$$c_{it} = \left(\frac{p_{it}}{P_t}\right)^{-\varepsilon} C_t \tag{3.5}$$

where the aggregate price index P_t is such that the expenditures are at the minimum possible level, and is defined as:

$$P_t = \left[\int_0^1 {p_{it}}^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}} \tag{3.6}$$

After determining optimal demand for the single product variety, the representative family maximizes aggregate utility, which provides us with following first order conditions for aggregate consumption bundle and real money balances:

$$U_C(C_t, H_t) = \beta R_t E_t \left[U_C(C_{t+1}, H_{t+1}) \frac{P_t}{P_{t+1}}\right] \tag{3.7}$$

$$\Lambda_{\frac{M}{P}}(\frac{M_t}{P_t}) = \frac{R_t - 1}{R_t} U_C(C_t, H_t) \tag{3.8}$$

The optimal behavior of the representative family is fully summarized by equations (3.7) and (3.8). The former equation represents standard Euler condition which describes optimal intertemporal allocation of the consumption and also defines asset pricing kernel, or stochastic discount factor, which will be subsequently used in the producer optimization problem. The latter condition is the standard *money in utility* models' solution for the money demand equation.

3.1.2 Vacancies, Unemployment and Frictional Labour Market

We postulate the existence of a continuum of workers (jobs) j and firms i, each of measure one. Aggregate output of every firm i depends on aggregate productivity A_t as well as on the job specific productivity denoted by $a_{i,j,t}$. This job specific productivity is a random variable whose particular realization is drawn every period from a stationary distribution described by a cumulative distribution function $F(a)$, whose support lies in the $[\underline{a}, \overline{a}]$ interval. Each firm i employ in aggregate $n_{i,t}$ workers every period and posts $v_{i,t}$ vacancies. As already stated, we model frictional labour markets, where the reduced form representation of the labour market frictions is obtained by employing the concept of the matching function. In a general form, the aggregate matching function $M_{t,t+1} \equiv m(u_t, v_t)$ determines the aggregate flow of new matches in the next period and it is a function of this periods' aggregate number of unemployed or searching workers u_t, and the total number of posted vacancies $v_t = \int_0^1 v_{i,t} di$. It will be concave, continuously differentiable, homogenous of degree one and characterized by constant returns to scale. Moreover, it will satisfy the following two properties:

$$\frac{\partial m(u_t, v_t)}{\partial u_t} > 0 \text{ and } \frac{\partial m(u_t, v_t)}{\partial v_t} > 0 \tag{3.9}$$

Under the assumption of constant returns to scale two meeting rates, defined by the probability of a worker finding a job and a firm filling in a vacancy in the next period, depend only on the labour market tightness. Assuming that each firm is sufficiently large the probability of a firm filling in a vacancy in the next period is given by:

$$q(\theta_t) = \frac{m(u_t, v_t)}{v_t} = m\left(\theta_t^{-1}, 1\right) \tag{3.10}$$

Similarly, the probability of a worker finding a job next period is defined as:

$$\theta_t q(\theta_t) = \frac{m(u_t, v_t)}{u_t} = m\left(1, \theta_t\right) \tag{3.11}$$

where $\theta_t = \frac{v_t}{u_t}$ defines the labour market tightness. One can easily establish that the probability of a firm filling in a vacancy will be decreasing, whereas the probability of worker finding a position will be increasing, function of labour market tightness. It is worthwhile pointing out that both the workers and the firms take θ_t as given when determining optimal decisions.

The dependence of output on the jobs' specific productivity implies that individual jobs will be endogenously destroyed if the jobs' specific productivity falls below the endogenously determined threshold $\tilde{a}_{i,t}$. We can therefore define the endogenous probability of destruction as $\rho_{i,t}^n = F(\tilde{a}_{i,t})$. Consistently with the search and matching literature we will assume that a constant fraction ρ^x of all the destroyed jobs $\rho_{i,t}$ in the firm i is exogenously destroyed every period. Within this endogenous job destruction framework, fluctuations in unemployment will be the result of both the cyclical variations in hiring in addition to the variations in the separations which are determined by the threshold $\tilde{a}_{i,t}$. Combining the previous definitions we can define the total separation rate in the firm i as:

$$\rho_{i,t} \equiv \rho(\tilde{a}_{i,t}) = \rho^x + (1 - \rho^x)F(\tilde{a}_{i,t}) \tag{3.12}$$

It is important to point out that our matching function specification is characterized by the implicit assumption of "time to hire". In other words we assume that the new hires do not become immediately operational. Intuitively, this assumption can easily be justified on the grounds that there is usually some time needed to find and train workers in order to become fully productive. Moreover, we will assume that if the firm i posts $v_{i,t}$ vacancies, it can expect to hire $v_{i,t}\frac{m(u_t,v_t)}{v_t}$ additional workers, which makes firm's i number of matches proportional to the ratio of its vacancies to total number of vacancies posted such that $v_{i,t}\frac{m(u_t,v_t)}{v_t} = v_{i,t}g(\theta_t)$. This assumption results in the following equation determining the evolution of the employment at the firms level:

$$n_{i,t} = (1-\rho_{i,t})(n_{i,t-1} + v_{i,t-1}g(\theta_{t-1})) \tag{3.13}$$

where the $g(\theta_t)v_{i,t}$ determines the inflow of the new hires at the firm i.

3.1.3 The Firms

Each variety of good i is produced by a monopolistically competitive firm whose production function is given by:

$$Y_{i,t} = n_{i,t}A_t \int_{\tilde{a}_{i,t}}^{\bar{a}} a_{i,t}\frac{f(a_{i,t})}{1-F(\tilde{a}_t)}da_{i,t} = n_{i,t}A_t H(\tilde{a}_{i,t}) \tag{3.14}$$

where $H(\tilde{a}_{i,t})$ defines the expected value of the idiosyncratic productivity $a_{i,t}$. Evidently, this function defines a constant returns to scale production technology that uses labour as the sole input. As stated in the introduction one of our objectives is to analyze the effects of a potential tax reform on economic performance. In order to accomplish our task we introduce two types of distortionary taxes into the analysis in addition to the lump sum transfers (taxes) entering the households aggregate resource constraint. More specifically we assume that the firms bear the burden of the payroll tax τ^f whereas workers are subjected to the wage tax τ^w payments.[35]

Beside the incurred payroll tax and in addition to the costs corresponding to the total wage bill, we subject the firms to three additional explicit costs. First, as is standard in the search-matching literature we assume that in order to open the vacancies the firms incur certain vacancy posting costs. Second, in order to give the model New-Keynesian flavour, we assume that the firms bare a burden of price adjustment costs. As in Rotemberg (1983) firms are assumed to face the quadratic adjustment costs of adjusting the nominal price from the steady state inflation π. Expressed in terms of produced goods, the cost function is given by $\Theta_t = \frac{\Psi}{2}\left(\frac{P_{i,t}}{P_{i,t-1}} - \pi\right)^2 Y_t$ with parameter $\Psi \geqslant 0$ determining the degree of price rigidity. We have opted for the Rotemberg(1983) pricing as an alternative to the widely used Calvo (1984) pricing scheme for the following two reasons. First, Calvo price-setting mechanism results in the price dispersion among the firms, while Rotemberg mechanism is consistent with the symmetric equilibrium which we subsequently consider. All else equal, they both result in the same New-Keynesian Phillips curve and therefore the implied dynamics of those two price setting mechanisms up to the first order approximation are equivalent. Second, Rotemberg's price setting mechanism implicitly assumes that consumers prefer series of small price changes over a single large price change, which is in line with empirical evidence recently reported in Chen et al. (2008).

Finally, we distort our model economy by imposing firing costs on the firms side. As in Mortensen and Pissarides (1994) and Pissarides (2000) we assume that when the job

---

[35] The payroll tax is equivalent to the social security contributions payed by the employer, and we will therefore interchangably use the two terms in rest of the chapter.

is destroyed the firms need to pay a fixed cost D per worker being laid off. In practice, this firing cost can be thought of as an implicit or shadow firing tax imposed on firms by various legislative employment protection regulations. It mimics the effect of various contractual obligations imposed by the government which distorts the firm firing process. It is important to point out that this cost is not the severance payment going from the firm to the worker, since such a transfer would have no allocative role as pointed out by Lazear (1990) and Burda (1992). What is important for our analysis is that the firing costs represent an additional policy instrument which can be used in the labour market reforms programs.

When output $Y_{i,t}$ is produced it it sold to the families at the unit price $P_{i,t}$. Consequently the firms' profit function reads as:

$$\Pi_{i,t} = \frac{P_{i,t}}{P_t} Y_{i,t} - W_{i,t}(1+\tau^f) - R(v_{i,t}) - \Theta_{i,t} - \Upsilon_t \tag{3.15}$$

where $W_{i,t} = n_{i,t} \int\limits_{\tilde{a}_{i,t}}^{\bar{a}} w(a_t) \frac{f(a_t)}{1-F(\tilde{a}_t)} da_t$ is the total wage bill and $R(v_{i,t})$ denotes the vacancy posting cost function.[36].

A firm's problem is to determine the optimal price of its product, the number of vacancies, the number of employed workers, and the job destruction threshold by maximizing the expected present discounted value of the future profit stream subject to the demand function (3.5), the employment evolution equation (3.13) and the production func-

[36] It is important to point out that the wage bill defined in this way is the conseqence of different productivities characterizing the individual jobs. This requires the total wage bill to be different from the case in which all of the jobs have same productivity. In the latter case the total wage bill would simply be equal to $w_t n_{i,t}$.

tion (3.14). Formally, each firm solves the following optimisation problem:

$$\max_{\{n_{i,t},v_{i,r},P_{i,t},\tilde{a}_{i,t},\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} Q_{0,t}\Pi_{i,t} \tag{3.16}$$

subject to

$$Y_{it} = \left(\frac{p_{it}}{P_t}\right)^{-\varepsilon} Y_t \tag{3.17}$$

$$n_{i,t} = (1-\rho_{i,t})(n_{i,t-1} + v_{i,t-1}g(\theta_{t-1})) \tag{3.18}$$

$$Y_{i,t} = n_{i,t}A_t H(\tilde{a}_{i,t}) \tag{3.19}$$

$$\Upsilon_t = (1-\rho^x)F(\tilde{a}_{i,t})(n_{i,t-1} + v_{i,t-1}g(\theta_{t-1}))D \tag{3.20}$$

As a consequence of the assumed diversified ownership by families of the firms, the firms discounts the revenues at the marginal utility of consumption $\frac{U_C(C_t,H_t)}{U_C(C_0,H_0)}$. We define $Q_{0,t} = \beta^t \frac{U_C(C_t,H_t)}{U_C(C_0,H_0)}$ to be the firm's stochastic discount factor for the real payoffs. After substituting (3.17) into (3.16) and denoting, respectively, the Lagrangian multipliers on employment evolution equation (3.18) and (3.19) by $\mu_{i,t}$ and $mc_{i,t}$ we obtain the following first order conditions with respect to $n_{i,t}$, $v_{i,t}$, $P_{i,t}$ and $\tilde{a}_{i,t}$ which are respectively given by:

$$E_t\left[Q_{t,t+1}(1-\rho_{i,t+1})\mu_{i,t+1}\right] + mc_{i,t}A_tH(\tilde{a}_{i,t}) - (1+\tau^f)\frac{\partial W_{i,t}}{\partial n_{i,t}} - E_tQ_{t,t+1}(1-\rho^x)F(\tilde{a}_{i,t+1})D = \mu_{i,t} \tag{3.21}$$

$$\frac{R'(v_{i,t})}{g(\theta_t)} = E_t\left[Q_{t,t+1}(1-\rho_{i,t+1})\mu_{i,t+1}\right] - \beta E_tQ_{t,t+1}(1-\rho^x)F(\tilde{a}_{i,t+1})D \tag{3.22}$$

$$\begin{aligned}(1-\nu)\left(\frac{P_{i,t}}{P_t}\right)^{-\varepsilon}\frac{1}{P_{i,t}}Y_t - \Psi\left(\pi_t-\pi\right)\frac{1}{P_{i,t-1}}Y_t + \nu mc_{i,t}\left(\frac{P_{i,t}}{P_t}\right)^{-\varepsilon}\frac{1}{P_{i,t}}Y_t \\ = -E_t\left[Q_{t,t+1}\Psi\left(\pi_{t+1}-\pi\right)\pi_{t+1}\frac{1}{P_{i,t}}Y_{t+1}\right]\end{aligned} \tag{3.23}$$

$$
\begin{aligned}
&\mu_{i,t}\acute{\rho}(\tilde{a}_{i,t})(n_{i,t-1}+v_{i,t-1}g(\theta_{t-1}))+(1+\tau^{f})\frac{\partial W_{i,t}}{\partial \tilde{a}_{i,t}} \\
= \;& mc_{i,t}n_{i,t}A_t\acute{H}(\tilde{a}_{i,t})-(1-\rho^{x})F'(\tilde{a}_{i,t})(n_{i,t-1}+v_{i,t-1}g(\theta_{t-1}))D \qquad (3.24)
\end{aligned}
$$

Standard interpretation of a Lagrange multipliers as a constrained resource marginal value implies that, in our framework, $\mu_{i,t}$ is the current period (marginal) average value of workers with different job specific productivities, whereas $mc_{i,t}$ is the current period marginal value of the additional unit of production, or equivalently the firms' real marginal cost.

Job Creation and Job Destruction Conditions

It is worthwhile spending several sentences on the interpretation of the above conditions. Condition (3.22) is the first order condition for vacancy posting, which equates the marginal cost of posting a vacancy and adding a new worker with its discounted marginal benefit. Substituting (3.22) into (3.21) and rearranging gives us the job creation condition defined as:

$$
\begin{aligned}
\frac{R'(v_{i,t})}{g(\theta_t)} = \;& \beta(1-\rho^{x})E_t\frac{\lambda_{t+1}}{\lambda_t}\left[(1-F(\tilde{a}_{i,t+1}))\left(\frac{R'(v_{i,t+1})}{g(\theta_{t+1})}+mc_{i,t+1}A_{t+1}H(\tilde{a}_{i,t+1})\right)\right] \\
& -\beta(1-\rho^{x})E_t\frac{\lambda_{t+1}}{\lambda_t}\left[(1-F(\tilde{a}_{i,t+1}))\left((1+\tau^{f})\frac{\partial W_{i,t+1}}{\partial n_{i,t+1}}\right)+F(\tilde{a}_{i,t+1})D\right] \qquad (3.25)
\end{aligned}
$$

This condition relates the expected cost of vacancy posting with the expected discounted future value of the firm's surplus from the marginal worker defined as a sum of two parts. The first part, given by $mc_{i,t+1}A_{t+1}H(\tilde{a}_{i,t+1})-(1+\tau^{f})\frac{\partial W_{i,t+1}}{\partial n_{i,t+1}}$, denotes the net earnings on the margin and the second part, defined as $\frac{R'(v_{i,t+1})}{g(\theta_{t+1})}$, represents the savings on the adjustment costs. Moreover, the presence of the firing costs extends the job creation condition relative to the standard case. The intuition behind this result comes from the fact that if the workers are laid off next period, the firm will bear the burden of this layoff which is taken into account when discounting the future value of the firm's surplus. It is easy to see that firms will post more vacancies if expected productivity rises since in this case the right hand side of (3.25) will rise, which in turn requires the fall in $g(\theta_t)$ in order for the optimality condition (3.25) to hold. Thus, (3.10) implies that in order for $q(\theta_t)$ to fall the number of vacancies must rise.

As in the standard search-matching literature, for a job to be destroyed the cost of laying off the worker must be equal to the benefits of this layoff. Combining (3.12), (3.13) and (3.24), we obtain the job destruction condition which is given by:

$$\begin{aligned} & \frac{R'(v_{i,t})}{g(\theta_t)} + mc_{i,t}A_tH(\tilde{a}_{i,t}) - (1+\tau^f)\frac{\partial W_{i,t}}{\partial n_{i,t}} \\ = \; & mc_{i,t}A_tH(\tilde{a}_{i,t}) - mc_{i,t}A_t\tilde{a}_{i,t} - \frac{(1-F(\tilde{a}_{i,t}))}{n_tF'(\tilde{a}_{i,t})}(1+\tau^f)\frac{\partial W_{i,t}}{\partial \tilde{a}_{i,t}} - D \end{aligned} \quad (3.26)$$

Intuitively, if $\tilde{a}_{i,t}$ rises it leads to job destruction, because the job now becomes unproductive and the firm loses current and expected future profits that would occur if the job is not destroyed. This is represented by the lower term of the equation (3.26). The upper part of (3.26) represents the benefits from this job destruction taking into account the costs that need to be paid when the job is destroyed. This is the direct consequence of the fact that the increase in $\tilde{a}_{i,t}$ leads to the increase in the expected value of the productivity once the unproductive jobs have been removed.

Using (3.12) and applying Leibnitz integral rule to the definition of the wage bill we can obtain expression for $\frac{\partial W_{i,t}}{\partial \tilde{a}_{i,t}}$ and $\frac{\partial W_{i,t}}{\partial n_{i,t}}$ which when substituted into job destruction condition (3.26) gives us implicit solution for the endogenous threshold value of the productivity. This implicit value below which the existing jobs will be destroyed is given by following condition :

$$\frac{R'(v_{i,t})}{g(\theta_t)} + mc_{i,t}A_t\tilde{a}_{i,t} - (1+\tau^f)w_{i,t}(\tilde{a}_{i,t}) + D = 0 \quad (3.27)$$

In what follows we will consider a symmetric equilibrium which allows us to remove the subscript i. Defining inflation as $\pi_t = \frac{P_{i,t}}{Pi_{,t-1}}$ and setting $P_t = P_{i,t}$ we can rewrite the first order condition for optimal price determination (3.23) as

$$(1-\varepsilon) - \Psi\left(\pi_t - \pi\right)\pi_t + \varepsilon mc_t + E_t\left[Q_{t,t+1}\Psi\left(\pi_{t+1} - \pi\right)\pi_{t+1}\frac{Y_{t+1}}{Y_t}\right] = 0 \quad (3.28)$$

This equations explicitly defines the dynamics of inflation (or inflation law of motion) as a function of the real marginal cost mc_t and represents a non-linear Phillips curve condition. As in the standard monopolistic competitive framework, a producer with market power sets optimal prices as a markup over marginal cost, with the size of the markup determined by the elasticity of demand. In our framework, as in the standard New-Keynesian models with Walrasian labour markets, in the case of no deviation of inflation from the steady state $\pi_t = \pi$, the Phillips curve condition (3.28) simply reduce to standard condition of $mc = \frac{\varepsilon-1}{\varepsilon}$, implying that the marginal cost in the steady state would be equal to the inverse of the markup.

3.1.4 Bellman Equations and Nash Bargaining

This section outlines the details of the functional equations defining the firm's and worker's values of the specific categories. Specifically, the marginal value of an employment relationship at time t for a firm with realized productivity a_t is given by:

$$\begin{aligned} \mathbf{J}_t^e(a_t) &= mc_t A_t a_t - (1+\tau^f)w(a_t) \\ &+\beta E_t Q_{t,t+1}\left[(1-\rho^x)\int_{\tilde{a}_{t+1}}^{\bar{a}} \mathbf{J}_{t+1}^e(a_{t+1})dF(a) - (1-\rho^x)\,F(\tilde{a}_{t+1})D + \rho_{i,t+1}J_{t+1}^u\right] \end{aligned} \quad (3.29)$$

The first two terms on the RHS of the upper part denote the real revenues of the marginal worker, whereas the second line of (3.29) represents the continuation value of the existing job reduced for the present discounted value of the future dismissal costs. With probability ρ_{t+1} the existing job is destroyed and would therefore generate a zero value for the firm.

In a similar fashion we can define the marginal value of a job for an employed worker characterized by a realized productivity a_t as follows:

$$\mathbf{W}_t^e(a_t) = (1-\tau^w)w(a_t) - \tau + \beta E_t Q_{t,t+1}\left[(1-\rho^x)\int_{\tilde{a}_{t+1}}^{\bar{a}} \mathbf{W}_{t+1}^e(a_{t+1})dF(a) + \rho_{i,t+1}\mathbf{U}_{t+1}\right] \quad (3.30)$$

Moreover, the marginal value of unemployment for a worker can be written as

$$\begin{aligned} \mathbf{U}_t &= b(h,w) \\ &+\beta E_t Q_{t,t+1}\left[\theta_t g(\theta_t)\,(1-\rho^x)\int_{\tilde{a}_{t+1}}^{\bar{a}} \mathbf{W}_{t+1}^e(a_{t+1})dF(a) + (1-\theta_t g(\theta_t)(1-\rho_{i,t+1}))\mathbf{U}_{t+1}\right] \end{aligned} \quad (3.31)$$

Equation (3.30) implies that the marginal value of a job for the employed worker with realized productivity a_t equals to the obtained wage (determined by this realized productivity) plus the continuation value. The continuation value is defined as the sum of two parts with the first part representing the present discounted expected value of the continuation of the existing job, which occurs with the probability $\left(1-\rho_{i,t+1}\right)$, and the second part represents the discounted marginal value of becoming unemployed, which occurs with the probability ρ_{t+1}. The marginal value of unemployment equals the certain constant income $b(h,w)$ plus the continuation value which is the sum of expected revenue from becoming employed, and the expected discounted revenue obtained if she remains unemployed. As already stated $b(h,w)$ represents the aggregate value of the unemployed workers' income. More precisely, we assume that $b(h,w)$ is the composite of the value that workers receive from the government if unemployed, determined through the replacement ratio ρ_R, and the value of its own home production h. The precise functional form of the unemployment income will be specified later. The probability of getting out of unemployment is the product of the probability of filling in a posted vacancy $\theta_t g(\theta_t)$ and the probability of the new job not being destroyed because of an unfavorable productivity realization.

The matching of the worker and a firm leads to the removal of the search and matching costs. This in turn generates the joint surplus relative to the continued search process. In the standard search and matching literature, following Diamond (1982) and Mortensen (1982), the representative wage is derived from Nash bargaining over the division of the surplus between the workers and the firm. However, the presence of taxes and firing costs slightly modifies the standard form of the Nash bargaining problem as well as the solution.

The general problem of bargaining over wages in terms of Nash product maximization can be stated as:

$$w_t(a_t) = \arg\max \left(\mathbf{W}_t^e(a_t) - \mathbf{U}_t\right)^\eta \left(\mathbf{J}_t^e(a_t) + D\right)^{1-\eta} \tag{3.32}$$

where $\mathbf{W}_t^e(a_t) - \mathbf{U}_t \equiv S_t^w$ is the workers and $\mathbf{J}_t^e(a_t) + D \equiv S_t^f$ is the firm's surplus from the match that is not destroyed as a consequence of the unfavorable productivity realization. η denotes the share of surplus going to the workers and equivalently represents the workers' bargaining power. Obviously, in order for the match to be beneficial for each party, both the workers' and firms' surplus must be positive. In other words, if $S_t^w > 0$ and $S_t^f > 0$ the Nash bargaining problem admits a solution of the following form:[37]

$$S_t^w = \frac{\eta(1-\tau^w)}{(1-\eta)(1+\tau^f)} S_t^f \tag{3.33}$$

To proceed with the model's solution we use the fact that the firms will open vacancies as long as they exhaust all of the profits stemming from the open vacancies, or equivalently as long as the value of the open vacancy goes to zero. Therefore, using (3.27) and (3.29) allows us to write:

$$\frac{R'(v_{i,t})}{g(\theta_t)} = \beta E_t Q_{t,t+1}(1-\rho^x)\left[\int_{\tilde{a}_{t+1}}^{\bar{a}} \left(\mathbf{J}_{t+1}^e(a_{t+1}) + D\right) dF(a) - D\right] \tag{3.34}$$

Substituting the sharing rule (3.33) into S_t^w and using (3.34) provides us with the equation determining the real wage $w(a_t)$

$$\begin{aligned} w(a_t) \quad = \quad & b(h,w)\frac{(1-\eta)}{(1-\tau^w)} + \tau\frac{(1-\eta)}{(1-\tau^w)} + \eta\frac{1}{(1+\tau^f)}\left[mc_t A_r a_t + \theta_t R'(v_{i,t})\right] \\ & + \eta\frac{1}{(1+\tau^f)}\left[D - (1-\theta_t g(\theta_t))\beta E_t Q_{t,t+1}\left(1-\rho^x\right) D\right] \end{aligned} \tag{3.35}$$

[37] Detailed derivation is presented in Appendix 3.A

The obtained wage depends on the real marginal costs, aggregate productivity and vacancy posting costs, as well as on the job specific productivity, labour market tightness and the workers outside option $b(h,w)$. Furthermore, it depends on both the wage and payroll tax rate and the parameter τ governing the degree of the progressivity of the tax system. Average (expected) real wage can be obtained by using (3.35) and substituting it into $w_t = \int_{\tilde{a}_{i,t}}^{\bar{a}} w(a_t)\frac{f(a_t)}{1-F(\tilde{a}_t)}da_t$, to obtain

$$\begin{aligned} w_t &= b\frac{(1-\eta)}{(1-\tau^w)} + \tau\frac{(1-\eta)}{(1-\tau^w)} + \eta\frac{1}{(1+\tau^f)}\left[mc_t A_r H(\tilde{a}_t) + \theta_t R'(v_{i,t})\right] \\ &\quad + \eta\frac{1}{(1+\tau^f)}\left[D - (1-\theta_t g(\theta_t))\beta E_t Q_{t,t+1}(1-\rho^x) D\right] \end{aligned} \tag{3.36}$$

In order for the job to be destroyed the marginal value of employment at time t for a firm with the productivity realized at a_t must be less than or equal to zero $(J_t^e \leqslant 0)$ Therefore, the threshold (reservation) value of the individual productivity $(\tilde{a}_t)$ below which the jobs will be destroyed can be obtained by using (3.34), (3.35) and the condition $J_t^e(\tilde{a}_t) = 0$ to get

$$\begin{aligned} \tilde{a}_t &= \frac{1}{mc_t A_t}\left[\frac{(1+\tau^f)}{(1-\tau^w)}(b+\tau) + \frac{1}{1-\eta}R'(v_{i,t})\left(\eta\theta_t - \frac{1}{g(\theta_t)}\right)\right] \\ &\quad - \frac{1}{mc_t A_t}\left[1 + \frac{\eta}{1-\eta}(1-\theta_t g(\theta_t))\beta E_t Q_{t,t+1}(1-\rho^x)\right] D \end{aligned} \tag{3.37}$$

The obtained reservation productivity solution is a function of aggregate productivity, real marginal cost, unemployed workers' total income, vacancy posting costs as well as labour market tightness, surplus share, firing costs and tax instruments. It is positively related to the unemployed workers total income, the parameter governing the progressivity of the tax system, vacancy posting costs and the tax instruments. However, it is negatively related to the real marginal costs and aggregate level of productivity whereas the effect of the labour market tightness can not be uniquely determined. Specifically, on the one hand the increase in the labour market tightness positively affects hiring costs $\frac{R'(v_{i,t})}{g(\theta_t)}$ as it reduces the probability of a firm finding a match and therefore reduces threshold level of individual productivity. On the other hand, the increase in the labour market tightness induces the pressures on the firms to increase the wage in order to attract new workers. This in turn leads to an increase in the reservation productivity level in order to compensate for the necessary increase in wage. Moreover, the effect of the firing costs is also ambiguous since the increase in the firing costs reduces reservation productivity which is a consequence of today's savings effect. But at the same time the reservation productivity is increased because of the future potential firing cost payments.

3.1.5 Taxes and Government

The enrichment of the model with proportional payroll wage and payroll tax rates and the progressivity of the tax system requires detailed specification of the fiscal side. Following Pissarides (1998) and Sinko (2005) we assume progressivity in the wage tax scheme, whereas we abstract from the progressivity of the payroll tax system. [38] We introduce progressive wage tax system by specifying a linear individual labour tax schedule of the following form

$$T_{i,t} = \tau + \tau^w w(a_{i,t}) \tag{3.38}$$

[38] Absence of the progressivity of the payroll tax system can easily be justified for most of the European countries.

determining the total tax payments of an employed worker. By setting $\tau^w = 0$ this tax specification results in pure employment subsidy (tax) if $a < 0$ ($a > 0$). Alternatively if $\tau = 0$ and $\tau^w > 0$ the specified tax system will be proportional. If both $\tau < 0$ and $\tau^w > 0$ the specified tax system will be progressive in a sense that average tax rate is an increasing function of income.[39] Using the definition of the tax schedule (3.38) we can define the after tax wage of a worker with idiosyncratic productivity $a_{i,t}$ as $(1 - \tau^w)w(a_{i,t}) - \tau$. Goverment's' pure wage tax revenues per worker are equal to $\tau^w w(a_{i,t}) + \tau$.

As in Pissarides (2000) we assume the following functional form for the aggregate unemployment income which is linear in the value of home production or leisure h, and the policy determined replacement ratio $\rho_b \in (0, 1)$

$$b(h, w) = h + \rho_b w \tag{3.39}$$

whereby we link unemployment income to the gross average steady state value of wage w. To simplify our analysis we assume that firing costs are simply transferred to the government and consider the consolidated government constraint. Furthermore, we will consider tax policy that involves both distortionary and lump-sum taxation. Specifically, on the liabilities side, the government is assumed to print money holdings M_t, to issue one period risk-free nominal bonds B_t and to transfer benefit payments to the unemployed in the amount given by $\rho_b w u_t$. The government's real revenues consist of tax receipts collected from both a flat (constant) wage and payroll taxes $\tau^w$and τ^f, endogenous lump-sum taxes τ_t^L, transfers from the firm stemming from the firing costs D and τ, as well as from the real

[39] We should also point out that our speficication of the tax schedule implies the wage subsidies are exempted from taxation.

seigniorage revenues defined as $\frac{M_t - M_{t-1}}{P_t}$. This allows us to define the total tax receipts T_t^R as:

$$T_t^R = (\tau^w + \tau^f) w_t n_t + \tau n_t + \tau_t^L + (1 - \rho^x) F(a_t)(n_{t-1} + v_{t-1} q(\theta_{t-1})) D \quad (3.40)$$

We also introduce the exogenous stream of real per capita government spending g_t where g_t denotes Dixit-Stiglitz aggregate government consumption bundle defined as $g_t = \left(\int_0^1 g_{it}^{\frac{\gamma-1}{\gamma}} di \right)^{\frac{\gamma}{\gamma-1}}$. Government demand for the single variety of the intermediate good i is obtained by solving a cost minimization problem same as the one previously defined for the consumers, which determines demand for the individual good i as $g_{it} = \left(\frac{p_{it}}{P_t} \right)^{-\gamma} g_t$. Thus, the government flow budget constraint is defined by following expression:

$$T_t^R + \frac{(M_t - M_{t-1})}{P_t} + \frac{B_t}{P_t} = g_t + R_{t-1} \frac{B_{t-1}}{P_t} + \rho_b w u_t \quad (3.41)$$

For ease of exposition let us introduce several notational shortcuts. Let us first define aggregate government spending by $s_t = g_t + \rho_b w u_t$. Let us also denote real government liabilities outstanding at the end of the period $t-1$ in terms of the units of $t-1$ goods as d_{t-1}

$$d_{t-1} = \frac{(M_{t-1} + R_{t-1} B_{t-1})}{P_{t-1}} \quad (3.42)$$

Finally, let us denote by $A_t = T_t^R - \tau_t^L$ government tax receipts plus receipts on the basis of firing costs but exclusive of the lump-sum taxes τ_t^L and let real money balances $\frac{M_t}{P_t}$ be denoted by m_t. This allows us to redefine the real government budget constraint in terms of real government debt and write the process governing government debt as follows:

$$\frac{d_t}{R_t} = \frac{d_{t-1}}{\pi_t} + (s_t - A_t) - \tau_t^L + m_t \frac{(1 - R_t)}{R_t} \quad (3.43)$$

We will consider Ricardian fiscal policy in the sense that the government runs the policy which satisfies its present value budget constraint at each date and in each state of nature. It is important to point out that this does not imply that government necessarily needs to run balanced budget. More specifically, we use a simple fiscal rule which assumes that every period a certain fraction of the outstanding debt is repaid. This rules breaks down the standard assumption of period by period zero net bond supply usually found in the literature. Following Chadha and Nolan (2007) and Schmitt-Grohe and Uribe (2007) we specify the following simple parameterization of the process governing the lump-sum taxes:

$$\tau_t^L = \tau_{ss}^L + \xi(d_{t-1} - d_{ss}) \tag{3.44}$$

where τ_{ss}^L and d_{ss} denote steady state level of lump-sum taxes and government liabilities. This rule ensures that the tax receipts are sufficient to meet part of the outstanding liabilities stemming out from the bond and money issuance. When substituted back into (3.43) we obtain the following sequential government budget constraint:

$$\frac{d_t}{R_t} = (1 - \xi\pi_t)\frac{d_{t-1}}{\pi_t} + (s_t - A_t) - \tau_{ss}^L + \xi d_{ss} + \frac{m_t}{R_t}(1 - R_t) \tag{3.45}$$

3.1.6 Monetary Policy

In order to close down the model we are required to specify the monetary policy reaction function. As it is standard in the literature we assume that the monetary policy maker operates a short term nominal interest rate rule. There are at least two reasons why this type of rule is plausible. First, as shown in Taylor (1999) these rules are empirically a good approximate characterization of the actual conduct of monetary policy in a wide range of developed countries. Second, Woodford (2003) shows that in models with nominal rigidities and imperfect competition those rules improve upon the macroeconomic stability of the model.

Following Taylor (1993), Clarida, Gali and Gertler (2000) and Schmitt-Grohe and Uribe (2007) we assume that nominal interest rate is set according to Taylor-type rules of the following form:

$$\log\left(\frac{R_t}{\overline{R}}\right) = \chi^r \log\left(\frac{R_{t-1}}{\overline{R}}\right) + \chi^{pi}\log\left(\frac{\pi_t}{\overline{\pi}}\right) + \chi^y \log\left(\frac{Y_t}{\overline{Y}}\right) \tag{3.46}$$

where bar denotes steady state value of the variable, χ^r is a measure of the interest rate persistence and χ^{pi} and χ^y denote respectively the impact of inflation and output on the short term nominal interest rate. Moreover by specifying this type of interest rate rule we postulate in fact, that, every period the monetary policy authority is eliminating a fraction $(1 - \chi^r)$ of the nominal interest rate deviation from its steady state value.

3.1.7 Aggregate Conditions and Equilibrium

We complete the description of the economy by defining the aggregate conditions. Aggregating over individual firms' employment evolution conditions we can define the corresponding aggregate as:

$$n_t = (1 - \rho_t)(n_{t-1} + v_{t-1}g(\theta_{t-1})) \tag{3.47}$$

Since in our setup the number of searching workers is equal to the number of unemployed workers, the normalization of the labour force implies that the aggregate unemployment rate equals to $1 - n_t$. Moreover, because the separation occurs as a consequence of the exogenous forces at work and the endogenous conditions determined by the threshold productivity level, the aggregate separation rate will be equal to $\rho_t = \rho^x + (1-\rho^x)F(\tilde{a}_t)$. Using households budget constraint, government budget constraint and firms profit function we obtain aggregate demand which reads as

$$Y_t^D = C_t + g_t + R(v_t) + \Theta_t \tag{3.48}$$

whereas aggregate supply is given by:

$$Y_t^S = n_t A_t \int_{\tilde{a}_t}^{\bar{a}} a_t \frac{f(a_t)}{1-F(\tilde{a}_t)} da_t \tag{3.49}$$

We can now define the competitive equilibrium. Since wages in our model are determined in a Nash bargaining process we refer to our equilibrium as a competitive bargaining equilibrium.

Definition 1 *Bargaining symmetric equilibrium of a distorted competitive economy is list of stochastic processes for prices* $\{P_t\}_{t=0}^{\infty} = \{w(a_t), \pi_t\}$ *and quantities* $\{Q_t\}_{t=0}^{\infty} = \left\{\{Q_t^{FA}\}_{t=0}^{\infty}, \{Q_t^{FW}\}_{t=0}^{\infty}\right\}$ *where*

$$\{Q^{FA}\}_{t=0}^{\infty} = \{C_t, B_t, M_t\}_{t=0}^{\infty} \tag{3.50}$$

$$\{Q_t^{FW}\}_{t=0}^{\infty} = \{Y_t, n_t, v_t, a_t\}_{t=0}^{\infty} \tag{3.51}$$

such that given the process for the nominal interest rate $\{R_t\}$*, exogenous process for* $\{A_t,\}$ *and initial holdings* B_0 *and* M_0*, the following holds:*

(i) given sequences of prices $\{P_t\}_{t=0}^{\infty}$ *an allocation* $\{Q^{FA}\}_{t=0}^{\infty}$ *solves the household maximization problem (3.1) subject to (3.2)*

(ii) an allocation $\{n_t, v_t, a_t\}_{t=0}^{\infty}$ *and price sequence* $\{\pi_t\}_{t=0}^{\infty}$ *solves the firms maximisation problem (3.16) subject to (3.17),(3.18) and (3.19) and satisfy (3.25),(3.26) and (3.28)*

(iii) Law of motion determining the number employed is given by (3.47)

(v) wages $\{w(a_t)\}_{t=0}^{\infty}$ *are determined by Nash bargaining and sastify (3.35)*

(vi) (3.41) holds, markets clear and $Y_t^D = Y_t^S$

3.2 Labour Market Frictions and Reforms

Presence of imperfect competition allows us to analyze the effect of product market reforms by considering a change in the parameter determining the elasticity of substitution. Change in this parameter can be thought of as a policy component whose increase could represent some market liberalisation measure, or the deregulation of some market practice, or a reduction in some trade barrier (domestically or externally) which has the effect of increasing product substitutability. The increase in the elasticity of substitution leads to a reduction in the markup and therefore to a reduction in market power (because of the increase in the similarity of the products produced) and therefore in the price charged by each monopolistic competitor. It is important to notice that there is a difference in the marginal costs obtained under the Walrasian labour market setup and the ones in the search-matching framework as first pointed out by Krause and Lubik (2007). Therefore, when analyzing the impact of product market reforms this difference should be taken into the account. To see this formally let us consider first order conditions for $n_{i,t}$ and $v_{i,t}$ as given by (3.21) and (3.22). By rewriting those two conditions we obtain the expression for the marginal cost in the search-matching framework given by:

$$mc_{i,t} = \frac{(1+\tau^f)\frac{\partial W_{i,t}}{\partial n_{i,t}}}{A_t H(\tilde{a}_{i,t})} + \frac{\mu_{i,t} - \frac{R'(v_{i,t})}{g(\theta_t)}}{A_t H(\tilde{a}_{i,t})} \tag{3.52}$$

It is evident that the marginal cost within this setup is a combination of two components. The first component represents the marginal product of each single worker which is equivalent to the marginal costs in Walrasian markets. The second component, specific to the search-matching framework, arises from the labour market frictions and depends on the difference between average current value of the employee and the expected average costs of vacancy posting. It should be noticed that this costs is equal to the present value of the expected contribution of the worker producing in the next period, which in turn implies the dependence of the current value of the marginal cost on the future expected value of the match.

To see the effect of the change in the elasticity of substitution on the relative price we can rearrange equation (3.23) and substitute (3.52) for $mc_{i,t}$ to get

$$\frac{P_{i,t}}{P_t} = \Omega(\varepsilon)\left(\frac{(1+\tau^f)\frac{\partial W_{i,t}}{\partial n_{i,t}}}{A_t H(\tilde{a}_{i,t})} + \frac{\mu_{i,t} - \frac{R'(v_{i,t})}{g(\theta_t)}}{A_t H(\tilde{a}_{i,t})}\right) \tag{3.53}$$

where $\Omega(\varepsilon) = \frac{\varepsilon}{\varepsilon-1}$ measures the markup. It is immediate to notice that the increase in the elasticity of substitution ε leads to a reduction in relative prices. Moreover relative prices depend on the wages which in turn depend on both present and expected future characteristics of the labour market. Intuitively, hiring costs generate a surplus for existing matches which results in a long-term employment relationship which reduces the allocative role for current real wages. Thus, even if real wages do not change, the presence of hiring frictions might induce the change in real marginal costs corresponding to the effect pointed out by Goodfriend and King (2001). Moreover, this also implies that the estimation of New Keynesian Phillips curve typically done in the literature, by using the unit labour costs as a proxy for marginal costs, are inadequate in the presence of search frictions and might result in non trivial consequences for the markup estimation.[40] Thus, there are complex forces at work which propagate the effects of the product market reforms on labour markets and overall economic performance.

Before considering the effects of various parameters describing labour market regulations let us first detail the wage equation (3.36) determined by Nash bargaining. It is easy to notice that the wage consists of two parts. Specifically, one is solely determined by labour market regulatory conditions whereas the second is determined by pure market conditions in addition to two policy parameters, namely the payroll tax rate and the level of firing costs. Furthermore, the size of the bargaining parameter determines the relative importance of those two parts in the wage solution. The larger is the share of the part determined by regulatory conditions relative to the size determined by market conditions, the smaller is the wage absorption of the exogenous shocks and more rigid the wage. All else equal, the more rigid the wage, the firms can use less the wage channel as an absorbing mechanism and therefore the shock absorption needs to go through job profitability conditions, or equivalently through the job creation and job destruction margin. In other words, all else equal, the more rigid the wages are the larger is the effect of the exogenous shocks

[40] For detailes of the standard approach to Phillips curve estimation base on the labour share, see Clarida et al. (1999) and Rotemberg and Woodford (1992). For estimation which controls for the presence of search frictions, see Krause et al. (2007).

on the profitability of jobs and thereby on the employment and vacancy posting. And this importance of market component of the wage is determined by the bargaining power. More formally, when bargaining power η goes to one wage becomes

$$\begin{aligned} w_t &= \frac{1}{(1+\tau^f)}\left[mc_t A_t H(\tilde{a}_t) + \theta_t R'(v_{i,t})\right] \\ &+ \frac{1}{(1+\tau^f)}\left[D - (1-\theta_t g(\theta_t))\beta E_t Q_{t,t+1}\left(1-\rho^x\right) D\right] \end{aligned} \quad (3.54)$$

which implies that the worker is getting all of the surplus and there is no effect of unemployment benefits and tax progression parameter on the wage. In the opposite case where the bargaining power goes to zero the wage would be constant and given by

$$w_t = \frac{1}{1-\tau^w}\left(b(h,w) + \tau\right)$$

implying that pure market conditions are irrelevant for the wage formation and the only things that matter are policy determined level of benefits as well as the marginal labour tax rate and parameter governing the degree of tax progression. The whole surplus goes to the firm and the effect of exogenous shocks is fully absent from the wage considerations. However as long as none of the parties in the bargaining process has all of the power, both the market as well as policy determined conditions will be captured in the negotiated wage. Then the bargaining power will determine to what extent pure labour market frictions stemming from hiring and firing costs affect the wage. Although some bargaining power on the worker side is required for the search frictions to affect the wage, because they are always present in the firms marginal costs they always influence the price formation, as can be seen from the equation (3.53).

3.3 Functional Forms and Calibration

We parameterize period utility function to be of CRRA form given as

$$U(C_t, H_t) = \frac{(C_t - H_t)^{1-\sigma} - 1}{1 - \sigma} \tag{3.55}$$

where σ is parameter governing curvature of the utility function defining the coefficient of relative risk aversion.

Preferences over real money balances are given by

$$\Lambda(\frac{M_t}{P_t}) = \Xi \log(\frac{M_t}{P_t}) \tag{3.56}$$

where Ξ is scaling parameter and denotes contribution of the unit utility of real money balances to aggregate households utility. Following most of the search and matching literature we postulate vacancy posting cost function to be linear in number of vacancies and is given by $R(v) = c^v v_t$.

Motivated by empirical work as surveyed by Petrongolo and Pissarides (2001) we assume Cobb-Douglas form of the matching function given by:

$$m(u_t, v_t) = \omega u_t^{\epsilon} v_t^{1-\epsilon} \tag{3.57}$$

ω stands for the level or matching efficiency parameter of the matching technology.[41] The parameter ϵ determines the relative contribution of unemployment to the matching process as well as the elasticity of the hazard rates with respect to the labour market tightness which is defined as $\theta_t = \frac{v_t}{u_t}$.

---

41 An alternative would be to use a matching function of the form proposed by den Haan et al. (2000) given by $M(u_t, v_t) = \frac{u_t v_t}{(u_t^{\epsilon} + u_t^{\epsilon})^{\frac{1}{\epsilon}}}$. The advantage of this specification is that it guarantees matching probabilites between zero and one for all u_t v_t. But in a linearized form both specifications would have identical implications.

Both exogenous government spending g_t and aggregate productivity are assumed to evolve according to univariate autoregressive processes respectively given by:

$$\log(g_t) = (1 - \rho_G)\log(g_{ss}) + \rho_G \log(g_{t-1}) + \varepsilon_t^G \tag{3.58}$$

and

$$\log(A_t) = (1 - \rho_A)\log(A_{ss}) + \rho_A \log(A_{t-1}) + \varepsilon_t^A \tag{3.59}$$

We calibrate our model to reflect the data properties of an average EU economy. The time unit is assumed to be a quarter. Parameters of the model can be separated into six broad categories reflecting household preferences, labour market parameters, policy parameters, and parameters determining the behaviour of the exogenous stochastic processes.

Labour Market and Policy Parameters

Using OECD data and following Shimer (2005) we calculate average quarterly job finding probability $\theta q(\theta)$ for the 14 EU countries to be 0.3. Steady state unemployment rate u is set to 8% which is the sample average unemployment rate. Using the fact that $n = 1 - u$, substituting into (3.47) and rearranging we can solve for the steady state aggregate job destruction rate ρ to get

$$\rho = \frac{u\theta q(\theta)}{(1 - (1 - \theta q(\theta))u)} \tag{3.60}$$

Calibrated values for the unemployment and job finding probabilities imply an aggregate job destruction rate of 2.6%, which is in line with Christoffel et al. (2009) and obtained by alternative direct calibration of the job destruction rate.[42] In line with most of the literature and based on the ECB (2002) and Weber (2000) calculations we calibrate our

[42] This value is also in line with the values used in the literature ranging from 2 to 10%.

vacancy filling rate to 0.7. Using our calibrated values for job finding probability $\theta q(\theta)$ and vacancy filling probability $q(\theta)$ we calculate labour market tightness θ to be equal to 0.33, which together with the calibrated value of unemployment implies a value of steady state vacancies of 0.034. We also need to calibrate endogenous job separation rate. Unfortunately there is no evidence on this parameter available for the EU countries. For US den Haan et al.. (2000) set the ratio of endogenous to total job destruction rate $\frac{\rho^n}{\rho}$ to 0.32, whereas Pissarides (2007) based on Davis and Haltiwanger (1999) and Farbers' (1997) analysis of workers displacement rates sets this ratio to 0.6. We choose the mid-point of 0.46 as a reference in our calibration. This gives us endogenous job destruction rate of 0.0117. Using the definition of total job destruction rate (3.12) exogenous job destruction rate is given by $\rho^x = \frac{\rho-\rho^n}{1-\rho^n}$ and is accordingly calibrated to 0.0141. Regarding the elasticity of matching function with respect to unemployment we follow Pissarides and Petrongolo (2001) and set the value of match elasticity with respect to unemployment to 0.5. The steady state number of matches m is given by $\frac{\rho}{1-\rho}(1-u)$ and is used to calculate matching efficiency ω. As it is standard in the literature we set the bargaining power equal to 0.5 in order to satisfy Hosios condition.

Based on OECD "Taxing wages" data sets we set wage tax rate corresponding to our sample average for the 14 EU countries to 0.24. The corresponding payroll (social security contributions) tax rate is set to 0.219, whereas we calibrate τ to -0.09.

As already stated job specific productivity shock is assumed to be independently and indentically distributed over time. Following den Haan et al. (2000), Lubik and Krause (2007) and Trigari (2006) we parameterize this distribution to be log-normal such that $a \sim$

$LN(\mu_a, \sigma_a)$, where we normalize μ_a to zero. Before calibrating σ_a we need to calibrate parameters describing potential labour market reforms. We model firing cost such that $D = \rho_D w$. As already pointed out, firing cost D in our model does not represent the severance payment going from the firm to the worker, and lacking a reliable estimate on its value we set ρ_D to 0.2. As previously explained we assume that benefits are given by $b = h + \rho_b w$ where h stands for level of home production, ρ_b for benefits replacement rate and w is the steady state value of wage. Using Nickell and Nunziata (2007) and OECD datasets we calculate the average replacement ratio for 14 EU countries in the period from 1997 to 2007 to be 0.35. Now, given the values of μ_a and σ_a and the assumed distribution of the idiosyncratic shock the steady state reservation productivity level is obtained as $\tilde{a}_t = F^{-1}(\rho^n)$, where $F^{-1}(\bullet)$ is an inverse of the cumulative distribution function F. We are left with two additional parameters to calibrate, namely vacancy posting cost c^v and the value of the home production. In order to obtain those values we use the steady state version of the equation determining the evolution of labour market tightness given by

$$\begin{aligned}
\frac{R'(v)}{g(\theta)} &= \beta(1-\rho^x)\left[(1-F(\tilde{a}))\left(\frac{R'(v)}{g(\theta)} + (1-\eta)mcAH(\tilde{a})\right)\right] \\
&\quad -\beta(1-\rho^x)\left[(1-F(\tilde{a}))\left(\eta\theta R'(v) + (1-\eta)\frac{(1+\tau^f)}{(1-\tau^w)}(b+\tau)\right) + F(\tilde{a})D\right] \\
&\quad -\beta(1-\rho^x)\left[(1-F(\tilde{a}))\eta\left(D - (1-\theta g(\theta))\beta\left(1-\rho^x\right)D\right)\right] \qquad (3.61)
\end{aligned}$$

as well as the steady state version of the wage (3.36) and reservation productivity equation (3.37) which are respectively given by:

$$\begin{aligned} w &= b\frac{(1-\eta)}{(1-\tau^{w})}+\tau\frac{(1-\eta)}{(1-\tau^{w})}+\eta\frac{1}{(1+\tau^{f})}\left[mcAH(\tilde{a})+\theta R'(v)\right] \\ &+\eta\frac{1}{(1+\tau^{f})}\left[D-(1-\theta g(\theta))\beta\left(1-\rho^{x}\right)D\right] \qquad (3.62) \\ \tilde{a} &= \frac{1}{mcA}\left[\frac{(1+\tau^{f})}{(1-\tau^{w})}(b+\tau)+\frac{1}{1-\eta}R'(v)\left(\eta\theta-\frac{1}{g(\theta)}\right)\right] \\ &-\frac{1}{mcA}\left[1+\frac{\eta}{1-\eta}(1-\theta g(\theta))\beta\left(1-\rho^{x}\right)\right]D \qquad (3.63) \end{aligned}$$

These three equations form a system in three unknowns, namely c^{v}, h and w that we solve for. Lacking more precise empirical evidence on this parameter for more countries we follow Abowd and Kramarz (2003) who have calculated the value of firing costs for the French firms to be about 2.4% of annual labour costs per worker. We calibrate σ_a such that solution of this system gives us value of c^{v} consistent with this estimate and set is to 0.25.

Based on the observed data we postulate the steady state ratio of government purchases to output to be 0.21. We also impose a steady state ratio of debt-to-GDP of 60 percent per year. This value is consistent with the Maastricht convergence criteria value for the debt-to GDP ratio. We follow Nelson (2001) and set χ^{r}, χ^{pi} and χ^{y} to 0.3, 2 and 0.3 respectively.

Household Preferences

We set σ equal to 2, which implies an intertemporal elasticity of substitution of 1/2. This value is in line with the values used in the real business cycle literature. The habit importance parameter, χ, is adapted from the existing empirical studies that suggest plausible estimates to take values between 0.4 and 0.8. We choose the lower bound for

Table 3.1. Long run effects of various tax reforms.

	Tax instruments		
	Wage tax	Payroll Tax	Progressivity
Output	1.80	0.76	2.464
Consumption	1.79	0.76	2.457
Employment	1.75	0.75	2.40
Real Wage	-0.07	0.79	-0.10
After-tax Real Wage	1.25	0.79	1.48
Vacancies	8.27	0.28	11.69
Reservation Productivity	-1.85	-0.98	-2.75
Tightness	38.57	10.62	59.59

Note: This table represents the steady-state effects of the selected variable to one percentage permanent reduction in two marginal tax rates as well as the change in the degree of progresivity from 0.09 to 0.1. Each column denotes the respective change in the case of single change in the respective tax instrument. All of the variables except employment are reported as a percentage deviations from the initial steady-state, whereas the employment is expressed as percentage point change.

χ and set it to 0.4. The time discount factor β is chosen to match average annualized quarterly real interest rate of 3.4% and is set to 0.99. The steady state markup in our model is given by $\frac{\varepsilon}{\varepsilon-1}$. Based on the estimation done by Martins et al. (1996) and Przybyla and Roma (2005) we set its value to 17% which amounts to setting the elasticity of substitution ε equal to 7. This value is also in line with the US evidence as reported in Basu and Fernald (1997) and Golosov and Lucas (2007). Finally, we set Ξ to match money to consumption ratio of 1.3, which is obtained using ECB data on money in circulation and overnight deposits held by households in the Euro Area from 1999 to 2007.

3.4 The Long Run Effects of Various Reforms

In this section we analyze the long-run effects of various structural reforms. First, we proceed by analyzing the effects of permanent changes in tax rates as well as the changes in the tax structure by varying the degree of tax systems' progressivity. Specifically, we utilize our model in order to examine the long run effects of wage and payroll tax reduction which are widely suggested as a major source of poor European labour market performance. Three alternative scenarios are considered, namely one percentage point reductions in wage and payroll tax rates and one percentage point increase in the degree of progressivity. Second, we analyze the long run effects of the increase in the degree of product market competition by varying the elasticity of demand ε, which captures the degree of substitutability between specific firm and its competitors.

3.4.1 The Long Run Effects of Tax Reforms

Table 3.1 summarizes the steady-state effects of the aforementioned tax reforms. As previously mentioned we depart in our analysis from the usual assumption of the per period balanced budget, and allow government to run a sustainable deficit, making it distinct from the previous scarce literature on policy reforms. In implementing each of those scenarios we assume that the implied loss in the fiscal revenues is financed by the change in the lump-sum taxes such that the calibrated government spending-to-GDP and debt-to-GDP ratio remain unchanged in the steady state. As it is evident from the table both the reduction in the wage tax rate as well as the reduction in the social security contributions are beneficial for the labour markets and overall economic performance. Reduction in the wage tax rate leads to the reduction in the average real wage because of the decrease in the relative value of the unemployment option to the workers as represented by the non-market part of the wage equation. This in turn induces a decreases in reservation productivity and the endogenous job destruction rate, which leads to the decrease in the unemployment rate and to an increase in vacancies and employment. Since employment rises, output and consumption rise too. Moreover, the reduction in the wage tax rate leads to an increase in the after-tax average wage received by the workers. Qualitatively, the fall in the job destruction threshold of 1.85% leads to an increase in employment of around 1.75% and an increase in the after tax wage of 1.25%. Output increases by 1.8%, whereas the consumption increase is slightly lower at around 1.79%.

Decrease in the social security contributions has the opposite effect on the average real wage because of the positive effect on the market part of the wage equation. However, the reduction in the payroll tax (or the social security contributions) has a positive effect on the reservation productivity leading to its reduction. This positive effect on the reservation productivity dominates the negative wage effect of reduction in the payroll tax, leading to an increase in employment or equivalently to fall in unemployment. In turn both output and consumption increase. Qualitatively, reservation productivity decreases by 0.98%, whereas the real wage increases by 0.79%. This reduction in reservation productivity leads to an increase in the employment rate by 0.75%, and an increase in output and consumption by around 0.76%.

Regarding the progressivity of the tax system we analyze the effect of a change in the tax structure reflected by a change in the value of τ from -0.09 to -0.1, which represent the approximate increase in the degree of progressivity of 11%. As can be seen from the Table 3.1 an increase in the degree of progressivity is also beneficial for the labour markets as well as for the economic efficiency. The more progressive tax system leads to a decrease in the average real wage because of a fall in the non-market part of the wage. Moreover, the increase in the degree of progressivity leads to a fall in reservation productivity which together with the fall in the average real wage leads to an increase in employment, output and consumption. One can therefore conclude that promoting income equality leads to positive employment, output and consumption effects. In other words, increasing progressivity of the tax system turns out to be beneficial for both labour markets and the economy as a whole. Extensive sensitivity analysis reveals that this result is robust to the assumption on the existence of tax progressivity in the initial benchmark steady state, that is regardless of whether the progressivity is assumed to characterize the initial steady state or it is assumed to be absent; this result always holds. Thus, it is consistent with Pissarides (1998) in the context of a partial equilibrium search-matching model but contrasts the general equilibrium findings of Vanhala (2006) where the initial degree of progressivity matters.

For the sake of completeness let us compare the effects of individual tax reforms. One can see that reduction in the wage tax and social security contributions influences all of the variables except wages in the same direction, although with different magnitudes. This difference in magnitude can be explained by the differential effect that those two type of tax reduction have on government revenue. The remarkable differential direction in the effect on real average wage is also noticed by Coenen et al. (2008) in standard New-Keynesian setup with Walrasian labour markets. But the mechanism at work generating this effect is different. In our model the reduction in social security contributions increases the surplus generated by a successful match to be equally shared by the firms and workers because of the assumed bargaining mechanism of the wage determination.

Table 3.2. The long run effects of the change in the degree of competition

Output	Consumption	Employment	Real Wage	Reservation Productivity
2.56	2.54	2.48	4.29	-2.52

Note: This table represents the steady-state effects of the selected variable to permanent increase in the elasticity of substitution. All of the variables except employment are reported as a percentage deviations from the initial steady-state, whereas the employment is expressed as percentage point change.

This results in the average real wage rising. Moreover, as previously explained, the payroll tax reduction produces positive effect on the reservation productivity which overcompensates the negative effect on the average real wage and thereby generates subdued positive long-run response of employment. Additionally, the fact that the equilibrium average real wage does react positively to the reduction in the payroll tax rate partially explains the dampened response of employment relative to the case of wage tax reduction. Lastly, it is worthwhile pointing out the same direction in the effects of wage tax reduction and the increase in the degree of tax progressivity on both labour markets and the overall economic performance, implying the isomorphic substitutability in their potential use as the policy reform tools.

3.4.2 The Long Run Effects of Product Market Reform

Let us now proceed with the long run analysis of product market reform. Table 3.2 shows the effects of a one-off permanent increase in the elasticity of demand represented by the increase in ε from 7 to 9.5. As already stated, the change in the elasticity of demand implies a change in the degree of substitutability between different goods. It can be viewed in a broader sense as a reflection of the change in the overall market structure. As such, this change in the market structure can reflect, for example, the increase in the number of firms leading to a higher degree of competition, or the implicit pressure from foreign competition. Increase in the elasticity of demand leads to an increase in aggregate long run consumption because of the reduction in the markup caused by the reduced pricing power of the competitive firms. This increase in consumption reflects an increase in output which leads to an increase in the demand for labour regardless of the subsequent increase in the average real wage caused by the increase in the steady state marginal costs. This is caused by the dominating negative effect that marginal costs have on the reservation productivity, which leads to the pronounced fall in the endogenous destruction rate, causing a fall in the unemployment and equivalent rise in the employment rates. Qualitatively, the reservation productivity decrease by 2.52% relative to the benchmark steady state value, which leads to the 2.48% increase in the employment. Output and consumption increase respectively by 2.56% and 2.54%. Overall, these results suggest that the implementation of the product market reforms in terms of increased competition have positive effects on the mean levels around which the economy fluctuates. In other words increased competition is, not surprisingly, at least in the long run beneficial for both the labour markets and the economy as a whole.

3.5 Dynamic Impacts of Reforms

3.5.1 The Effects of Technology Shocks and Product Market Reform

Figure 3.1 shows the impulse responses of selected variables to a one standard deviation technology shock for two different calibrations of the intertemporal elasticity of substitu-

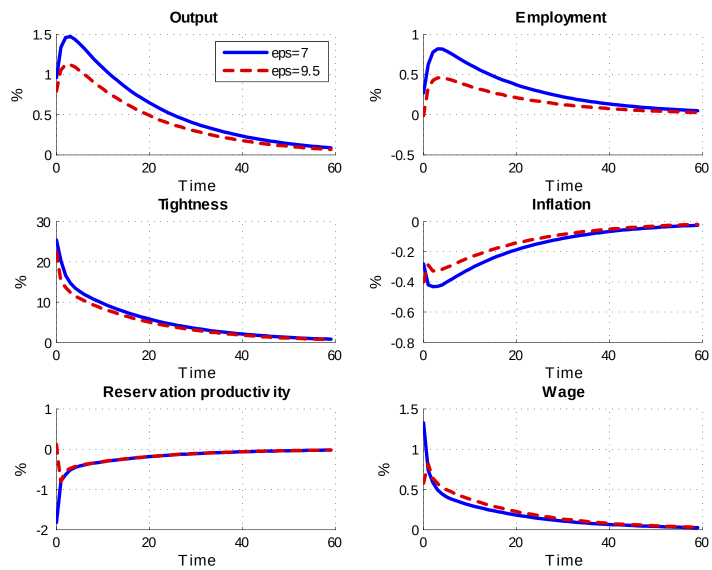


Fig. 3.1. Impulse responses to a positive technology shock for two different calibrations of ε.

tion ε. The solid line represents the responses for the benchmark calibration with the value of ε set to 7, whereas the dashed line shows the responses where value of ε is increased by 35%, implying the reduction in the markup of around 40%. Under the increased elasticity of substitution, the volatility of inflation relative to the benchmark case is dampened. Both output and employment rise followed by the pronounced hump-shape adjustment path, but the impact effect as well as the persistence is lower then under the benchmark case. The real wage increases but again the increase is smaller relative to the benchmark case, which implies that the productivity increase under increased competition leads, on impact, to a reduction in real marginal costs. Furthermore, labour market tightness increases by less under increased competition because the lower reduction in the reservation productivity leads to relatively lower fall in unemployment. These results stand in contrast to the ones obtained in Zanetti (2009). The explanation lies in the fact that, although increased com-

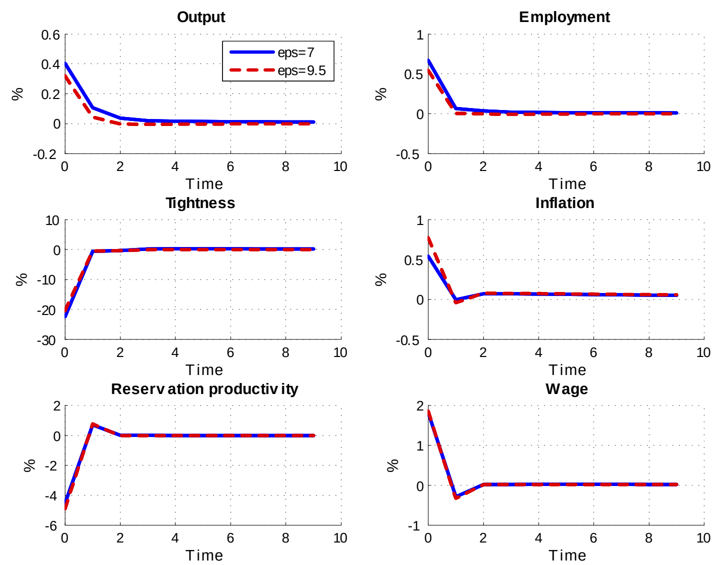


Fig. 3.2. Impulse responses to a positive government spending shock for two different calibration of ε.

petition leads to a decrease in the required markup and would thereby imply an increase in the marginal cost under the costly price change in the face of technology shock, the relative cost of adjusting prices under increased competition becomes lower, allowing prices to absorb relatively more of the impact effect. It turns out that following a positive technology shock the latter effect dominates and leads to a decrease in the real marginal costs.

3.5.2 The Effects of Government Spending Shocks and Product Market Reform

Figure 3.2 shows impulse responses to a one standard deviation positive government spending shock for two different calibrations of ε. In this case both output and employment slightly increase and the increase is again lower under the increased competition relative to the benchmark case. Moreover, the fall in unemployment under increased competition is

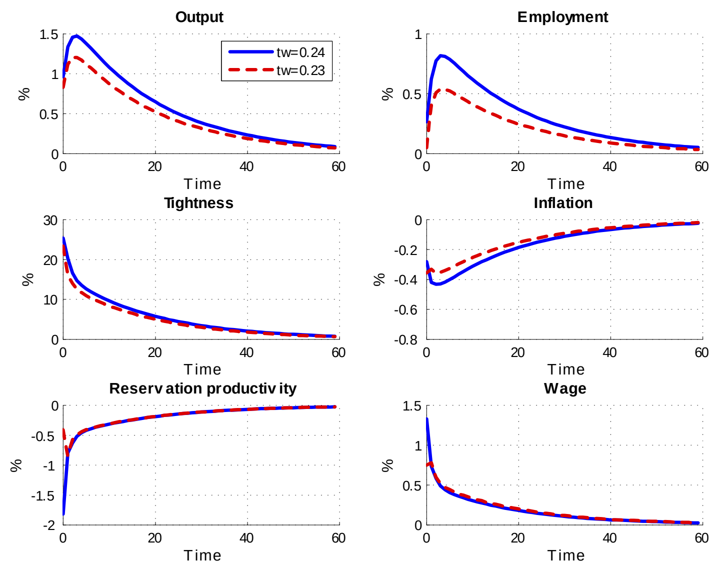


Fig. 3.3. Impulse responses to a positive technology shock for two different calibration of wage tax rate.

larger as a consequence of a larger reduction in reservation productivity. Moreover, this is reflected in a slightly lower fall in labour market tightness relative to the benchmark case. However, following a positive government spending shock, and in contrast to the technology shock, the expansion in economic activity leads to a somewhat stronger response of inflation relative to the benchmark case along the whole adjustment path as a result of a slightly larger increase in the marginal costs and decrease in reservation productivity. Why is this so? The expansion of economic activity puts upward pressure on marginal costs, which is not offset by the increase in the aggregate productivity, causing an upward pressure on inflation. In this case the reduction in the relative cost of the price change leads to the larger response of inflation relative to the benchmark case, and keeps the response always above the benchmark case.

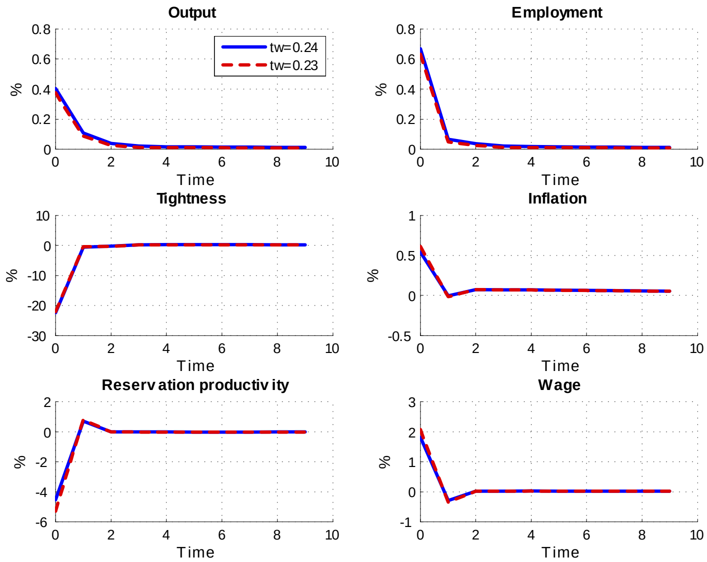


Fig. 3.4. Impulse responses to a positive government spending shock for two different calibration of wage tax rate.

3.5.3 The effects of shocks and tax reforms

The effects of the tax reforms, in terms of a one percentage point reduction in the respective marginal tax rates, on the impulse response functions to a one standard deviation positive technology shock are respectively represented by the dashed lines in Figures 3.3 and 3.5. The Figures 3.4 and 3.6 represent the impulse response functions to a one standard deviation positive government spending shock with a respective reduction in the marginal tax rates. For the sake of brevity we will only analyze the responses to a positive technology shock since the analysis of the government spending shock closely follows that in the case of product market reforms. The solid lines in each of the figures visualize the corresponding responses for the benchmark calibration. It is easy to see that the reduction in both the wage and payroll tax rates generally dampens the impulse responses of each variable.

Specifically, the peak effects as well as the persistence tends to be smaller. A notable exception to this general pattern concerns the behaviour of inflation. The impact effect on inflation is larger when compared to the benchmark case, and the reason behind this is the effect of the reduced wage tax rate on the average real wage and the marginal cost. Reduction in the wage tax rate leads to a decrease in the non-market part of the wage making it less rigid relative to the benchmark case. However, this reduction in wage rigidity leads to the smaller fall in the reservation productivity. This in turn decreases the response of the endogenous job destruction rate relative to the benchmark case and thereby increases the relative aggregate costs of workers layoff. As a result the unemployment as well as the employment reaction is reduced. Moreover, the decrease in the non-market part of the wage is not sufficient to offset the opposite effect of the reduction in reservation productivity, leading to a smaller response of the average real wage. The smaller fall of the marginal costs leads to a larger impact response in inflation. We can see that the effect of the reduction in the wage tax rate generates the same responses in the economy as does an increase in the degree of competition, albeit for different reasons.

3.6 Constant Marginal Tax Wedge Reform

This section analyzes the effect of a payroll tax reduction partially compensated by a wage tax increase which is widely advocated by policy makers and recently adopted by several OECD countries. Instead of considering the revenue neutral tax reform which is widely used in the existing literature we follow Heijdra and Ligthart (2009) and assume that the

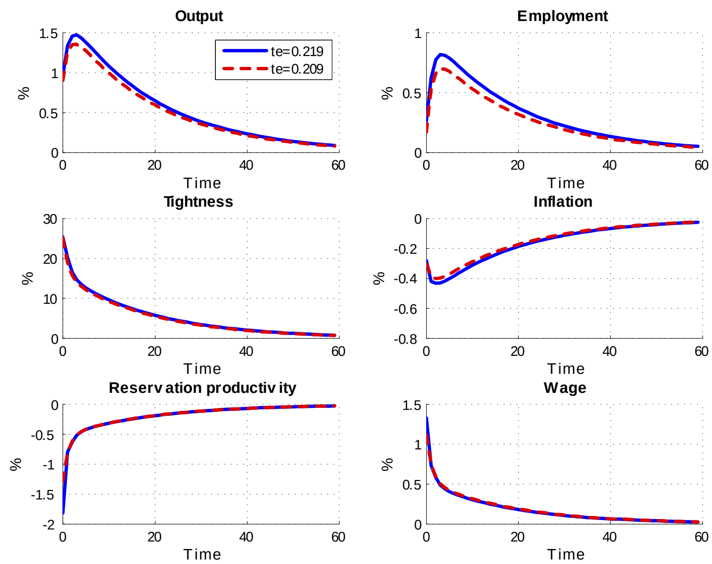


Fig. 3.5. Impulse responses to a positive technology shock for two different calibration of payroll tax rate.

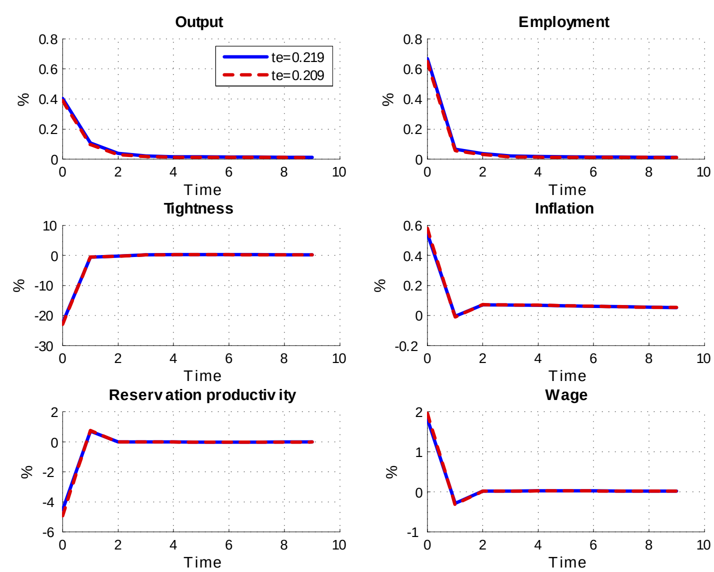


Fig. 3.6. Impulse responses to a positive government spending shock for two different calibration of payroll tax rate.

policy maker is adjusting taxes such that the marginal tax wedge remains unchanged.[43] The main reason is the practical simplicity of this type of reform, since the revenue neutral tax change requires complete knowledge of the complex reforms' effects on the tax base. In practice the policy makers lack all of the necessary information regarding the reforms' tax base effect, whereas the reform which makes the marginal tax wedge unchanged only requires the knowledge of marginal tax rates and it is therefore easy to implement it. We maintain the assumption that all of the changes in revenues are compensated by the change in lump-sum transfers so to keep the respective ratios of government spending and debt to GDP same as in the benchmark calibration.

Let us first consider the long run effect of a 3% increase in the marginal labour tax rate which is offset by a decrease in the payroll tax rate of around 5%, thereby making the marginal tax wedge constant. In our model characterized by search matching friction, imperfect competition and endogenous job destruction, this tax reform policy leads to the decrease in employment of around 4% and to a slightly larger fall in output and consumption of around 4.25%. These results pose a challenge to the conventional view and contradict the ones obtained by Heijdra and Ligthar (2009) in the model with perfect competition and exogenous job destruction.

What explains these results? In our setup there are two channels at work. First, an increase in the wage tax leads to an increase in the non-market part of the wage, whereas a decrease in the marginal payroll tax rate leads to an increase in the market part of the bargained wage. Overall, the average real wage increases. Effectively, what is important is the

[43] In our setting the marginal tax wedge is simply defined as $\frac{\tau^w+\tau^e}{1+\tau^e}$.

impact of the reduction in the payroll tax on the producers after tax wage. In our model under plausible calibration, the producer's wage slightly increases, by 0.6%. This implies that the reduction in the payroll tax rate necessary to keep the marginal tax wedge unchanged was not sufficient to offset the effect of the increase in the average real wage which in turn reduces the firms' marginal value of an additional worker. As a result firms post less vacancies and the worker's probability of finding a job decreases. Second, in our model the job destruction rate is endogenous and the change in the average real wage is interrelated with the reservation productivity since the long run marginal cost is solely determined by the degree of competition. Therefore in order to satisfy the marginal cost requirement, the adjustment takes place through the job destruction rate as well as through the wage. Moreover, the wage and payroll tax rate have opposite effects on the reservation productivity level and in principle the effect of tax reforms can go either way. It turns out that this specific type of reform, by leading to an average real wage increase, leads to an equilibrium increase in reservation productivity level which in turn increases the job destruction rate and decreases employment. [44]As a consequence both output and consumption fall.[45]

3.6.1 Anticipated Reform and Transitional Dynamics

The anticipation of the increase in the producer's wage in the next period leads to the impact decrease in the current period vacancy posting. It is the consequence of the "time

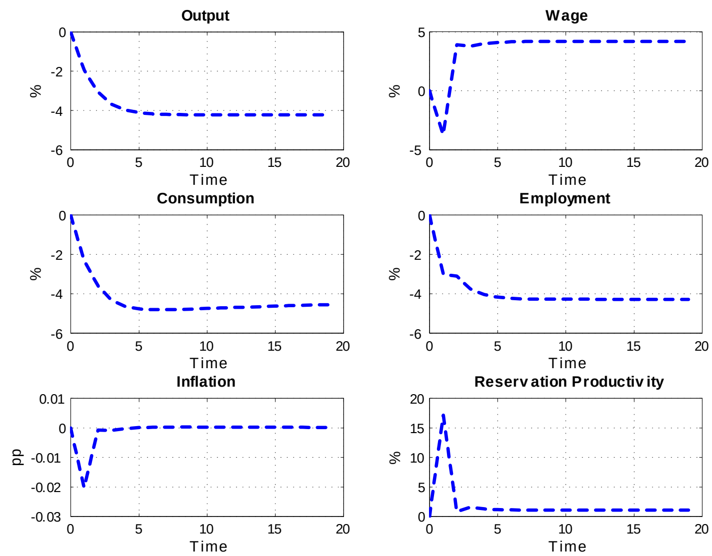
[44] It is worthwile pointing out that this type of reform increases workers after tax wage but at the expense of employment which is opposite to the results obtained in Koskela and Schob (1999) in the case of revenue neutral tax reforms.

[45] Extensive sensitivity analysis reveals that the tax reform scheme analyzed in the text can generate positive but negligible changes in employment for unrealistically small changes in the wage tax rate (of less than 0.3%). However, since such small tax changes are unimportant from the practical view we abstract from their analysis.

to hire" assumption which implies that the workers matched in current period become operational in the next period. This in turn reduces labour market tightness which puts downward pressures on the current period wage. The fall in the current period wage implies in turn a reduction in marginal costs which leads to a decrease in inflation and to a decrease in the real interest rate. The ultimate employment consequences of this behavior will be determined by the change in the reservation productivity. Figure 3.7 shows that the reservation productivity increases which is the consequence of two effects potentially working in opposite direction. The first effect is attributed to the reduction in current marginal costs which leads to an increase in the reservation productivity, but the increase being dampened by the influence of hiring costs. The second effect, as already explained, depends on the relative influence of labour market tightness on the reservation productivity. In our case when tax reform is anticipated one period in advance, the negative effects of marginal costs and labour market tightness on the reservation productivity dominate the negative effect of labour market tightness on average vacancy costs, and thereby positive effect on the reservation productivity. As a result reservation productivity increases on impact, which leads to an increase in unemployment and a decrease in employment caused by an increase in the endogenous job destruction rate.

After the reform has been implemented, the average real wage increases quickly towards the new steady state level in the next period, after which the increase becomes more gradual. The increase in the wage leads to even further, albeit smaller, fall in labour market tightness whereas the marginal costs increase because of the increase in the average real wage. As a result reservation productivity falls, but the fall is not sufficient to com-

Fig. 3.7. Transitional dynamics for anticipated one period preanounced tax reform.



pensate for the previous deterioration of the vacancy postings and therefore employment continues to fall until it reaches the new steady state level. The increase in marginal costs is followed by an increase in inflation, with the inflation dynamics being much smoother relative to the marginal costs as a result of the price stickiness. Furthermore, output and consumption decrease all the way along the transition, with the smoothness in transition being the consequence of the habit formation.

3.7 Concluding Remarks

In this chapter we have developed the New-Keynesian model with imperfect competition, costly price adjustment and labour markets characterized by search-matching frictions in order to analyze the effects of specific tax structures and product market reforms on various macroeconomic variables. On the modeling side, our setup differs from previous general equilibrium literature used to analyze the effects of tax and product market reforms by two important aspects, namely by introduction of the search-matching framework with endogenous job destruction and costly firing decisions into the standard New-Keynesian model and by explicit fiscal considerations via the use of two types of distortionary taxes, that is progressive wage tax and flat payroll tax. This general setup allows us to analyze both the long run effects of changes in tax and product market structures as well as their dynamic implications. We confirm in the general equilibrium setup with endogenous job destruction the widely held view that the reduction in marginal tax distortions has positive long run effects on labour markets and the economy as a whole. We also find the positive long run effects of the increase in the tax system's progressivity on employment, output and consumption independent of the initial progressivity level. Furthermore, we find that the decrease in each of the marginal tax rates as well as the increase in the degree of progressivity leads to a decrease in the volatility of output, consumption and employment. Following a positive technology shock only the impact response in inflation in a reformed economy is larger relative to the non reformed case, whereas following the positive government spending shock the inflation response is larger along the whole adjustment path.

We also find the positive effect of product market reform aimed at competition increase on labour market and the overall economic performance. This type of reform also leads to a reduction in the volatility of employment, output and consumption following the positive technology shock. Following the positive government spending shock the volatility of inflation increases but the volatility of employment, consumption and output again decreases.

To complete the analysis we consider the effect of a reduction in the marginal payroll tax partial offset by an increase in the wage tax rate such that the marginal tax wedge remains unchanged. We find, contrary to conventional view, that this type of reform is detrimental for employment in the long run. If this reform is anticipated one period in advance the short run positive employment effects are also absent.

3.A Appendix A to Chapter 3

3.A.1 The Firm's Profit Maximisation Problem

The Lagrangian for a firm's profit maximisation is given by:

$$\begin{aligned} L &= \max_{\{n_{i,t},v_{i,r},P_{i,t},\tilde{a}_{i,t},\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left\{ \frac{P_{i,t}}{P_t} Y_{i,t} - W_{i,t}(1+\tau^f) - R(v_{i,t}) - \Theta_t - \Upsilon_t \right. \\ &\left. + mc_{i,t} \left[n_{i,t} A_t H(\tilde{a}_{i,t}) - \left(\frac{P_{i,t}}{P_t} \right)^{-\varepsilon} Y_t \right] + \mu_{i,t} \left[(1-\rho_{i,t})(n_{i,t-1} + v_{i,t-1} g(\theta_{t-1})) - n_{i,t} \right] \right\} \end{aligned} \tag{3.A.1}$$

such that

$$Y_{i,t} = \left(\frac{P_{i,t}}{P_t} \right)^{-\varepsilon} Y_t \tag{3.A.2}$$

$$\Theta_t = \frac{\Psi}{2} \left(\frac{P_{i,t}}{P_{i,t-1}} - \pi \right)^2 Y_t \tag{3.A.3}$$

$$\Upsilon_t = (1-\rho^x) F(\tilde{a}_{i,t})(n_{i,t-1} + v_{i,t-1} g(\theta_{t-1})) D \tag{3.A.4}$$

and $\lambda_t = U_C(C_t, H_t)$.

The first order conditions with respect to $\{n_{i,t}, v_{i,r}, P_{i,t}, \tilde{a}_{i,t},\}$ for the above problem read as follows:

$$\begin{gathered} \frac{\partial L}{\partial n_{i,t}} = 0 \Rightarrow \\ -\beta^t \frac{\lambda_t}{\lambda_0} \frac{\partial W_{i,t}}{\partial n_{i,t}} (1+\tau^f) + \beta^t mc_{i,t} \frac{\lambda_t}{\lambda_0} A_t H(\tilde{a}_{i,t}) - \beta^t \frac{\lambda_t}{\lambda_0} \mu_{i,t} \\ + \beta^{t+1} E_t \left[\frac{\lambda_{t+1}}{\lambda_0} (1-\rho_{i,t+1}) \mu_{i,t+1} \right] - \beta^{t+1} E_t \left(\frac{\lambda_{t+1}}{\lambda_0} \right) (1-\rho^x) F(\tilde{a}_{i,t+1}) D = 0 \end{gathered}$$

$$\mu_{i,t} = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} (1-\rho_{i,t+1}) \mu_{i,t+1} \right] + mc_{i,t} A_t H(\tilde{a}_{i,t}) - (1+\tau^f) \frac{\partial W_{i,t}}{\partial n_{i,t}} \\ - \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) (1-\rho^x) F(\tilde{a}_{i,t+1}) D$$

$$\begin{aligned} \mu_{i,t} &= mc_{i,t} A_t H(\tilde{a}_{i,t}) \\ &\quad -(1+\tau^f) \frac{\partial W_{i,t}}{\partial n_{i,t}} + \beta(1-\rho^x) E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[\left(1 - F(\tilde{a}_{i,t+1})\right) \mu_{i,t+1} - F(\tilde{a}_{i,t+1}) D \right) \right] \right\} \end{aligned} \tag{3.A.5}$$

$$\frac{\partial L}{\partial v_{i,t}} = 0 \Rightarrow$$

$$\begin{aligned} & -\beta^t \frac{\lambda_t}{\lambda_0} R'(v_{i,t}) + \beta^{t+1} g(\theta_t) E_t \left[\frac{\lambda_{t+1}}{\lambda_0} (1-\rho_{i,t+1}) \mu_{i,t+1} \right] \\ = \; & \beta^{t+1} g(\theta_t) E_t \left(\frac{\lambda_{t+1}}{\lambda_0} \right) (1-\rho^x) F(\tilde{a}_{i,t+1}) D \end{aligned}$$

$$\frac{R'(v_{i,t})}{g(\theta_t)} = \beta(1-\rho^x) E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[\left(1 - F(\tilde{a}_{i,t+1})\right) \mu_{i,t+1} - F(\tilde{a}_{i,t+1}) D \right) \right] \right\} \tag{3.A.6}$$

$$\frac{\partial L}{\partial P_{i,t}} = 0 \Rightarrow$$

$$\begin{aligned} & \beta^t \frac{\lambda_t}{\lambda_0} \left[\begin{array}{c} (1-\varepsilon)(P_{i,t})^{-\varepsilon-1} (P_t)^{-(1-\varepsilon)} Y_t \\ -\Psi \left(\frac{P_{i,t}}{P_{i,t-1}} - \pi \right) \frac{1}{P_{i,t-1}} Y_t + \varepsilon mc_{i,t} (P_{i,t})^{-\varepsilon-1} (P_t)^{-(1-\varepsilon)} Y_t \end{array} \right] \\ = \; & -\beta^{t+1} E_t \left[\frac{\lambda_{t+1}}{\lambda_0} \Psi \left(\frac{P_{i,t+1}}{P_{i,t}} - \pi \right) \frac{P_{i,t+1}}{P_{i,t}} \frac{1}{P_{i,t}} Y_{t+1} \right] \end{aligned}$$

$$\begin{aligned} & (1-\varepsilon) \left(\frac{P_{i,t}}{P_t} \right)^{-\varepsilon} \frac{1}{P_{i,t}} Y_t - \Psi (\pi_t - \pi) \frac{1}{P_{i,t-1}} Y_t + \nu mc_{i,t} \left(\frac{P_{i,t}}{P_t} \right)^{-\varepsilon} \frac{1}{P_{i,t}} Y_t \\ = \; & -\beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \Psi (\pi_{t+1} - \pi) \pi_{t+1} \frac{1}{P_{i,t}} Y_{t+1} \right] \end{aligned} \tag{3.A.7}$$

$$\frac{\partial L}{\partial \tilde{a}_{i,t}} = 0 \Rightarrow$$

$$-\beta^t \frac{\lambda_t}{\lambda_0} \frac{\partial W_{i,t}}{\partial \tilde{a}_{i,t}} + \beta^t \frac{\lambda_t}{\lambda_0} mc_{i,t} n_{i,t} A_t H'(\tilde{a}_{i,t}) - \beta^t \frac{\lambda_t}{\lambda_0} \mu_{i,t} \rho'(\tilde{a}_{i,t})(n_{i,t-1} + v_{i,t-1} g(\theta_{t-1}))$$
$$= \beta^t \frac{\lambda_t}{\lambda_0} (1-\rho^x) F'(\tilde{a}_{i,t})(n_{i,t-1} + v_{i,t-1} g(\theta_{t-1}))D$$

$$\begin{aligned} & \mu_{i,t} \rho'(\tilde{a}_{i,t})(n_{i,t-1} + v_{i,t-1} g(\theta_{t-1})) + (1-\rho^x) F'(\tilde{a}_{i,t})(n_{i,t-1} + v_{i,t-1} g(\theta_{t-1}))D \\ = \; & mc_{i,t} n_{i,t} A_t H'(\tilde{a}_{i,t}) - (1+\tau^f) \frac{\partial W_{i,t}}{\partial \tilde{a}_{i,t}} \end{aligned} \quad (3.A.8)$$

3.A.2 Further Analytics Needed to Solve the Model

Using

$$\frac{R'(v_{i,t})}{g(\theta_t)} = \beta(1-\rho^x) E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[(1 - F(\tilde{a}_{i,t+1}))\mu_{i,t+1} - F(\tilde{a}_{i,t+1}) D \right] \right\}$$

and

$$\begin{aligned} \mu_{i,t} &= \beta(1-\rho^x) E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[\left(1 - F(\tilde{a}_{i,t+1})\right)\mu_{i,t+1} - F(\tilde{a}_{i,t+1}) D \right) \right] \right\} \\ & \quad + mc_{i,t} A_t H(\tilde{a}_{i,t}) - (1+\tau^f) \frac{\partial W_{i,t}}{\partial n_{i,t}} \end{aligned}$$

and updating the previous two equations for one period to get

$$\begin{aligned} \mu_{i,t+1} &= \beta(1-\rho^x) E_{t+1} \left\{ \frac{\lambda_{t+2}}{\lambda_{t+1}} \left[\left(1 - F(\tilde{a}_{i,t+2})\right)\mu_{i,t+2} - F(\tilde{a}_{i,t+2}) D \right) \right] \right\} \\ & \quad + mc_{i,t+1} A_{t+1} H(\tilde{a}_{i,t+1}) - (1+\tau^f) \frac{\partial W_{i,t+1}}{\partial n_{i,t+1}} \end{aligned} \quad (3.A.9)$$

and

$$\frac{R'(v_{i,t+1})}{g(\theta_{t+1})} = \beta(1-\rho^x)E_{t+1}\left\{\frac{\lambda_{t+2}}{\lambda_{t+1}}\left[(1-F(\tilde{a}_{i,t+2}))\mu_{i,t+2} - F(\tilde{a}_{i,t+2})D)\right]\right\}$$

we can rewrite the first updated equation to get a solution for $\mu_{i,t+1}$ given by:

$$\mu_{i,t+1} = \frac{R'(v_{i,t+1})}{g(\theta_{t+1})} + mc_{i,t+1}A_{t+1}H(\tilde{a}_{i,t+1}) - (1+\tau^f)\frac{\partial W_{i,t+1}}{\partial n_{i,t+1}} \tag{3.A.10}$$

We can than substitute (3.A.10) into (3.A.9) to obtain

$$\begin{aligned}\frac{R'(v_{i,t})}{g(\theta_t)} &= \beta(1-\rho^x)E_t\frac{\lambda_{t+1}}{\lambda_t}\left[(1-F(\tilde{a}_{i,t+1}))\left(\frac{R'(v_{i,t+1})}{g(\theta_{t+1})} + mc_{i,t+1}A_{t+1}H(\tilde{a}_{i,t+1})\right)\right] \\ &\quad -\beta(1-\rho^x)E_t\frac{\lambda_{t+1}}{\lambda_t}\left[(1-F(\tilde{a}_{i,t+1}))\left((1+\tau^f)\frac{\partial W_{i,t+1}}{\partial n_{i,t+1}}\right) + F(\tilde{a}_{i,t+1})D\right]\end{aligned} \tag{3.A.11}$$

Let us now rearrange the equation (3.A.8). Substitute for $n_{i,t}$ on the RHS of (3.A.8) to get

$$\begin{aligned}&\mu_{i,t}\rho'(\tilde{a}_{i,t})(n_{i,t-1} + v_{i,t-1}g(\theta_{t-1})) + (1-\rho^x)F'(\tilde{a}_{i,t})(n_{i,t-1} + v_{i,t-1}g(\theta_{t-1}))D \\ &= mc_{i,t}(n_{i,t-1} + v_{i,t-1}g(\theta_{t-1}))A_tH'(\tilde{a}_{i,t}) - (1+\tau^f)\frac{\partial W_{i,t}}{\partial \tilde{a}_{i,t}}\end{aligned}$$

$$\begin{aligned}&\mu_{i,t}\rho'(\tilde{a}_{i,t}) + (1-\rho^x)F'(\tilde{a}_{i,t})D \\ &= mc_{i,t}(1-\rho_{i,t})A_tH'(\tilde{a}_{i,t}) - \frac{1}{\underbrace{n_{i,t-1} + v_{i,t-1}g(\theta_{t-1})}_{\frac{n_{i,t}}{1-\rho_{i,t}}}}(1+\tau^f)\frac{\partial W_{i,t}}{\partial \tilde{a}_{i,t}}\end{aligned}$$

$$\mu_{i,t}\rho'(\tilde{a}_{i,t}) + (1-\rho^x)F'(\tilde{a}_{i,t})D = mc_{i,t}(1-\rho_{i,t})A_tH'(\tilde{a}_{i,t}) - \frac{1-\rho_{i,t}}{n_{i,t}}(1+\tau^f)\frac{\partial W_{i,t}}{\partial \tilde{a}_{i,t}} \tag{3.A.12}$$

Recall that the total job destruction can be written as:

$$\rho_{i,t} \equiv \rho(\tilde{a}_{i,t}) = \rho^x + (1-\rho^x)F(\tilde{a}_{i,t}) \tag{3.A.13}$$

and

$$H(\tilde{a}_{i,t}) = \int_{\tilde{a}_{i,t}}^{\bar{a}} \frac{a_t f(a_t)}{1 - F(\tilde{a}_{i,t})} da_t$$

Than the first derivative of $\rho(\tilde{a}_{i,t})$ is given by :

$$\frac{\partial \rho_{i,t}}{\partial \tilde{a}_{i,t}} = (1 - \rho^x) F'(\tilde{a}_{i,t})$$

By applying Leibnitz rule to the $H(\tilde{a}_{i,t})$ we obtain:

$$\begin{aligned}
\frac{\partial H(\tilde{a}_{i,t})}{\partial \tilde{a}_{i,t}} &= \int_{\tilde{a}_{i,t}}^{\bar{a}} \frac{\partial \left(\frac{a_t f(a_t)}{1-F(\tilde{a}_{i,t})} \right)}{\partial \tilde{a}_{i,t}} da_t + 0 - \frac{\tilde{a}_{i,t} f(\tilde{a}_{i,t})}{1 - F(\tilde{a}_{i,t})} \\
&= \frac{f(\tilde{a}_{i,t})}{1 - F(\tilde{a}_t)} \int_{\tilde{a}_{i,t}}^{\bar{a}} \frac{a_t f(a_t)}{1 - F(\tilde{a}_{i,t})} da_t - \frac{\tilde{a}_{i,t} f(a_{i,t})}{1 - F(\tilde{a}_{i,t})} \\
&= \frac{f(\tilde{a}_{i,t})}{1 - F(\tilde{a}_{i,t})} H(\tilde{a}_{i,t}) - \frac{\tilde{a}_{i,t} f(\tilde{a}_{i,t})}{1 - F(\tilde{a}_{i,t})} \\
&= (H(\tilde{a}_{i,t}) - \tilde{a}_{i,t}) \frac{f(\tilde{a}_{i,t})}{1 - F(\tilde{a}_{i,t})}
\end{aligned}$$

We also use the condition derived from (3.A.13) and given by

$$1 - \rho_t = (1 - \rho^x)(1 - F(\tilde{a}_{i,t}))$$

to get

$$\begin{aligned}
&\mu_{i,t} + D \\
= \; & \frac{1}{(1 - \rho^x) F'(\tilde{a}_{i,t})} \left[mc_{i,t}(1 - \rho_{i,t}) A_t (H(\tilde{a}_{i,t}) - \tilde{a}_{i,t}) \frac{f(\tilde{a}_{i,t})}{1 - F(\tilde{a}_{i,t})} - \frac{1 - \rho_{i,t}}{n_{i,t}} (1 + \tau^f) \frac{\partial W_{i,t}}{\partial \tilde{a}_{i,t}} \right]
\end{aligned}$$

$$\begin{aligned}
\mu_{i,t} + D \;=\; & mc_{i,t} A_t (1 - \rho^x)(1 - F(\tilde{a}_{i,t}))(H(\tilde{a}_{i,t}) - \tilde{a}_{i,t}) \frac{f(\tilde{a}_{i,t})}{(1 - F(\tilde{a}_{i,t}))} \frac{1}{(1 - \rho^x) f(\tilde{a}_{i,t})} \\
& - \frac{(1 - \rho^x)(1 - F(\tilde{a}_{i,t}))}{n_t (1 - \rho^x) F'(\tilde{a}_{i,t})} (1 + \tau^f) \frac{\partial W_{i,t}}{\partial \tilde{a}_{i,t}}
\end{aligned}$$

$$\mu_{i,t} = mc_{i,t}A_t(H(\tilde{a}_{i,t}) - \tilde{a}_{i,t}) - \frac{(1-F(\tilde{a}_{i,t}))}{n_t F'(\tilde{a}_{i,t})}(1+\tau^f)\frac{\partial W_{i,t}}{\partial \tilde{a}_{i,t}} - D \tag{3.A.14}$$

By combining (3.A.14) and (3.A.10) we obtain the following condition:

$$\begin{aligned}&\frac{R'(v_{i,t})}{g(\theta_t)} + mc_{i,t}A_t H(\tilde{a}_{i,t}) - (1+\tau^f)\frac{\partial W_{i,t}}{\partial n_{i,t}} \\ &= mc_{i,t}A_t H(\tilde{a}_{i,t}) - mc_{i,t}A_t\tilde{a}_{i,t} - \frac{(1-F(\tilde{a}_{i,t}))}{n_t F'(\tilde{a}_{i,t})}(1+\tau^f)\frac{\partial W_{i,t}}{\partial \tilde{a}_{i,t}} - D\end{aligned}$$

Using the definition of the wage bill given by

$$W_{i,t} = \int_0^{n_{i,j,t}}\int_{\tilde{a}_{i,t}}^{\bar{a}} w_{i,j,t}(a_{i,t})da_t dj = n_{i,t}\int_{\tilde{a}_{i,t}}^{\bar{a}} w_{i,t}(a_{i,t})\frac{f(a_t)}{1-F(\tilde{a}_{i,t})}da_t$$

we can obtain:

$$\frac{\partial W_{i,t}}{\partial a_{i,t}} = \frac{\partial}{\partial a_{i,t}}\left\{n_{i,t}\int_{\tilde{a}_{i,t}}^{\bar{a}} w_{i,t}(a_{i,t})\frac{f(a_t)}{1-F(\tilde{a}_{i,t})}da_t\right\}$$

$$\frac{\partial W_{i,t}}{\partial a_{i,t}} = n_{i,t}\int_{\tilde{a}_{i,t}}^{\bar{a}} w_t(a_{i,t})\frac{f(a_t)}{(1-F(\tilde{a}_{i,t}))^2}f(\tilde{a}_{i,t})da_t - n_{i,t}w_{i,t}(\tilde{a}_{i,t})\frac{f(\tilde{a}_{i,t})}{1-F(\tilde{a}_{i,t})}$$

$$\frac{\partial W_{i,t}}{\partial a_{i,t}} = n_{i,t}\frac{f(\tilde{a}_{i,t})}{1-F(\tilde{a}_{i,t})}\left(\int_{\tilde{a}_{i,t}}^{\bar{a}} w_{i,t}(a_{i,t})\frac{f(a_t)}{(1-F(\tilde{a}_{i,t}))}da_t - w_{i,t}(\tilde{a}_{i,t})\right)$$

and

$$\frac{\partial W_{i,t}}{\partial n_{i,t}} = \int_{\tilde{a}_{i,t}}^{\bar{a}} w_{i,t}(a_{i,t})\frac{f(a_t)}{1-F(\tilde{a}_{i,t})}da_t$$

Substituting previous results into

$$\begin{aligned}&\frac{R'(v_{i,t})}{g(\theta_t)} + mc_{i,t}A_t H(\tilde{a}_{i,t}) - (1+\tau^f)\frac{\partial W_{i,t}}{\partial n_{i,t}} \\ =\; & mc_{i,t}A_t H(\tilde{a}_t) - mc_{i,t}A_t\tilde{a}_t - \frac{(1-F(\tilde{a}_{i,t}))}{n_{i,t}F'(\tilde{a}_{i,t})}(1+\tau^f)\frac{\partial W_{i,t}}{\partial \tilde{a}_{i,t}} - D\end{aligned} \tag{3.A.15}$$

we can write

$$\frac{R'(v_{i,t})}{g(\theta_t)} + mc_{i,t}A_tH(\tilde{a}_{i,t}) - (1+\tau^f)\int_{\tilde{a}_{i,t}}^{\bar{a}} w_{i,t}(a_{i,t})\frac{f(a_t)}{1-F(\tilde{a}_t)}da_t = mc_{i,t}A_tH(\tilde{a}_{i,t}) - mc_{i,t}A_t\tilde{a}_{i,t}$$

$$-\frac{(1-F(\tilde{a}_{i,t}))}{n_tF'(\tilde{a}_{i,t})}n_t\frac{f(\tilde{a}_{i,t})}{(1-F(\tilde{a}_{i,t}))}(1+\tau^f)\left(\int_{\tilde{a}_{i,t}}^{\bar{a}} w_{i,t}(a_{i,t})\frac{f(a_t)}{(1-F(\tilde{a}_{i,t}))}da_t - w_{i,t}(\tilde{a}_{i,t})\right) - D$$

which after rearranging gives us

$$\frac{R'(v_{i,t})}{g(\theta_t)} + mc_{i,t}A_t\tilde{a}_{i,t} - (1+\tau^f)w_{i,t}(\tilde{a}_{i,t}) + D = 0 \tag{3.A.16}$$

Since the aggregate employment develops according to the following equation

$$n_t = (1-\rho_t)(n_{t-1} + g(\theta_{t-1})v_{t-1})$$

and we assume that all of the workers who are not employed are actively searching for a job, unemployment in the model is given by

$$u_t = 1 - n_t$$

In what follows we consider the symmetric equilibrium which allows us to ignore the subscript i.

3.A.3 The Bellman Equations

The marginal value of an employment for a firm is

$$\begin{aligned}\mathbf{J}_t^e(a_t) &= mc_t A_t a_t - (1+\tau^f)w_t(a_t) \\ &+\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[(1-\rho^x)\int_{\tilde{a}_{t+1}}^{\bar{a}} \mathbf{J}_{t+1}^e(a_{t+1})dF(a) - (1-\rho^x)\,F(\tilde{a}_{t+1})D + \rho_{t+1}J_{t+1}^u\right]\end{aligned} \tag{3.A.17}$$

The marginal value of a job for a worker is given by

$$\begin{aligned}\mathbf{W}_t^e(a_t) &= (1-\tau^w)w_t(a_t) - \tau \\ &+\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[(1-\rho^x)\int_{\tilde{a}_{t+1}}^{\bar{a}} \mathbf{W}_{t+1}^e(a_{t+1})dF(a) + \rho_{t+1}\mathbf{U}_{t+1}\right]\end{aligned} \tag{3.A.18}$$

whereas the marginal value of an unemployment for a worker is given by

$$\begin{aligned}\mathbf{U}_t &= b + \beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[\theta_t g(\theta_t)\,(1-\rho^x)\int_{\tilde{a}_{t+1}}^{\bar{a}} \mathbf{W}_{t+1}^e(a_{t+1})dF(a)\right] \\ &+\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\theta_t g(\theta_t)(1-\rho_{t+1}))\mathbf{U}_{t+1}\end{aligned} \tag{3.A.19}$$

Moreover, for what follows we can rewrite (3.A.18) and (3.A.19) as

$$\begin{aligned}\mathbf{W}_t^e(a_t) &= (1-\tau^w)w_t(a_t) - \tau + \beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[(1-\rho^x)\int_{\tilde{a}_{t+1}}^{\bar{a}} \left(\mathbf{W}_{t+1}^e(a_{t+1}) - \mathbf{U}_{t+1}\right)dF(a)\right. \\ &\left.+(1-\rho^x)\int_{\tilde{a}_{t+1}}^{\bar{a}} \mathbf{U}_{t+1}dF(a_{t+1}) + \rho^x U_{t+1} + (1-\rho^x)\int_{\underline{a}}^{\tilde{a}_{t+1}} \mathbf{U}_{t+1}dF(a)\right] \\ \mathbf{W}_t^e(a_t) &= (1-\tau^w)w_t(a_t) - \tau \\ &+\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[(1-\rho^x)\int_{\tilde{a}_{t+1}}^{\bar{a}} \left(\mathbf{W}_{t+1}^e(a_{t+1}) - \mathbf{U}_{t+1}\right)dF(a) + U_{t+1}\right]\end{aligned} \tag{3.A.20}$$

and

$$\mathbf{U}_t = b + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \left[\theta_t g(\theta_t)\left(1-\rho^x\right) \int_{\tilde{a}_{t+1}}^{\bar{a}} \left(\mathbf{W}^e_{t+1}(a_{t+1}) - \mathbf{U}_{t+1}\right) dF(a) \right.$$
$$\left. +(1-\theta_t g(\theta_t)(1-\rho_{i,t+1}))\mathbf{U}_{t+1} + \theta_t g(\theta_t)(1-\rho^x) \int_{\tilde{a}_{t+1}}^{\bar{a}} \mathbf{U}_{t+1} dF(a) \right]$$

$$\mathbf{U}_t = b + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \left[\theta_t g(\theta_t)\left(1-\rho^x\right) \int_{\tilde{a}_{t+1}}^{\bar{a}} \left(\mathbf{W}^e_{t+1}(a_{t+1}) - \mathbf{U}_{t+1}\right) dF(a) + U_{t+1}\right] \tag{3.A.21}$$

It is also useful to obtain the expression for $\mathbf{W}^e_t(a_t) - \mathbf{U}_t$

$$\mathbf{W}^e_t(a_t) - \mathbf{U}_t = (1-\tau^w)w_t(a_t) - \tau - b$$
$$+\beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \left[\left(1-\rho^x\right)\left(1-\theta_t g(\theta_t)\right) \int_{\tilde{a}_{t+1}}^{\bar{a}} \left(\mathbf{W}^e_{t+1}(a_{t+1}) - \mathbf{U}_{t+1}\right) dF(a)\right] \tag{3.A.22}$$

3.A.4 Nash Bargaining Problem and Wage Equation

The wage is determined by Nash bargaining over the match surplus which is assumed to be shared between a firm and the workers according to the parameter η denoting workers' bargaining power Formally, the problem of Nash product maximization is stated as follows:

$$w_t(a_t) = \arg\max \left(\mathbf{W}^e_t(a_t) - \mathbf{U}_t\right)^{\eta} \left(\mathbf{J}^e_t(a_t) + D\right)^{1-\eta} \tag{3.A.23}$$

The first order condition of the above problem is given by:

$$\eta \frac{\partial\left(\mathbf{W}^e_t(a_t)\right)}{\partial w_t(a_t)} \left(\mathbf{W}^e_t(a_t) - \mathbf{U}_t\right)^{\eta-1} \left(\mathbf{J}^e_t(a_t) + D\right)^{1-\eta}$$
$$= -\left(1-\eta\right) \frac{\partial\left(\mathbf{J}^e_t(a_t)\right)}{\partial w_t(a_t)} \left(\mathbf{W}^e_t(a_t) - \mathbf{U}_t\right)^{\eta} \left(\mathbf{J}^e_t(a_t) + D\right)^{-\eta} \tag{3.A.24}$$

Using

$$\frac{\partial\left(\mathbf{W}_t^e(a_t)\right)}{\partial w_t(a_t)} = 1-\tau^w \text{ and } \frac{\partial\left(\mathbf{W}_t^e(a_t)\right)}{\partial w_t(a_t)} = -(1+\tau^f)$$

substituting into (3.A.24), dividing by $\left(\mathbf{W}_t^e(a_t)-\mathbf{U}_t\right)^{\eta}\left(\mathbf{J}_t^e(a_t)+D\right)^{1-\eta}$ and rearranging we obtain sharing rule as the solution of the Nash bargaining problem, which in our case is given by:

$$\mathbf{W}_t^e(a_t)-\mathbf{U}_t = \frac{\eta(1-\tau^w)}{(1-\eta)(1+\tau^f)}\left(\mathbf{J}_t^e(a_t)+D\right) \tag{3.A.25}$$

Using (3.A.25) we can than write

$$\begin{aligned}\mathbf{W}_t^e(a_t)-\mathbf{U}_t &= (1-\tau^w)w_t(a_t)-b-\tau \\ &+\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[\int_{\tilde{a}_t}^{\bar{a}} \begin{array}{c}(1-\theta_t g(\theta_t))(1-\rho^x)\bullet \\ \frac{\eta(1-\tau^w)}{(1-\eta)(1+\tau^f)}\left(\mathbf{J}_{t+1}^e(a_{t+1})+D\right)dF(a)\end{array}\right]\end{aligned} \tag{3.A.26}$$

Using (3.A.16) and (3.A.17) evaluated at the reservation productivity level $\tilde{a}_t$ we can obtain the following condition:

$$\frac{R'(v_t)}{g(\theta_t)} = \beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)\left[\int_{\tilde{a}_{t+1}}^{\bar{a}}\left(\mathbf{J}_{t+1}^e(a_{t+1})+D\right)dF(a)-D\right]$$

which allows us to obtain a solution for the wage function in the following way:

$$\begin{aligned}&(1-\tau^w)w_t(a_t)-b-\tau+(1-\theta_t g(\theta_t))\frac{\eta(1-\tau^w)}{(1-\eta)(1+\tau^f)}\frac{R'(v_t)}{g(\theta_t)} \\ &+(1-\theta_t g(\theta_t))\frac{\eta(1-\tau^w)}{(1-\eta)(1+\tau^f)}\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)D \\ =\; &\frac{\eta(1-\tau^w)}{(1-\eta)(1+\tau^f)}\left[mc_tA_ta_t-(1+\tau^f)w(a_t)+\frac{R'(v_t)}{g(\theta_t)}+D\right]\end{aligned} \tag{3.A.27}$$

In order to derive the previous condition we have used the fact that

$$\mathbf{J}_t^e(a_t)+D = mc_tA_ta_t-(1+\tau^f)w_t(a_t)+\frac{R'(v_t)}{g(\theta_t)}+D$$

It then follows that

$$(1-\tau^{w})w_t(a_t)(1-\eta)(1+\tau^{f})-b\,(1-\eta)\,(1+\tau^{f})-\tau\,(1-\eta)\,(1+\tau^{f})$$
$$=-(1-\theta_t g(\theta_t))\eta(1-\tau^{w})\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^{x})\,D-(1-\theta_t g(\theta_t))\eta(1-\tau^{w})\frac{R'(v_t)}{g(\theta_t)}$$
$$+\eta(1-\tau^{w})\left[mc_tA_ta_t-(1+\tau^{f})w_t(a_t)+\frac{R'(v_t)}{g(\theta_t)}+D\right]$$

$$w_t(a_t)(1-\eta)(1+\tau^{f})-b\,(1-\eta)\,\frac{(1+\tau^{f})}{(1-\tau^{w})}-\tau\,(1-\eta)\,\frac{(1+\tau^{f})}{(1-\tau^{w})}+(1-\theta_t g(\theta_t))\eta\frac{R'(v_t)}{g(\theta_t)}$$
$$=-(1-\theta_t g(\theta_t))\eta\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^{x})\,D+\eta\left[mc_tA_ta_t-(1+\tau^{f})w_t(a_t)+\frac{R'(v_t)}{g(\theta_t)}+D\right]$$

$$w_t(a_t)(1+\tau^{f})-b\,(1-\eta)\,\frac{(1+\tau^{f})}{(1-\tau^{w})}-\tau\,(1-\eta)\,\frac{(1+\tau^{f})}{(1-\tau^{w})}-\eta\theta_tR'(v_t)$$
$$=\eta\left[mc_tA_ta_t-(1+\tau^{f})w_t(a_t)+\frac{R'(v_t)}{g(\theta_t)}+D\right]-(1-\theta_t g(\theta_t))\eta\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^{x})\,D$$

$$w_t(a_t)-b\frac{(1-\eta)}{(1-\tau^{w})}-\tau\frac{(1-\eta)}{(1-\tau^{w})}$$
$$=\eta\frac{1}{(1+\tau^{f})}\left[mc_tA_ta_t+\theta_tR'(v_t)+D-(1-\theta_t g(\theta_t))\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^{x})\,D\right]$$

$$\begin{aligned} w_t(a_t) &= b\frac{(1-\eta)}{(1-\tau^{w})}+\tau\frac{(1-\eta)}{(1-\tau^{w})}+\eta\frac{1}{(1+\tau^{f})}\left[mc_tA_ta_t+\theta_tR'(v_t)\right] \\ &\quad +\eta\frac{1}{(1+\tau^{f})}\left[D-(1-\theta_t g(\theta_t))\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^{x})\,D\right] \end{aligned} \tag{3.A.28}$$

The average (expected) real wage now becomes

$$\begin{aligned}\frac{\partial W_t}{\partial n_t} \equiv\ & w_t = b\frac{(1-\eta)}{(1-\tau^w)} + a\frac{(1-\eta)}{(1-\tau^w)} + \eta\frac{1}{(1+\tau^f)}\left[mc_t A_t H(\tilde{a}_t) + \theta_t R'(v_t)\right] \\ & +\eta\frac{1}{(1+\tau^f)}\left[D - (1-\theta_t g(\theta_t))\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)\, D\right] \qquad (3.A.29)\end{aligned}$$

3.A.5 Derivation of The Reservation Productivity Level

In order to derive the reservation productivity level we use $(3.A.16)$ and the wage equation $(3.A.28)$. Evaluating $(3.A.28)$ at the reservation productivity level $\tilde{a}_t$ and substituting into $(3.A.16)$ we can write

$$\begin{aligned}mc_t A_t \tilde{a} =\ & (1+\tau^f)\left\{b\frac{(1-\eta)}{(1-\tau^w)} + \tau\frac{(1-\eta)}{(1-\tau^w)} + \eta\frac{1}{(1+\tau^f)}\left[mc_t A_t H(\tilde{a}_t) + \theta_t R'(v_t)\right]\right\} \\ & +\eta\left[D - (1-\theta_t g(\theta_t))\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)\, D\right] - D - \frac{R'(v_t)}{g(\theta_t)}\end{aligned}$$

$$\begin{aligned}(1-\eta) mc_t A_t \tilde{a} =\ & (1-\eta)\frac{(1+\tau^f)}{(1-\tau^w)}(b+\tau) + \frac{1}{1-\eta}R'(v_t)\left(\eta\theta_t - \frac{1}{g(\theta_t)}\right) \\ & -(1-\eta)D - \eta(1-\theta_t g(\theta_t))\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)\, D\end{aligned}$$

The final solution for the reservation productivity level can then be written as:

$$\begin{aligned}\tilde{a}_t =\ & \frac{1}{mc_t A_t}\left[\frac{(1+\tau^f)}{(1-\tau^w)}(b+\tau) + \frac{1}{1-\eta}R'(v_t)\left(\eta\theta_t - \frac{1}{g(\theta_t)}\right)\right] \\ & -\frac{1}{mc_t A_t}\left[1 + \frac{\eta}{1-\eta}(1-\theta_t g(\theta_t))\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)\right] D\end{aligned}$$

(3.A.30)

3.A.6 Derivation of the Evolution of Labour Market Tightness Equation

Let us consider the condition (3.A.11) which by assuming symmetry can be rewritten as:

$$\begin{aligned}\frac{R'(v_t)}{g(\theta_t)} &= \beta(1-\rho^x)E_t\frac{\lambda_{t+1}}{\lambda_t}\left[(1-F(\tilde{a}_{t+1}))\left(\frac{R'(v_{t+1})}{g(\theta_{t+1})}+mc_{t+1}A_{t+1}H(\tilde{a}_{t+1})\right)\right]\\ &\quad -\beta(1-\rho^x)E_t\frac{\lambda_{t+1}}{\lambda_t}\left[(1-F(\tilde{a}_{t+1}))\left((1+\tau^f)\frac{\partial W_{t+1}}{\partial n_{t+1}}\right)+F(\tilde{a}_{t+1})D\right]\end{aligned} \tag{3.A.31}$$

Using the definition of the conditional expectation of a random variable a_t given by:

$$H(a_t)=\int_{\tilde{a}_t}^{\bar{a}} a_t\frac{a_t f(a_t)}{1-F(\tilde{a}_t)}da_t \tag{3.A.32}$$

as well as the solution for the wage equation (3.A.28) together with the solution for the aggregate average wage (3.A.29) both updated for one period and substituting this one period update into $(3.A.31)$ we arrive at:

$$\begin{aligned}\frac{R'(v_t)}{g(\theta_t)} &= \beta(1-\rho^x)E_t\frac{\lambda_{t+1}}{\lambda_t}\left[(1-F(\tilde{a}_{t+1}))\left(\frac{R'(v_{t+1})}{g(\theta_{t+1})}+(1-\eta)mc_{t+1}A_{t+1}H(\tilde{a}_{t+1})\right)\right]\\ &\quad -\beta(1-\rho^x)E_t\frac{\lambda_{t+1}}{\lambda_t}\left[(1-F(\tilde{a}_{t+1}))\left(\eta\theta_{t+1}R'(v_{t+1})+(1-\eta)\frac{(1+\tau^f)}{(1-\tau^w)}(b+\tau)\right)\right]\\ &\quad -\beta(1-\rho^x)E_t\frac{\lambda_{t+1}}{\lambda_t}F(\tilde{a}_{t+1})D\\ &\quad -\beta(1-\rho^x)E_t\frac{\lambda_{t+1}}{\lambda_t}\left[\begin{array}{c}(1-F(\tilde{a}_{t+1}))\eta\bullet\\ \left(D-(1-\theta_{t+1}g(\theta_{t+1}))\beta E_{t+1}\left(\frac{\lambda_{t+2}}{\lambda_{t+1}}\right)(1-\rho^x)\,D\right)\end{array}\right]\end{aligned} \tag{3.A.33}$$

Chapter 4

Optimal Monetary and Fiscal Policy in the Economy with non-Walrasian labour market

Most of the optimal monetary and fiscal policy literature abstracts from any real frictions in the labour markets. Regardless of whether the analysis is conducted within the neoclassical setup characterized by perfect competition and fully flexible prices, or within the more recent New-Keynesian setup with imperfect competition and costly price adjustment, labour markets are assumed to be Walrasian. By assuming Walrasian labour markets, one neglects an important short run inflation-unemployment trade-offs. Beside this important drawback, most of the standard models used for optimal policy analysis are highly stylized, neglecting many theoretical and policy considerations. For example, even though the New-Keynesian modeling environment is characterized by imperfect competition, the vast majority of literature assumes the existence of the production and/or employment subsidies that would eliminate distortions arising from this imperfection. Additionally, it is either implicitly or explicitly assumed that the government has access to lump-sum taxes used to finance its budget. As a result, the availability of lump-sum taxes implies no explicit role for fiscal policy in optimal policy determination. The major policy implication is that is that the inflation should be kept at zero or close to zero in every possible state and in every time period.[46] Moreover, since various subsidies are available, this policy of strict price stability makes the flexible price allocation feasible and implementable.

[46] See Erceg et al. (2000), Khan et al (2000) and Woodford (2003a).

There are notable exceptions in the New-Keynesian literature that depart from the assumption of lump-sum tax and production subsidies availability initiated by Benigno and Woodford (2003) and followed by Schmitt-Grohe and Uribe (2004b). This departure requires in turn explicit consideration of fiscal policy consequences and provides valuable lessons for optimal policy conduct, in many ways different from the previous literature. More precisely and as detailed in the Chapter 1, it turns out that the optimal monetary policy features price stability even for a small degree of price rigidity, whereas the optimal fiscal policy should smooth out both tax rates and the outstanding debt.

However, the Walrasian labour market assumption and the related absence of the short-run inflation-unemployment trade-off still remains present. The search-matching framework seems a natural way to allow the Walrasian auctioneer to be replaced by a more realistic mechanism. But despite the long tradition and importance that the search-matching partial equilibrium models have in labour economics, there are very few, very recent attempts to incorporate their features in the general equilibrium New-Keynesian macroeconomics setup.

Moreover, most of the literature takes a normative approach and analyzes quantitative features of the incorporation of the matching mechanism in the standard New-Keynesian framework. To our knowledge there are only three papers which take the positive approach and analyze the effects of the matching externalities on optimal monetary policy conduct. Moreover, all of the papers follow the previously mentioned tradition and assume the availability of lump-sum taxes, thereby making their analysis moot with respect to optimal fiscal policy considerations. We aim at filling this gap evident in the literature.

In order to fulfill our objective, we construct a model in the New-Keynesian tradition which incorporates various distortions in the short and long run. More precisely, we maintain two key New-Keynesian ingredients by characterizing the goods market with imperfect competition and subjecting producers to costly price changes. But at the same time, we depart from mainstream New-Keynesian literature and replace Walrasian labour markets with a search-matching mechanism. In addition, we introduce fiscal policy explicitly into our analysis, which has been so far neglected in the few papers on New-Keynesian models featuring matching characteristics of labour markets.

Specifically we contribute to the existing literature in several ways. First, we differ from standard New-Keynesian literature by replacing Walrasian labour markets with a more realistic setup captured within the search-matching mechanism characterized by an instantaneous hiring process as recently proposed in Blanchard and Gali (2008). Second, we assume that all government revenues are collected by the use of distortionary means. In other words, we do not assume the availability of lump-sum tax instruments. This distinguishes our analysis from the existing New-Keynesian literature such as Trigari (2006), Krause and Lubik (2007b) and Faia (2009) in which the government budget constraint plays no explicit role for the policy analysis and can be therefore treated as a residual. This assumption leads in turn to an endogenous evolution of the tax rate and defines an environment where the monetary and fiscal policies to be pursued by the distinct branches of government are jointly determined in a coordinated fashion. In such a setup and as identified by New-Keynesian models of optimal monetary and fiscal policy, inflation plays a role in the satisfaction of the fiscal solvency requirements, whereas tax rate dynamics affect inflation through effects on marginal costs and markups.

Third, we abstract from the unrealistic assumption of production and employment subsidies initiated by Rotemberg and Woodford (1999b) and subsequently widely used in the literature. As is known from standard New-Keynesian models, the absence of subsidies used by policy makers to remove the distortions related to competition imperfections leads to deviations from the hypothetical steady state arising in first best economies. In our case, the presence of matching externalities introduces a new and additional source of inefficiency related to the deviation from the well known Hosios condition, which is absent from models with Walrasian labour markets. Specifically, we depart from the majority of literature and analyze optimal policies in the situation where the Hosios condition is not artificially imposed, thereby allowing the policy maker to correct for its absence. Moreover, by explicitly considering the government budget constraint, we find an additional source of inefficiency resulting from the presence of unemployment benefits. This inefficiency has been so far largely neglected because it was masked by the assumption of the availability of lump-sum taxes.

Fourth, we follow public finance literature approach in the spirit of Lucas and Stokey (1983) and Chari et al. (1991), recently applied also by Schmitt-Grohe and Uribe (2004b) and Siu (2004) within the New-Keynesian setup, and solve a constrained Ramsey problem which takes into account all of the constraints characterizing competitive equilibrium in addition to all of the wedges resulting from distortions inherent in the model economy. Thus we provide the positive aspects of the effects that search-matching externalities have on the policy maker's behavior. Our methodology is similar to the one employed by Faia (2009), but different from one employed by Thomas (2008) and Blanchard and Gali (2008), all of whom analyze optimal monetary policy in a model with matching frictions but ignore the fiscal aspects of the problem. Specifically, Thomas (2008) and Blanchard and Gali (2008) follow Rotemberg and Woodford (1999b) and Giannoni and Woodford (2003), and use linear-quadratic method based on first order approximations of the competitive equilibrium conditions and second order approximations of the agent's utility function. The peculiarity of this approach is that one needs to assume a non-distorted steady state around which the conditions will be approximated in order for the methodology to provide the correct welfare rankings of alternative policies. To fulfill this requirement they impose the Hosios efficiency condition by assuming the availability of hiring subsidies which will correct for the search externalities resulting from hiring costs and the congestion externalities arising when deviating from Hosios condition. Arguably, this assumption might be valid when the policy maker has lump-sum taxes at his disposal. However, in a more realistic setup with lump-sum taxes absent and the distortionary taxes present, this assumption can not easily be justified. Therefore, as already stated, we depart from assuming the availability of subsidies of any kind.

Before reporting the results, let us first summarize the inefficiencies present in our model. Broadly speaking, they can be divided into three main groups. The first group contains the inefficiencies resulting from monopolistic competition and the existence of producer price adjustment costs. As it is already known that distortions caused by imperfect competition lead to an output level which is below the efficient one, this calls for a mild deviation from strict price stability. In contrast, the second distortion arising from non-flexible price changes calls for strict price stability in order to close the gap between efficient and prevailing output. Thus, these two inefficiencies impose a nontrivial decision problem for the policy maker, who on one hand has an incentive to use unexpected inflation and on the other hand needs to close down an inflation gap that the policy maker has herself generated. The second set of distortions is the product of inefficient employment fluctuations arising from the presence of a matching mechanism and related congestion externalities which lead to the increase in labour market tightness. This important channel introduces an additional dimension to the trade-off that the policy maker faces. Thus, when search-matching frictions are present, the policy maker needs to make an optimal choice regarding the reduction in the costs stemming from costly price change, imperfect competition and the costs arising from inefficient unemployment fluctuations. Finally, the third set of inefficiencies is generated by distortionary taxation, or in other words by the absence of lump-sum taxes in addition to the presence of unemployment benefits.

We resort to numerical techniques to illustrate the dynamic implications of our setup. Specifically, we consider optimal policy responses in cases where the economy is hit either by a positive technological shock or by positive government spending shock. The main results can be summarized as follows. An increase in the technological level, which leads to an increase in consumption and employment, allows the Ramsey planner to reduce both inflation and the tax rate to fully exploit the benefits of productivity enhancement. This in turn leads to an increase in demand and increase in the firm's marginal profits, thereby boosting vacancy posting and increasing employment. Thus, by exploiting the effects of the unexpected inflation change, the Ramsey planner can correct for the inefficiencies generated by matching externalities. Therefore we find that, when search-matching frictions characterize the labour markets, the optimal policy is achieved by deviating from strict price stability. In other words, an optimal policy mix requires both inflation and tax rate to be volatile.

In addition, the presence of unemployment benefits and the expectational dynamic effects of tax rates on wages identify additional channels through which Ramsey planner can influence efficiency. First, by using taxes, the Ramsey Planner can directly reduce inefficiencies stemming from the presence of unemployment benefits. Second, tax changes affect the contemporaneous wage through its effect on both current and the expected future tax rates and thereby firms' marginal costs. We find that the presence of distortionary taxes allows the Ramsey planner to transfer part of the burden from using the inflation changes to tax changes, thereby making those two instruments complementary. In addition, we find that the optimal tax rate and the optimal level of real government liabilities inherit the time series properties of the underlying shock, which is in contrast to the results obtained in the standard New-Keynesian literature with sticky prices and Walrasian labour markets.

When the economy is hit by a positive government spending shock, optimality again requires volatility in both inflation and tax rates. However, under this shock, the optimal deviation from strict price stability is smaller than in the previous case. But, the tax rate and real government liabilities again inherit the time series properties of the underlying shock. Moreover, the fiscal as well as price setting distortions turn out to be more important than labour market inefficiencies.

We also find that the optimal policy responses under a positive productivity shock show a certain degree of overshooting in inflation and the tax rate. In contrast to this case, under a positive government spending shock, inflation and tax rate are characterized by undershooting occurring after several periods. This result is the consequence of the assumption of commitment in policy maker behavior, whereby the policy maker internalizes the current effects of its behavior on the agents' expectations regarding the future.

We organize the rest of the chapter as follows. In Section 4.1 we present the details of the model subsequently used to analyze dynamic properties of the optimal policy. Section 4.2 sets up the Social Planner problem and discusses the specific differences between our distorted economy and the socially optimal one. It also aims to provide additional intuition for the Ramsey optimal behavior derived later on. In Section 4.3 we formally set out the Ramsey problem and discuss the calibration issues in our model. Section 4.4 analyzes the dynamic properties of optimal policy responses and Section 4.5 concludes. In Appendix 4.A, we provide a detailed account of the derivations underlying our model, whereas the Appendix 4.B formally discusses the details of the numerical procedure employed to solve for the Ramsey steady state.

4.1 The Model

Our model economy follows the recent literature by incorporating search and matching frictions in the Mortensen and Pissarides (1999) tradition in an otherwise standard New Keynesian DSGE framework. More precisely, we postulate the existence of a continuum of infinitely lived agents of total measure normalized to one who make decisions each period regarding consumption and non-state contingent securities. As is standard in most of the search-matching literature, we abstract from labour participation decisions. In other words, we assume that labour is inelastically supplied, whereby each agent can either be employed or unemployed. This assumption can easily be justified on empirical grounds, since most empirical studies suggest small fluctuations over the participation margin at business cycle frequencies. In particular, Elsby, Michaels, and Solon (2009) argue that because the adjustments in the participation margin over business cycles are small abstracting from the intensive adjustment margin is a useful approximation which allows one to focus purely on labour market transition mechanisms. These arguments are widely used in the theoretical work as a justification of the fixed (over the business cycle) labour force assumption.

We also assume that existing jobs are destroyed at an exogenous rate and subject transitions into employment to search and matching frictions. As the search and matching externalities generate rents, the wage will be determined as a solution to a Nash bargaining problem. Firms are assumed to act as monopolistic competitors producing differentiated goods. To introduce a Keynesian spirit into the model and motivate the analysis of optimal monetary and fiscal policy, price setting decisions are assumed to be affected by the convex costs of price adjustment.

In this section we proceed by presenting the decision problems of the representative firm and representative household. Moreover, we provide full characterization of the wage determination problem via a Nash bargaining process as well as the decision problem of the government. We complete the section by defining the competitive equilibrium of our model economy.

4.1.1 Production and the Firm's Problem

The production sector of our economy is populated by a continuum of monopolistically competitive firms i each producing single variety of good whose measure is normalized to one. Before production commences and in order to hire workers necessary for production process, each firm must engage into the costly activity of vacancy openings. Following Rotemberg (2006) each firm is assumed to be large in the sense that it employs many workers who operate at different jobs indexed by j, in each individual firm. Each single variety of good i is produced using labour as the sole factor of production. Moreover in order to fill in the opened vacancies each firm must undertake a costly search activity in order to match vacancy with a particular worker. After matches are formed, firms and workers bargain over the pre-tax wage for every job j.

Based on our assumptions, we can write the total output in any job j within the monopolistically competitive firm i as

$$y_{i,j,t} = A_t \tag{4.1}$$

where A_t denotes an aggregate technology process to be specified later. For simplicity we will assume no heterogeneity among the employed workers with respect to their productive capabilities. This allows us to suppress indexation over subscript j and write the total aggregate output of a firm i as $y_{i,t} = A_t n_{i,t}$.

We also assume that each firm i employs in aggregate $n_{i,t}$ workers and posts $v_{i,t}$ vacancies every period. Following Blanchard and Gali (2008), Gertler, Sala and Trigari (2008) and Krause, Lubik and Lopez-Salido (2008) we will depart from the standard search-matching literature assumption of time-to-hire. Instead we will assume that the workers hired in period t start producing instantaneously. As argued by these aforementioned authors, the assumption of "instantenous-hiring" is better description of labour markets especially when prices are assumed to be sticky.

As in every search-matching model, the reduced form representation of the labour market frictions is captured by an aggregate matching function. Under the instantaneous hiring assumption general aggregate matching function is defined as $M_t \equiv m(u_t, v_t)$ where M_t denotes aggregate number of matches in period t, u_t is the number of period t unemployed and searching workers and v_t is the total number of posted vacancies given by $v_t = \int_0^1 v_{i,t} di$. As previously stated matches are destroyed exogenously at the rate ρ^x whereby we assume that this job destruction happens at the end of every period t. By normalizing the size of the labour force to one we also make u_t "before the separations" unemployment rate.

The matching function is assumed to satisfy standard properties; that is to be concave, continuously differentiable, homogenous of degree one and increasing in both of its arguments. Under the assumption of constant returns to scale two meeting rates, that is both the probability of a worker finding a job and a firm filling a vacancy will depend only on the labour market tightness which we denote by θ_t. We define as $\theta_t = \frac{v_t}{u_t}$. Assuming that each firm is sufficiently large, the probability of a firm filling a vacancy in the next period is given by:

$$q(\theta_t) = \frac{m(u_t, v_t)}{v_t} = m\left(\theta_t^{-1}, 1\right) \tag{4.2}$$

Similarly the probability of a worker finding a job next period is given by:

$$p(\theta_t) = \frac{m(u_t, v_t)}{u_t} = m\left(1, \theta_t\right) \tag{4.3}$$

Under our assumptions the probability of a firm filling a vacancy will be a decreasing $(q'(\theta_t) < 0)$, whereas probability of a worker finding a vacancy will be an increasing function of labour market tightness $(p'(\theta_t) > 0)$. Intuitively, the tighter the labour market is, the more likely a worker is to find a job, and less likely a firm is to fill in the vacancy. It is worthwhile noticing that both workers and firms take θ_t as given when making optimal decisions. Moreover, one should also notice that $p(\theta_t) = \theta_t q(\theta_t)$.

We can now define the law of motion for the firm's i workforce as

$$n_{i,t} = (1 - \rho^x)n_{i,t-1} + v_{i,t}q(\theta_t) \tag{4.4}$$

This law of motion implies that the number of workers employed in the firm i in period t equals the number of workers employed in period $t-1$ who did not exogenously separate in addition to the flow of new workers matched in period t.

Beside distortions arising from search-matching process, defining the crucial feature of our model economy, we subject the firms to the costly price adjustment. Stickiness in pricing behavior is modeled as in Rotemberg (1983). More precisely, we assume that firms face a quadratic costs when changing prices; defined as $\Theta_t = \frac{\Psi}{2}\left(\frac{P_{i,t}}{P_{i,t-1}} - 1\right)^2$, with parameter $\Psi \geqslant 0$ representing the degree of sluggishness in the price adjustment process. When $\Psi = 0$ price changes are costless and we are back in the situation of perfect price flexibility. We are fully aware that, by modelling price setting behavior as in Rotemberg (1983), as opposite to the widely used Calvo (1984) mechanism, price dispersion is absent. However, we opt for this setup since it implicitly assumes that consumers prefer series of small price changes over a single large price change. And it is this type of behavior which fits best the recent empirical evidence as reported in Chen et al. (2008).

When making optimal decisions, our representative firm i chooses number of vacancies to post $v_{i,t}$, current employment stock $n_{i,t}$ and prices $p_{i,t}$ in order to maximize the expected present discounted value of its future real profit stream taking as given wages, aggregate labour market conditions and consumers' demand for its differentiated product. Formally, our firm i solves the following optimization problem

$$\max_{\{n_{i,t},v_{i,t},P_{i,t}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} Q_{t,0} \left(\frac{P_{i,t}}{P_t} Y_{i,t} - w_{i,t} n_{i,t} - c^h v_{i,t} - \Theta_{i,t} \right) \tag{4.5}$$

subject to

$$Y_{it} = \left(\frac{p_{it}}{P_t} \right)^{-\epsilon} Y_t \tag{4.6}$$

$$n_{i,t} = (1 - \rho^x) n_{i,t-1} + v_{i,t} g(\theta_t) \tag{4.7}$$

where E_0 denotes a conditional expectation defined on all the available up to and including time $t = 0$, and $Q_{t,0} = \beta^t \frac{u'(c_t)}{u'(c_0)}$ represents the stochastic discount factor which firms use in order to discount its real payoffs. Notice also that this stochastic discount factor is period zero value of the firm's real profit flow to the representative family. The assumption of a diversified ownership in every firm i, which makes families the ultimate owners of the firms, explains why firms use this discount factor in order to discount its profits.

Let us substitute the individual demand solution (4.6) into (4.5), and denote respectively with $mc_{i,t}$ and $\mu_{i,t}$ the Lagrangian multipliers on the demand constraint and the employment law of motion. Then the first order conditions with respect to employment and vacancies read as

$$\mu_{i,t} = -w_{i,t} + mc_{i,t}A_t + \beta E_t\left[Q_{t+1,t}(1-\rho^x)\mu_{i,t+1}\right] \tag{4.8}$$

and

$$\frac{c^h}{g(\theta_t)} = \mu_{i,t} \tag{4.9}$$

By rearranging two previous equations we arrive at the standard search and matching job-creation condition

$$\frac{c^h}{g(\theta_t)} = -w_{i,t} + mc_{i,t}A_t + \beta E_t\left[Q_{t+1,t}(1-\rho^x)\frac{c^h}{g(\theta_{t+1})}\right] \tag{4.10}$$

where $Q_{t+1,t} = \beta\frac{u'(c_{t+1})}{u'(c_t)}$ is the profits discount factor between periods $t+1$ and t. This job creation condition implies that, by optimally choosing the number of vacancies to post and number of workers to employ, the expected cost of vacancy posting must be equated to the expected discounted value of the profits arising from marginal worker's match. As implied by the right-hand side of (4.10), profits contain both wage cost and marginal revenue product determining net earnings of the match on the margin, plus the asset value of the pre-existing employment relationships which represents adjustment costs savings.

Taking the derivative of the objective function (4.5) with respect to individual prices we obtain the following first order condition:

$$
\begin{aligned}
& (1-\nu)\left(\frac{P_{i,t}}{P_t}\right)^{1-\nu}\frac{1}{P_{i,t}}Y_t - \Psi\left(\frac{P_{i,t}}{P_{i,t-1}}-1\right)\frac{1}{P_{i,t-1}} + \nu\varepsilon_{i,t}\left(\frac{P_{i,t}}{P_t}\right)^{1-\nu}\frac{1}{P_{i,t}}Y_t \\
= & -\beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\Psi\left(\frac{P_{i,t+1}}{P_{i,t}}-1\right)\frac{P_{i,t+1}}{P_{i,t}}\frac{1}{P_{i,t}}\right] \qquad (4.11)
\end{aligned}
$$

Additionally, by assuming symmetry among the firms which allows us to set $P_t = P_{i,t}$ and defining inflation as $\pi_t = \frac{P_{i,t}}{Pi_{,t-1}}$, we can rewrite the first order condition for optimal price determination and obtain a non-linear expectational Phillips curve of the following form

$$
Y_t\left[(1-\nu)+\nu mc_t\right] = \Psi\left(\pi_t-\pi\right)\pi_t - \beta E_t\left[Q_{t+1,t}\Psi\left(\pi_{t+1}-\pi\right)\pi_{t+1}\right] \qquad (4.12)
$$

It is useful to point out, at this stage, the difference in markup solutions between the models featuring search-matching externalities and the markups usually obtained under the Walrasian labour markets assumption, first noticed by Krause and Lubik (2007b). In order to do so let us simplify the analysis and consider zero inflation situation which allows us to rewrite (4.12) and obtain the following expression for the marginal costs

$$
mc_t = \frac{w_t}{A_t} + \frac{\frac{c^h}{g(\theta_t)} - \beta E_t\left[Q_{t+1,t}(1-\rho^x)\frac{c^h}{g(\theta_{t+1})}\right]}{A_t} \qquad (4.13)
$$

There is an evident difference between this marginal cost solution and the one derived in the standard New Keynesian models with Walrasian labour markets. The first term in the marginal cost equation (4.13) represents the marginal (unit) cost of an employed worker and corresponds to the standard expression for the marginal cost obtained under Walrasian labour markets assumption. The second term on the right hand side is a direct consequence of the existence of long-term labour relationships in a search-matching setup; the matches formed today, if not destroyed, will also have a positive value tomorrow. Therefore, there are cost savings present, arising from the absence of the need to hire an additional worker next period. Thus, this second term on the RHS represents the difference between average vacancy posting costs and the cost-savings stemming from the long-term labour relationship. Moreover, these cost savings equivalently represent a present discounted value of the worker's future marginal contributions.

4.1.2 Households

We assume the existence of a continuum of infinitely lived identical households (families) on the unit interval living in our economy. Each household is populated by a large number of individuals who, as already stated, can either be employed or unemployed. In addition, we also assume that all of the unemployed individuals are actively searching for the job during their unemployment spell. In order to abstract from heterogeneity complications arising from the difference in the employment status of particular family members, we follow Merz (1995) and Andolfatto (1996) by assuming that family members perfectly insure each other against potential fluctuations in income. This perfect consumption insurance allows us then to analyze the behavior of the infinitely lived representative family.

Representative family is characterized by preferences defined solely over real consumption bundle denoted by c_t and described by a single period utility function $U(c_t)$. The utility function U is assumed to be continuous, strictly concave, twice continuously differentiable and strictly increasing in its argument. The consumption bundle is defined as the Dixit-Stiglitz CES aggregate of intermediate differentiated goods i

$$c_t = \left[\int_0^1 c_{it}^{\frac{\varepsilon - 1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon - 1}} \tag{4.14}$$

where $\varepsilon > 1$ denotes the elasticity of substitution

Besides making decisions regarding consumption, we allow families to invest but restrict investment opportunities to one-period state contingent nominal assets. Every unit of nominal asset pays a random amount D_{t+1} if in the period $t+1$ a particular state has occurred. Then the problem of the representative family is to choose the consumption and nominal assets sequences by maximizing the present discounted value of its future consumption stream

$$\max_{\{C_t, D_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t U(c_t) \tag{4.15}$$

subject to their budget constraint defined in real terms as

$$c_t + E_t r_{t+1} \frac{D_{t+1}}{P_t} = (1-\tau_t) w_t n_t + \frac{D_t}{P_t} + b(1-n_t) + \Pi_t \tag{4.16}$$

w_t stands for individual wage bill obtained by the employed representative family member and b is the individual unemployment benefit received by the unemployed family members u_t. τ_t is labour income tax paid by the employed workers and r_{t+1} is the period t price of one unit of currency delivered in particular state of period $t+1$ divided by the probability of that state's occurrence conditional on information available in period t. Π_t denotes aggregate profits received by the representative family based on their diversified ownership stake in the firms. In addition to the budget constraint (4.16) households must satisfy the constraint (4.17)

$$\lim_{j \to \infty} E_t p_{t+j+1} D_{t+j+1} \geqslant 0 \tag{4.17}$$

which prevents them from engaging in Ponzi schemes at all dates and in all states, where p_t denotes period zero price of one unit of currency delivered in a particular state in period

t, again divided by the probability of that state's occurrence conditional on information available at time zero. Formally, $p_t = \prod_{i=1}^{t} r_i$ and $p_0 \equiv 1$.

When optimizing, the representative family proceeds in two steps. First it determines the optimal demand schedules for every single type of differentiated product by minimizing the costs of bundle purchases

$$\min_{c_{it}} \int_0^1 p_{it} c_{it} di := P_t C_t \tag{4.18}$$

subject to

$$C_t = \left[\int_0^1 c_{it}^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{4.19}$$

which results in the standard demand function for the single product variety i given by:

$$c_{it} = \left(\frac{p_{it}}{P_t} \right)^{-\varepsilon} C_t \tag{4.20}$$

P_t denotes the aggregate price index such that expenditures are at the minimum possible level and is defined as:

$$P_t = \left[\int_0^1 p_{it}^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}} \tag{4.21}$$

Let λ_t denote the Lagrangian multiplier on the representative family budget constraint (4.16). The first order conditions of the household's optimization problem can then be written as:

$$U'(c_t) = \lambda_t \tag{4.22}$$

$$\frac{\lambda_t}{P_t} r_{t+1} = \beta \frac{\lambda_{t+1}}{P_{t+1}} \tag{4.23}$$

These two conditions can be combined in a single consumption Euler equation

$$U'(c_t) = \beta R_t E_t \left[\frac{U'(c_{t+1})}{\pi_{t+1}} \right] \tag{4.24}$$

which describes optimal intertemporal allocation of the consumption and also defines the asset pricing kernel or stochastic discount factor explained earlier in the text. In order to derive (4.24) we have used the fact that the $E_t r_{t+1}$ is the (average) price of the period-t asset paying one unit of currency in period $t+1$ in *every* state of the world. Therefore, $E_t r_{t+1}$ represents the inverse of the risk-free nominal interest rate R_t, which when substituted into (4.23) gives us (4.24).

4.1.3 Bellman Equations and Nash Bargaining

In what follows we define the value functions characterizing both the firm's and worker's decisions processes as well as the Nash bargaining problem of surplus sharing. A firm's marginal value of employment relationship at time t is defined by:

$$\mathbf{J}_t^e = mc_t A_t - w_t + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)\,\mathbf{J}_{t+1}^e \tag{4.25}$$

The first two terms on the LHS denote real revenues of the marginal worker whereas the rest represents the continuation value of the existing job. With probability ρ^x the existing job is destroyed and would therefore generate a zero value for the firm.

In similar fashion we can define the marginal value of a job for an employed worker as

$$\mathbf{W}_t^e = (1-\tau_t)w_t + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[(1-\rho^x)\,\mathbf{W}_{t+1}^e + \rho^x \mathbf{U}_{t+1}\right] \tag{4.26}$$

and the marginal value of unemployment for the same worker by

$$\mathbf{U}_t = b + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[\theta_{t+1} g(\theta_{t+1})\,(1-\rho^x)\,\mathbf{W}_{t+1}^e + (1-\theta_{t+1} g(\theta_{t+1})(1-\rho^x))\mathbf{U}_{t+1}\right] \tag{4.27}$$

Equation (4.26) implies that the marginal value of a job for the employed equals to the sum of the obtained wage and the continuation value. The continuation value is defined as the sum of the part representing the expected present discounted value of the continuation of the existing job, which occurs with the probability $(1-\rho^x)$, and the part that represents the discounted marginal value of becoming unemployed, which occurs with the probability ρ^x. The marginal value of unemployment equals the unemployment benefits plus the continuation value which is the sum of expected revenue from becoming employed, and the expected discounted revenue obtained if she remains unemployed.

Externalities inherent in the search-matching process imply that successful matches generate positive surplus relative to the continuation of the search process. This generated surplus requires the specification of the wage setting mechanism. We follow most of the literature and assume that the wages are determined by Nash bargaining (surplus sharing) between both the newly-hired as well as the existing workers and firms. It is important to stress that this bargained wage is taken as given by firms when making decisions regarding employment and vacancies. That might seem to be a strong assumption, especially when firms are assumed to be large. It might appear more natural to assume that large firms take the employment effects on wages into account when determining the same. And this would certainly be true in the cases where the wage is a function of the workers marginal product, which is the condition that holds within the Nash bargaining setup. But, it can easily be explained why the absence of the employment effect on bargained wages does not influence our results. The reason is that even if the firms believe they could manipulate wages by either over- or under-hiring, the constant returns to scale assumption and the consequent independence of workers marginal product from the total employment prevents them from doing so. In other words, although the holdup problems would be in principle present in the standard Mortensen-Pissarides setup with exogenous productivity, there is no lever at firms' disposal to strategically react to them. Additionally, as shown in Krause and Lubik (2007a), the effect of the intra-firm bargaining on the search-matching process is negligible. Thus, without loss of generality, we can deviate from the intra-firm bargaining process, assumed for example in Rotemberg (2006), and trade it for greater analytical convenience.

The presence of taxes slightly modifies the standard form of the Nash bargaining solution. In this case the problem of bargaining over wages in terms of Nash product maximization can be written as:

$$w_t(a_t) = \arg\max \left(\mathbf{W}_t^e(a_t) - \mathbf{U}_t\right)^{\eta} \left(\mathbf{J}_t^e(a_t) + D\right)^{1-\eta} \tag{4.28}$$

where $\mathbf{W}_t^e(a_t) - \mathbf{U}_t \equiv S_t^w$ is the workers, and $\mathbf{J}_t^e(a_t) \equiv S_t^f$ is the firms surplus from the match. We define $\eta \in (0,1)$ to be the share of the surplus going to the workers. Obviously in order for the match to be beneficial for both parties in the bargaining process, both surpluses must be positive, that is $S_t^w > 0$ and $S_t^f > 0$ must be satisfied. In this case the Nash bargaining problem admits a solution of the following form:[47]

$$S_t^w = \frac{\eta(1-\tau_t)}{(1-\eta)} S_t^f \tag{4.29}$$

[47] Detailed derivation are presented in Appendix 4.A at the end of this chapter.

Substituting for S_t^w and S_t^f into the sharing rule (4.29) we derive the equation for the real wage w_t given by:

$$\begin{aligned} w_t &= \eta mc_t A_t + b\frac{(1-\eta)}{(1-\tau_t)} \\ &+ \frac{\eta}{(1-\tau_t)}\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)\left[\tau_{t+1}-\tau_t+\theta_{t+1}g(\theta_{t+1})(1-\tau_{t+1})\right]\frac{c^h}{g(\theta_{t+1})} \end{aligned} \tag{4.30}$$

Several comments are useful in order to provide the intuition behind this wage solution. The first two terms of the bargained wage represents a convex combination of the total contemporaneous payment to a firm from a marginal employment relationship (marginal revenue product) and a minimum value obtained by the household in case of unemployment. The remaining terms are the consequence of the benefits arising from the long term employment relationship. More precisely, they capture forward looking aspects of those relationships which are naturally capitalized in the period t wage. One should also notice an additional important feature of our wage solution: the expectations of future wage taxes determine the current wage and it is precisely this feature of wage equation which is the novelty relative to the ones obtained in the standard Mortensen-Pissarides model. This effect of future taxes on current expectations generate dynamic effects on contemporaneous wages and provide an additional incentive to analyse the optimal monetary-fiscal policy mix.

4.1.4 The Government

To complete the model description we need to characterize the government's behavior. In every period the government generates exogenous stream of stochastic, unproductive public spending of the government's consumption bundle g_t.[48] As in the households case, the government consumption bundle is a Dixit-Stiglitz aggregate of intermediate goods g_{it} given by $g_t = \left(\int_0^1 g_{it}^{\frac{\varepsilon-1}{\varepsilon}} di\right)^{\frac{\varepsilon}{\varepsilon-1}}$. The demand for a single variety of the intermediate good i is obtained by solving cost minimization problem resulting in individual goods' demand functions given by $g_{it} = \left(\frac{p_{it}}{P_t}\right)^{-\varepsilon} g_t$. In addition to the unproductive spending, the government must finance the exogenous stream of unemployment benefits b per unemployed worker each period .

The total government expenditures are financed by levying the endogenous wage income tax at the rate τ_t and by issuing one-period state non-contingent nominal bonds denoted by B_t. This allows us to define the government budget constraint in real terms as:

$$\frac{B_t}{P_t} + \tau_t w_t n_t = R_{t-1}\frac{B_{t-1}}{P_t} + g_t + b(1-n_t) \tag{4.31}$$

It is important to point out the specifics of the search-matching model with endogenous taxation with respect to the treatment of the government budget constraint. In most of the New-Keynesian search-matching literature, the government budget constraint can be treated as a residual object due to the availability of lump-sum taxes which automatically

48 We do not maket government spending enter the utility function here. By doing this we do not imply that the government spending is truly wasteful, which is certainly not true. It is pure analytical convenience justified by the fact that our results would not be changed if the government spending entered additively in the utility function.

adjust as needed.[49] In that case unemployment benefits would enter the household budget constraint, but are excluded from the economy wide resource constraint. However, in our case, the inability of government to use lump-sum taxes prevents us from treating (or in other words ignoring) the government budget constraint as a residual object and requires a precise specification of the government budget constraint as well as the economy wide resource constraint. This is necessary since, in the Ramsey problem subsequently analyzed either the household or the government budget constraint, in addition to the aggregate resource constraint, enters as an optimisation object. Therefore, we assume that the benefit payments are simply the insurance transfers from the government to the unemployed. By introducing such assumption our setup is also in line with most of the standard literature on optimal monetary and fiscal policy.

4.1.5 Equilibrium

We are now ready to define an equilibrium. As already pointed out, we concentrate our analysis on symmetric equilibria. Aggregating the employment evolution conditions (4.7) over individual firms we can define aggregate employment as:

$$n_t = (1 - \rho^x) n_{t-1} + v_t g(\theta_t) \tag{4.32}$$

Since all of the families are alike, in equilibrium there will be no borrowing or lending between them. This in turn implies that all of the interest-bearing asset holdings by families

---

[49] See Krause and Lubik (2007b), Faia (2008, 2009) and Krause, Lubik and Lopez-Salido (2008) among others.

must be in the form of government issued bonds. Formally

$$D_t = R_{t-1} B_{t-1} \tag{4.33}$$

must hold at all dates and in every state of the world. Using the households budget constraint, the government budget constraint and firm's profit function we obtain aggregate demand which reads as:

$$Y_t^d = c_t + g_t + c^h v_t + \frac{\Psi}{2} (\pi_t - 1)^2 \tag{4.34}$$

whereas the aggregate supply is given by:

$$Y_t^s = n_t A_t \tag{4.35}$$

Since wages in our model are determined in a Nash bargaining process we refer to our equilibrium as a competitive bargaining equilibrium and define it as:

Definition 2 *Competitive bargaining equilibrium of a distorted competitive economy is list of stochastic processes for prices* $\{P_t\}_{t=0}^{\infty} = \{w_t, \pi_t\}$ *and quantities* $\{Q_t\}_{t=0}^{\infty} = \{\{Q_t^{FA}\}_{t=0}^{\infty}, \{Q_t^{FW}\}_{t=0}^{\infty}\}$ *where*

$$\{Q^{FA}\}_{t=0}^{\infty} = \{c_t, D_t\}_{t=0}^{\infty} \tag{4.36}$$

$$\{Q_t^{FW}\}_{t=0}^{\infty} = \{Y_t, n_t, v_t, mc_t\}_{t=0}^{\infty} \tag{4.37}$$

such that given the process for the nominal interest rate and taxes $\{R_t, \tau_t\}$*, exogenous process for* $\{A_t, g_t\}$ *and initial holdings* $R_{-1}B_{-1}$*, the following holds:*

(i) given sequences of prices $\{P_t\}_{t=0}^{\infty}$ *an allocation* $\{Q^{FA}\}_{t=0}^{\infty}$ *solves the household maximization problem (4.15) subject to (4.16) and (4.17)*

(ii) an allocation $\{n_t, v_t, mc_t\}_{t=0}^{\infty}$ *and price sequence* $\{\pi_t\}_{t=0}^{\infty}$ *solves the firms maximization problem (4.5) subject to (4.6) and (4.7) and satisfy (4.10) and (4.11).*

(iii) law of motion determining the number of employmed is given by (4.32).

(v) wages $\{w_t\}_{t=0}^{\infty}$ *are determined by Nash bargaining and satisfy (4.30).*

(vi) markets clear, (4.17), (4.33) and (4.31) hold and $Y_t^d = Y_t^s = Y_t$.

4.2 Social Planner's Problem

In order to gain some intuition for the optimal fiscal and monetary policy results and before proceeding to the analysis of the Ramsey problem, we will first analyze the conditions of the constrained-efficient allocation chosen by a benevolent Social Planner. As already described there are several distortions characterizing our model economy. Beside ones present in the standard New-Keynesian models, such as imperfect competition and costly price adjustment, we introduce distortionary proportional labour taxation and most importantly search-matching frictions. Those frictions together with distortionary labour taxation impose additional restrictions on the decentralized economy which to our knowledge have not been analyzed before in the literature on the optimal monetary and fiscal policy.[50]

Before formalizing the Social Planner's problem it is worth noticing the irrelevance of unemployment benefits for the efficiency conditions. This is because unemployment benefits do not enter the economy wide resource constraint, since they represent transfers between families and the government. In other words, efficiency is determined solely by

[50] Possible exceptions include Faia (2009) who ignores fiscal considerations; and Sanya and Chugh (2008) who ignore price adjustment costs but introduce "time to hire" assumption.

the characteristics of the preferences and technology and, under our assumptions, benefits characterize neither of them.[51]

Let us slightly simplify the analysis by abstracting from price adjustment costs and monopolistic competition distortions in order to concentrate on the labour markets mechanism. In this case Social Planner's problem can be stated as

$$\max_{\{c_t,n_t,v_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t u(c_t) \tag{4.38}$$

subject to aggregate resource constraint and employment evolution condition represented by following two equations

$$n_t A_t = c_t + g_t + c^h v_t \tag{4.39}$$

$$n_t = (1-\rho^x) n_{t-1} + M(u_t, v_t) \tag{4.40}$$

Let us denote with χ_t^1 and χ_t^2 Lagrangian multipliers on the previous two constraints. Then the following three equations represent the first order conditions for consumption, employment and vacancies

$$c_t{}^{-\sigma} = \chi_t^1 \tag{4.41}$$

$$\beta^t \left(A_t \chi_t^1 - b - \chi_t^2 \right) + \beta^{t+1} E_t \left[\chi_{t+1}^2 (1 - \rho^x + M_{t+1}^n ((1-(1-\rho^x) n_t), v_{t+1})) \right] = 0 \tag{4.42}$$

$$-\chi_t^1 c^h + \chi_t^2 M_t^v ((1-(1-\rho^x) n_{t-1}), v_t)) = 0 \tag{4.43}$$

[51] The same condition holds within the Walrasian labour markets setup.

where M_t^v and M_t^n denote the first derivatives of the aggregate matching function with respect to vacancies and employment. Motivated by the empirical studies summarized in Petrongolo and Pissarides (2001) we follow most of the search-matching literature and postulate the aggregate matching function to be of a Cobb-Douglas form:

$$m(u_t, v_t) = m u_t^{\epsilon} v_t^{1-\epsilon} \tag{4.44}$$

Here m represents the efficiency parameter of the matching technology and ϵ determines relative contribution of unemployment to the matching process (as well as the elasticity of the hazard rates with respect to the labour market tightness). Under the Cobb-Douglas assumption the following two expressions define M_t^v and M_t^n:

$$M_t^v = m(1-\xi)\theta_t^{-\xi}$$

$$M_t^n = -(1-\rho^x)\xi m \theta_t^{1-\xi}$$

Rearranging (4.42) and substituting for M_{t+1}^n, we get

$$A_t \chi_t^1 - b - \chi_t^2 + \beta(1-\rho^x) E_t \left[\chi_{t+1}^2 (1 - \xi m \theta_{t+1}^{1-\xi}) \right] = 0 \tag{4.45}$$

Using (4.43) and the definition of the matching function, the following interim condition emerges

$$\frac{c^h}{m} \theta_t^{\xi} = \frac{\chi_t^2}{\chi_t^1} (1-\xi) \tag{4.46}$$

By substituting (4.46) into (4.45) and rearranging we finally obtain the optimality condition (first best solution) for the Planner's problem in terms of the optimal evolution of labour market tightness

$$\frac{c^h}{m} \theta_t^{\xi} = (1-\xi) A_t + \beta(1-\rho^x) E_t \left(\frac{c_{t+1}}{c_t} \right)^{-\sigma} \left[\frac{c^h}{m} \theta_{t+1}^{\xi} (1 - \xi m \theta_{t+1}^{1-\xi}) \right] \tag{4.47}$$

We are now in position to determine the conditions which allow the decentralized solution to be supported as Pareto efficient one. Thus, we proceed by comparing the Social Planner solution for the evolution of the labour market tightness with the decentralized Nash bargaining solution. One can immediately notice that four necessary conditions emerge:

- marginal costs mc_t must be equal to one in all states and $\forall t$
- unemployment benefits must be set to zero
- proportional tax rate τ_t must be some positive constant in all states and $\forall t$
- bargaining power η must be equal to the elasticity of matching function ξ

There are several important point to notice. First, it is easy to see the equivalence between our first condition and the condition obtained under Walrasian labour markets in standard New-Keynesian models which renders perfect competition in both settings. Second, our last condition is equivalent to the Pareto efficiency condition obtained by Hosios (1990) in a partial equilibrium setting and in the absence of proportional taxation. However, the difference in the assumed labour market mechanism, as well as the addition of distortionary taxation, result in the two extra conditions which are absent from both the standard New-Keynesian models with Walrasian labour markets as well as from partial equilibrium search-matching models. Both of the conditions are a direct consequences of the search-matching framework with distortionary taxation.

Before proceeding, let us slightly depart from the rest of the analysis and point out an interesting result which arises in a situation of zero unemployment benefits and perfect competition, which shows, somewhat surprisingly, that the Ramsey planner is able to implement the socially efficient outcome with positive proportional wage tax. In what follows we will combine several simplifying assumptions in order to shed some light on the incentives imposed on the optimizing policy maker.

4.2.1 Socially Efficient Allocation and Proportional Labour Tax

As already said, let us consider the simple case where the economy is characterized by perfect competition. We will also assume that the Hosios condition is satisfied and abstract from the benefits otherwise accruing to the workers. In this setting and under positive government spending, the Ramsey Planner has only the labour wage tax as policy instrument at his disposal. Because of the assumed positive government spending, the wage income tax must be set at the rate different from zero. Yet, the Ramsey planner can still implement steady state socially-efficient allocation even with a positive labour tax. This result might come as a surprise, but it can easily be explained. The intuition behind this result lies in the way the Ramsey planner implements its policy. It is well known that a Ramsey planner will typically implement his policy by influencing the allocations by affecting the prices. Within our simplified setup real wage is the "price" to be manipulated in order to achieve the desired result. Therefore the question to be answered is how wages react to the changes in wage tax rate. This in turn provides the intuition behind our result.

By inspecting the steady state solution for the Nash bargained wage derived from (4.30) it is easy to see that, within our simplified setup, the steady state wage is independent of the labour income tax rate. On the other hand, the wage is crucial for determining the number of vacancies posted by firms, which in the case of invariance of the wage with respect the change in the tax rate implies independence of vacancies' margin on wage taxation. Furthermore, since labour supply by households is inelastic, no other decision is affected by the changes in tax rates. That implies that no allocation will be affected by the fact that labour income tax is non-zero positive number. In this case labour tax can be thought of as lump-sum labour levy which allows Ramsey to attain the first best solution even with positive wage tax rate.[52]

However the case of zero unemployment benefits is clearly unrealistic and empirically irrelevant one. Moreover, by introducing imperfect competition and sticky prices considerations even with endogenous time varying taxation the Ramsey planner will in general not be able to implement socially efficient outcome even if the Hosios condition is satisfied. In what follows we will concentrate on the case in which unemployment benefits are strictly positive and the economy is characterized by the all of the previously detailed distortions.

---

[52] The zero benefits assumption is crucial for the derivation of our previous result. Alternatively, one can think of zero benefits assumption as the situation which mimics the indifference between working and not working in the economy with perfect consumption insurance. In this case, that is if individuals are truly indifferent between working and not working, taxes will not affect steady state wage and or any other allocation. This in turn allows Ramsey planner to implement socially efficient allocation even with positive labour tax but conditional on the search-matching distortions being neutralized via the Hosios condition.

4.2.2 Policy Maker's Trade-Offs

Let us first consider the case where Ramsey planner is confronted with sticky prices but government spending is assumed to be absent and the Hosios conditions is satisfied. In this case the Social Planner achieves optimum by setting $\pi_t = 1$ at all times that is by following the policy of strict price stability. The reason that drives this behavior is simple. Price stickiness implies loss of real resources in the process of costly price adjustment and therefore the best thing policy maker can do is to prevent prices from changing.

However introducing fiscal considerations into the analysis changes the results. It is clear that policy maker faces a dynamic trade-off along several dimensions within our setup. First, as it is the standard case in the models with state non-contingent debt, the government would like to use unanticipated inflation as an non-distortionary tax on the financial wealth. By behaving in such way, the policy maker's need to vary distortionary taxes over the business cycle would be minimized. Furthermore, the presence of the monopolistic competition implies suboptimal level of production and demand and, as shown by Schmitt-Grohe and Uribe (2004a), provides additional motive for the policy maker to deviate from strict price stability. However, the abandonment of strict price stability would not be costless. The presence of price adjustment costs implies that the use of unanticipated inflation imposes an additional cost on the firms facing nominal rigidities. This in turn generates the standard trade-off between tax smoothing and price stability which is present both in the standard Walrasian setup as well as in under the search-matching mechanism.

As already stated the most important distinction between standard New Keynesian models used for the optimal monetary and fiscal policy analysis and the one presented in this paper is the replacement of Walrasian auctioneer with the matching technology. But, this departure from the standard setup, in addition to providing the more realistic description of labour markets, introduces additional distortions which are caused by the costly search-matching process. As previously shown, the presence of search-matching externalities generates deviations from the Pareto efficient outcome which are caused by the government financed unemployment benefits and the deviation from the well-known Hosios condition. Therefore, these inefficiencies (in addition to the ones caused by the imperfect competition and sticky price adjustment) introduce an additional dimension in the trade-off faced by policy maker choosing path of inflation and labour tax rates.

In order to gain some intuition on the specifics of particular trade-offs, let us first concentrate on the situation which arises in the case of deviation from Hosios efficiency condition. When the Hosios condition is not satisfied and the bargaining power is low, the firms profitability of forming a match is large. This induces excessive vacancy creation and the unemployment rate falls below the socially efficient level. In the opposite case, when the bargaining power is larger than the matching function elasticity, vacancy creation falls below socially efficient level which results in the unemployment rate above the Pareto efficient rate. And, as shown by Hosios, any deviation from the equality of bargaining power and the matching elasticity requires some kind of hiring subsidy in order to restore efficiency. If no hiring subsidy is available (which is the case in our model), both monetary policy through inflation and tax policy in hands of fiscal authority can be used in order to steer the economy towards socially efficient outcome.

The intuition for the effects of labour taxes can be provided by considering the steady state wage equation. In the steady state with positive unemployment benefits, even if the Hosios condition is satisfied, the firms are creating vacancies below the socially efficient level which implies that the extensive margin is inefficient. This costly vacancy creation crowds out private consumption which is the consequence of the imposed resource constraint. Furthermore, positive government spending financed via labour income tax leads to even bigger increase in the bargained wage which again lowers the steady state vacancy creation. In this case, the Ramsey planner would like to find the optimal mix of efficiency and government budget financing and has the incentive to create negative steady state inflation and to reduce the tax rate since this would increase demand and thereby profits and increase the number of vacancies created. But again the presence of sticky prices and monopolistic competition implies a trade-off for this kind of policy.

In a dynamic setting, the price change incentives of a Ramsey policy maker can be understood by forward solving equation representing the job creation condition (4.10) which yields

$$\frac{c^h}{g(\theta_t)} = \sum_{k=0}^{\infty} \left(\beta(1-\rho^x)\right)^k E_t Q_{t+k,t} \left(mc_{t+k} A_{t+k} - w_{t+k}\right) \tag{4.48}$$

As in the standard New-Keynesian model, the real leverage at the disposal of monetary policy is a result of imperfect competition and costly price adjustment process. Moreover it is known that the presence of monopolistic competition implies positive markup over marginal cost which generates the inefficiency since the marginal cost of good production is now below the marginal utility of consuming the same. Therefore, as pointed out by Mankiw (1990) and Romer (1993), if feasible policies exist it would be desirable to use them in order to expand aggregate economic activity. It is the price stickiness that provides the monetary policy with certain ability to alter the markup and thereby to expand or to contract the economic activity. In our setup, this mechanism will also allow monetary policy to affect labour market inefficiencies again by affecting the markup as well as marginal costs through the change in demand.

Conversely, by increasing inflation above zero the Ramsey planner would decrease demand and thereby profits. The reason is that, in the sticky prices setup, costly price adjustment makes the markup countercyclical. In other words, a decrease in the demand leads to a decrease in the marginal cost which, because of the slow price adjustment, increases the price markup and thereby reduces profits. By inspecting the equation (4.48) one can easily see that this would in turn lead to a reduction in the number of vacancy posted, an increase in the congestion externality and a reduction in inefficient employment level. In addition, the incentives for excessive use of inflation will certainly be dampened because of the costly price adjustment. This will contribute to the aforementioned policy trade-offs.

On the other hand fiscal policy impacts the decisions by directly affecting wages. By inspecting the wage equation (4.30) one should notice that the time-varying tax rate introduces an extra wedge in the bargaining process. This dynamic effect of the taxes on wages is the channel through which fiscal policy can affect and correct the inefficiencies in the labour market and as far as we know it is the channel that has yet not been analyzed in the literature. However in order to determine optimal responses of both monetary and fiscal policies in the presence of various shocks, as well as to explain which of the aforementioned channels dominate requires resorting to numerical techniques which we subsequently do.

Specific Monetary Policy Trade-Off in the Presence of Real Imperfections

Before proceeding to the numerical analysis is it worthwhile elaborating on the results first noticed by Faia (2009) regarding the trade-off facing monetary policy. It is widely known that the design of optimal monetary policy depends on the implementability of a flexible price allocation with constant mark-up in the presence of monopolistic competition. Most of the literature in the New Keynesian tradition concludes that it is optimal to set the deviation of the output gap and inflation from its flexible price level to zero. This holds under both technology and government spending shocks.[53] The necessary condition for this condition to hold is that flexible price allocation with constant markups is always implementable. which will indeed be the case in the presence of Walrasian labour markets and no cost-push shocks caused by *real imperfections*. However it is easy to show this condition can no longer be satisfied when search-matching frictions are present. In order to show impossibility of the implementation of the flexible price allocation with constant markup, let us compare the expectational Phillips curve under the assumption of Walrasian labour markets with the corresponding condition in the presence of search-matching externalities. Within the Walrasian labour markets assumption the Phillips curve is given

[53] For a textbook treatment of the optimal monetary policy issues see Gali (2008), and for more advanced exposition see Woodford (2003a).

by

$$(1-\nu)+\nu\frac{w_t}{A_t}-\Psi\left(\pi_t-\pi\right)\frac{\pi_t}{Y_t}+\beta E_t\left[Q_{t+1,t}\Psi\left(\pi_{t+1}-\pi\right)\pi_{t+1}\right]\frac{1}{Y_t}=0 \quad (4.49)$$

It is easy to see that if the monetary policy is following the rule of strict price stability at every date and in every state, the flexible price equilibrium with constant markup, which also coincides with the socially optimal one, will be implemented. In this case the wages move one to one with the corresponding move in the productivity implying no change in the marginal costs as well as no change in the average markup which coincides with the desired one.

Let us now consider the Phillips curve (4.12) derived under the assumption of search-matching labour markets and assume that the monetary policy is following the rule of strict price stability. By substituting job creation condition (4.10) into (4.12) and rearranging we get

$$\begin{aligned}&(1-\nu)+\nu\left(\frac{w_t}{A_t}+\frac{\frac{c^h}{g(\theta_t)}-\beta E_t\left[Q_{t+1,t}(1-\rho^x)\frac{c^h}{g(\theta_{t+1})}\right]}{A_t}\right)\\ =\;&\Psi\left(\pi_t-\pi\right)\frac{\pi_t}{Y_t}+\beta E_t\left[Q_{t+1,t}\Psi\left(\pi_{t+1}-\pi\right)\pi_{t+1}\right]\frac{1}{Y_t}\end{aligned} \quad (4.50)$$

where

$$mc_t=\frac{w_t}{A_t}+\frac{\frac{c^h}{g(\theta_t)}-\beta E_t\left[Q_{t+1,t}(1-\rho^x)\frac{c^h}{g(\theta_{t+1})}\right]}{A_t} \quad (4.51)$$

Comparing equation (4.50) with (4.49) it is easy to see that in the presence of search-matching externalities the policy maker following the rule of strict price stability can never implement flexible price allocation with constant markup. The reason lies in the fact that the future asset value of pre-existing employment relationships, which as already stated, represents the savings on the adjustment costs, makes the marginal cost variable in response to the changes in productivity. This in turn prevents the policy maker from implementing the flexible price allocation with constant markup. To gain additional intuition, let us suppose that A_t increases. From the job creation condition this change implies increase in the $\frac{c^h}{g(\theta_t)}$ which in turn leads to the increase in the second term on the RHS of the marginal cost equation (4.51) that is to overall increase in marginal costs. But this increase in marginal costs needs to be accompanied by the increased prices. Under quadratic price adjustment costs, firms prefer to smooth out the price changes over time, but inflation would still immediately rise implying that flexible price allocation is not feasible. This inherent variability of the marginal cost in the search-matching setup represents a real imperfection which is caused by a term equivalent to the time varying *endogenous* cost push shock. Moreover, it generates dynamic trade-off for the monetary policy between stabilizing prices and stabilizing employment.

4.3 The Ramsey Problem

We define optimal monetary and fiscal policy as the process for $\{R_t, \tau_t\}$ such that the choice of R_t and τ_t results in the competitive bargaining equilibrium associated with the highest level of utility for the representative family. In other words, it is the optimal policy determined by monetary and fiscal authority which jointly maximizes the present discounted value of representative family's utility, conditional on the constraints imposed by the competitive bargaining economy.

We conduct our analysis by using the "semi" primal approach in the spirit of Lucas and Stokey (1983). As pointed out by Schmitt-Grohe and Uribe (2004b), in a setup with sticky prices and state non-contingent debt (in contrast to the setup with either flexible price or the one with sticky prices and state contingent debt) it is no longer possible to reduce equilibrium conditions to a single period zero implementability constraint and feasibility constraint holding in every period.[54] This impossibility carries over to the setup with search-matching frictions and sticky prices which is also pointed out by Faia (2009). Thus we need to find a minimum number of constraints' describing a competitive bargaining equilibrium involving, in as much as possible, only a real allocation. It turns out that following set of constraints in addition to (4.22) and (4.23) is sufficient to fully describe competitive bargaining equilibrium

$$\begin{aligned}\frac{c^h}{g(\theta_t)} &= (1-\eta)mc_t A_t - b\frac{(1-\eta)}{(1-\tau_t)} \\ &+\beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1-\rho^x)\frac{c^h}{g(\theta_{t+1})}\left[1-\frac{\eta}{(1-\tau_t)}(\tau_{t+1}-\tau_t+\theta_{t+1}g(\theta_{t+1})(1-\tau_{t+1}))\right]\end{aligned} \tag{4.52}$$

$$Y_t\left[(1-\nu)+\nu mc_t\right] = \Psi\left(\pi_t-\pi\right)\pi_t - \beta E_t\left[Q_{t+1,t}\Psi\left(\pi_{t+1}-\pi\right)\pi_{t+1}\right] \tag{4.53}$$

$$n_t = (1-\rho^x)n_{t-1} + mu_t^{\xi}v_t^{1-\xi} \tag{4.54}$$

$$d_t = R_t\frac{d_{t-1}}{\pi_t} + R_t(s_t - T_t) \tag{4.55}$$

$$n_t A_t = c_t + g_t + c^h v_t + \frac{\Psi}{2}\left(\pi_t - 1\right)^2 \tag{4.56}$$

---

[54] For details see Schmitt-Grohe and Uribe (2004b).

The first equation determines the evolution of labour market tightness and it is obtained by substituting Nash bargained wage (4.30) into the job creation condition (4.10). The last equation determines the evolution of government liabilities and can be obtained by substituting $d_t = R_t \frac{B_t}{P_t}$, $s_t = g_t + b(1 - n_t)$ and $T_t = \tau_t w_t n_t$ into government budget constraint (4.31).

We can therefore define the Ramsey problem as the one to choose $\{c_t, \lambda_t, n_t, v_t, mc_t, \pi_t, R_t, \tau_t, l_t\}_{t=0}^{\infty}$ that maximize $E_0 \sum_{t=0}^{\infty} \beta^t U(c_t)$, subject to (4.22), (4.23), (4.52), (4.53), (4.54), (4.55) and (4.56), taking as given $\{g_t, A_t\}_{t=0}^{\infty}$ and values of the choice variables listed above dated $t < 0$, and values of the Lagrange multipliers associated with the above constraints dated $t < 0$. In order to derive this reduced system we first eliminate the wage from (4.56) by using (4.30) and then cast θ_t in terms of n_{t-1} and v_t only by substituting for the relationship between labour market tightness and employment as well as for the relationship between employment and unemployment. Those two relationships are given by $\theta_t = \frac{v_t}{u_t}$ and $u_t = 1 - (1 - \rho^x) n_{t-1}$ respectively. In this way we eliminate θ_t and u_t and rewrite the problem solely in terms of n_t and v_t. However we deliberately leave the interest rate R_t and the tax rate τ_t as Ramsey choice variables and thereby depart from the pure primal approach which casts the Ramsey problem solely in terms of quantities. We name our specification "semi" primal because of mixing the allocation and policy variables as Ramsey choices.

It is known that Ramsey problem will be time inconsistent in general. We solve the problem of time inconsistency by following most of the literature and assume that the government has the ability to fully commit to the state contingent plans announced at date

$t = 0$. Moreover, our formal definition of the Ramsey problem implies an assumption that the government has been operating for an infinite number of periods in the past. This in turn implies that the government is honoring its past promises when making optimal decisions, which is referred in the literature as "timeless-perspective" optimality, first introduced by Woodford (2003). In addition, we assume also that the first order conditions of the Ramsey problem are necessary and sufficient and that all of the allocations are in the interior of the feasible set.

4.4 Functional Forms and Calibration

As it is standard in most of the New-Keynesian literature we parameterize per period utility function to be of CRRA form which is given by

$$U(c_t) = \frac{c_t^{1-\sigma} - 1}{1 - \sigma} \tag{4.57}$$

where σ determines the curvature of the utility function and also defines the coefficient of relative risk aversion. Following most of the real business cycles literature we set this parameter to 2.

The employment rate is calibrated to 0.9 which falls well within the range of values used in the search-matching literature. Following den Haan et al. (2000) we set firms matching rate to 0.7 and the exogenous probability of job destruction to 0.1. Motivated by the empirical work surveyed by Petrongolo and Pissarides (2001) we set the matching elasticity with respect to unemployment to 0.4. Using the definition of the matching function, and the condition determining number of searching workers, we can obtain expression for the steady state number of matches. This allows us to derive the expression for the value of the search efficiency parameter m and the expression for the labour market tightness calibration which are given respectively by:

$$m = \left(\rho^x \frac{n}{u}\right)^{\xi} (q(\theta))^{1-\xi} \text{ and } \theta = \left(\frac{m}{q(\theta)}\right)^{\frac{1}{\xi}} \tag{4.58}$$

In calibrating the model we deliberately deviate from the assumption of Hosios efficiency in order to confront the policy maker with labour market distortions as previously explained and set the value of bargaining power to 0.6.

Following Schmitt-Grohe and Uribe (2004) we assume that the deterministic steady state of our competitive economy is characterized by the inflation rate of 4.2% which is the average growth rate of U.S. GDP deflator between $1960 - 2008$. We calibrate annual interest rate at 4% which results in the subjective discount factor β of 0.9902. Moreover we postulate the steady state value for the markup of prices over the marginal cost to be 10%, which implies the value of the constant elasticity of substitution parameter ε of 11.

The steady state value of government spending share in GDP is set to 17% which is in line with most of the literature on optimal monetary and fiscal policy. We also assume that all of the government revenues are collected from wage taxation. Moreover we deviate from the simplifying assumption of balanced budget widely used in the literature and assume the steady state of government debt to GDP to be 44%. This number is in line with the U.S. empirical facts and widely used across most of the literature. Using the steady state version of (4.31) we can calibrate the steady state value of government receipts. We also normalize the steady state value of technology to one.

We are left with three additional parameters to calibrate which are the value of vacancy posting costs, unemployment benefits and the steady state wage tax rate. In order to calibrate those parameters we postulate the value of unemployment benefits to be 40% of the steady state wage. This value is in line with empirical observations by Shimer (2005) and Hall (2003). We proceed by solving the three equation system determined by (4.30), (4.52) and the steady state version of expression for fiscal revenues and obtain the values required for calibration.

Exogenous processes for the government spending g_t and aggregate productivity are assumed to evolve according to univariate autoregressive process given respectively by:

$$\log(g_t) = (1 - \rho_G)\log(g_{ss}) + \rho_G \log(g_{t-1}) + \varepsilon_t^G \tag{4.59}$$

and

$$\log(A_t) = (1 - \rho_A)\log(A_{ss}) + \rho_A \log(A_{t-1}) + \varepsilon_t^A \tag{4.60}$$

where ε_t^G and ε_t^A are iid shocks with standard deviations σ_t^G and σ_t^A. Following the estimation by Lambertini et al. (2007) we set the value of autoregressive coefficient for the government spending process to 0.9 and for the technology progress to 0.88. Standard deviations of ε_t^G and ε_t^A are set to 0.016 and 0.0064. Time unit is assumed to be a quarter.

4.4.1 Dynamic Responses of Optimal Policies

To analyze the optimal behavior of the government benevolent in the Ramsey sense we examine the optimal responses of both monetary and fiscal policy instruments when subjected to neutral technology as well as to government expenditure shocks. Following Schmitt-Grohe and Uribe (2005), we define the Ramsey equilibrium as an equilibrium that maximizes lifetime utility of the representative family with respect to the competitive equilibrium constraints, as detailed in the section describing the Ramsey problem. We should point out that the difference between our equilibrium definition and the standard Ramsey equilibrium is purely technical. Under the standard Ramsey equilibrium definition, the optimality conditions in the first period are different from the ones in the subsequent periods. In our case and under the "timeless-perspective" assumption, the structure of optimality conditions is time invariant.

In order to obtain the dynamic responses of the Ramsey policies we solve for the first order conditions of the Ramsey problem using MATLAB's symbolic solver and compute second order approximation of the conditions obtained around the Ramsey steady state.[55] We define the Ramsey steady state as long run (stationary) allocation that characterizes the non-stochastic steady state of the Ramsey's first order conditions.

Let us first consider dynamic responses of the optimal policy to the 1% positive technology shock. Impulse responses of the selected variables are showed in Figure 4.1. As can be seen from this figure, positive increase in the productivity leads to the increase in both consumption and employment. This allows a Ramsey benevolent government to reduce inflation as well as the wage tax rate and thereby fully exploit the benefits of the productivity increase. As previously explained, the inefficiencies resulting from the search-matching process imply a natural trade-off between inflation, tax stabilization and inefficient employment fluctuations. Under the positive productivity shock, reduction in the inefficient employment fluctuation can be accommodated easily by this improved productivity. It is

[55] We use perturbation algorithm developed by Schmitt-Grohe and Uribe (2004c). The details of the numerical procedure used to obtain the Ramsey steady state can be found in Appendix 4.B.

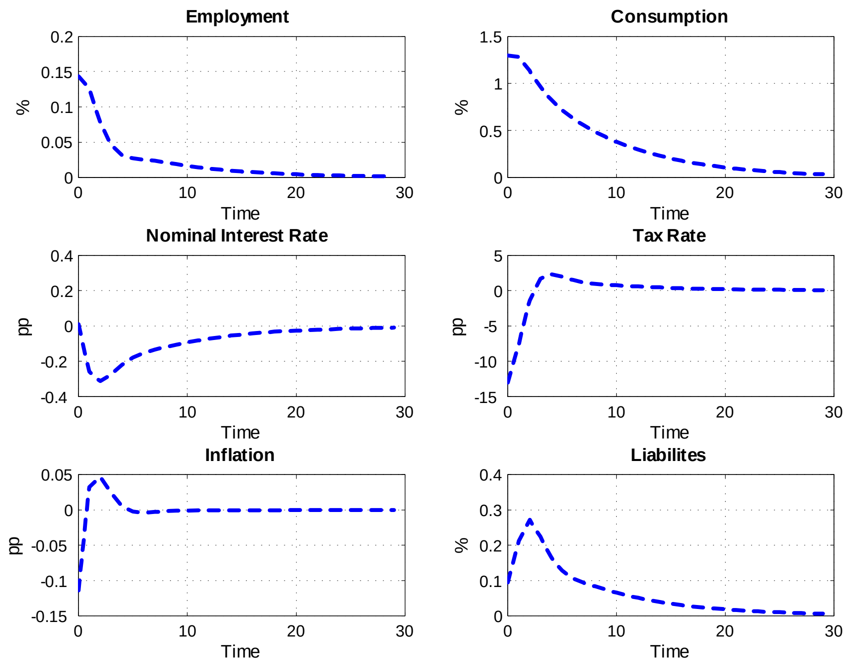


Fig. 4.1. Impulse responses of selected variables to a 1% positive productivity shock. All variables except the interest rate, the tax rate and the inflation are expressed as a percentage deviation from the Ramsey steady state. The interest rate, the tax rate and the inflation rate are expresed in terms of percentage points.

therefore reasonable for the policy maker to reduce inflation and wage tax rate in order to boost the consumption and thereby increase aggregate demand. Given sticky prices, this would lead to an increase in marginal costs and a decrease in the markup. Moreover marginal profits increase and labour demand increases. It is worthwhile emphasizing that employment volatility would not sub-optimal in our setting since the family members are fully insured against changes in employment status. It turns out that the price volatility is also not sub-optimal. The explanation for this result is pretty simple, and one can easily see the similarity of this result to the corresponding result which arrises in the standard New-Keynesian model with exogenous cost push shocks. It is a pure consequence of the search-matching imperfections which introduce endogenous real cost push shock into the expression for marginal cost, making the marginal cost, and thereby optimal inflation, time varying.

Moreover, introducing the fiscal policy into the story provides two additional reasons for the policy maker to deviate from strict price stability. Firstly, as already pointed out, the inability to issue nominal state contingent claims, as well as the absence of lump-sum taxes, makes the use of the unexpected inflation as an implicit lump-sum tax on privately held government debt particularly attractive for the policy maker. Secondly, the presence of unemployment benefits as a rent accruing to the families, and the absence of the direct instrument to tax these transfers, induces the Ramsey planner again to use inflation as an implicit lump-sum tax. All of those distortions call for volatile inflation when considered separately. In the model with matching frictions this turns out to be true even when considering these distortions jointly. More precisely, and somewhat in contrast to

New-Keynesian literature on optimal monetary and fiscal policy, the presence of matching frictions calls for inflation volatility by optimal policy maker. This result is more in line with the flexible price case optimal policy recommendations.[56] However, under plausible parameter calibration it turns out that the optimal policy in our setup calls for volatile wage taxes which now contrasts the flexible price literature where the inflation takes the role of a shock absorber of unexpected innovations in fiscal deficit. In addition, the optimal policy requires larger tax response to the positive productivity shock then is the response of real government liabilities which implies greater role of tax rate as a fiscal shock absorbers relative to the liabilities.

Let us provide more intuition behind this results. As already noted, we can calibrate our model such that the workers bargaining power is above social planner efficient condition which implies low producers incentive to post vacancies. In this case the unemployment rate is above Pareto efficient one, and as already explained the presence of unemployment benefits implies an even greater deviation from Pareto efficient employment. Since the policy maker has two instruments at its disposal, the inefficient unemployment fluctuations can be offset by using both inflation and wage tax. But the use of inflation is not without its costs, whereas there is no direct real cost of using taxes. It turns out that regardless of the costly inflation change it still pays the Ramsey planner not to give up the inflation instrument completely, but to combine the use of both unexpected inflation and tax rate deviation in order to dampen the inefficient employment fluctuations. Neverthe-

[56] For the analysis within a New-Keynesian paradigm see Goodfriend and King (2001) and Schmitt-Grohe and Uribe (2004a,b and 2005) among others; and for the RBC flexible price optimal monetary and fiscal policy analysis see Chari et. al. (1991).

less, this reduction in inefficient unemployment fluctuations, together with lower interest rates and the deflation induced, leads to a higher level of real government liabilities. In other words, the reduction in the tax rate in addition to the deflation actually boosts the real value of government liabilities.

Why is it then optimal to reduce tax rate in response to positive productivity shock? Again, the Ramsey planner wants to take full advantage of technological improvement and the reduction in the tax rate has the same implication on marginal costs as inflation. By reducing tax rates the policy maker reduces the inefficiencies generated by the presence of unemployment benefits and induces the firms to increase vacancy posting and thereby employment. This in turn leads to an increase in marginal costs and a decrease in markup. The reduction in tax rates is financed by the increase in the real government liabilities which allows policy maker to reduce the inflation change (as well as inflation costs) needed to reduce the inefficiency generated by the search-matching friction. In other words reduction in tax rate offsets the part of the deflation burden the policy maker would need to undertake in the absence of this instrument. In short, the optimal policy mix requires the use of both deflation and decrease in the tax rate in response to the positive neutral technological shock thereby making deflation and reduction in the tax rate complementary.

It is important to notice the overshooting of both inflation and tax rate, with the tax rate overshooting happening later then the inflation. This is the result to be expected for the policy maker that acts under commitment. The explanation is that under commitment the policy maker is taking into account its ability to influence future expectation. Thus, by overshooting the planner is compensating for the initial changes thereby internalizing the

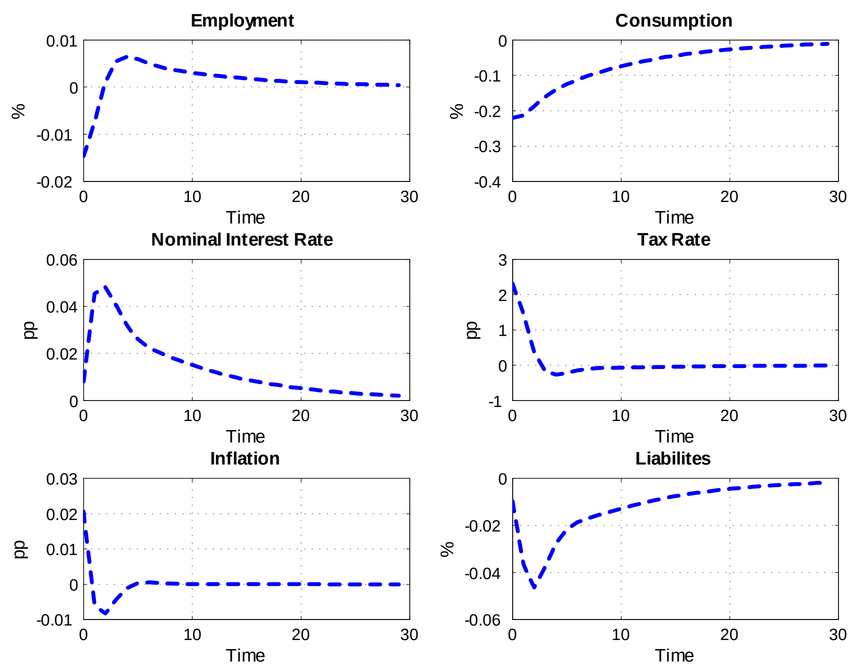


Fig. 4.2. Impulse responses of selected variables to a 1% positive government spending shock. All variables except the interest rate, the tax rate and the inflation rate are expressed as a percentage deviation from the Ramsey steady state. The interest rate, the tax rate and the inflation rate are expresed in terms of percentage points.

effect of its policies on the future paths of available instruments. Additionally, one should notice that our results contrast the New-Keynesian optimal policy literature with respect to the time series properties of both taxes and government debt. In our case neither tax nor public liabilities smoothing is optimal. In other words, neither of variables is characterized by a near random walk behavior. The intuition behind this result lies in the inelastic labour supply assumption. Under this assumption taxes are distortionary only to the producers since they affect the wages and thereby incentive to post vacancies, whereas the families decisions on labour supply are invariant to the changes in tax rate.

Figure 4.2 presents the optimal dynamics of the variables of interest under the 1% positive government spending shock. We can see that the unexpected increase in the government spending has an opposite effect on all of the variables of interest. Namely, employment, consumption and real liabilities now decrease, implying crowing out of private by government consumption. In contrast to the optimal policy following unexpected technology change, the policy maker now increases both inflation and wage tax rate. Moreover, the optimal behaviour is again somewhat in contrast to the prediction of the New-Keynesian literature with Walrasian labour markets. More precisely, perfect price stability is again sub-optimal as is tax smoothing as well. However, the optimal deviation from price stability in this case is much smaller than under an unexpected technology shock of comparable size, which is in line with the standard New-Keynesian literature. In our setup the tax increase and the deviation from price stability induce a fall in the value of real government liabilities. The reason is that the increase in taxes reduces the burden of newly issued liabilities and by deviating from price stability the Ramsey planner is inflating away the part of the real value of government outstanding debt. In other words, despite the costly price change, an optimal policy maker would find it optimal to inflate away the part of real government liabilities and would be helped in doing so by the increase in tax rate. It turns out therefore that under an government spending shock, the fiscal with price adjustment distortions taken together are larger then the ones induced by the search-matching inefficiencies.

Simple Implementable. Policy Rules

The outcomes of the Ramsey-type welfare-maximizing framework are important theoretical constructs, but they remain silent on the issue of what policy regime can implement them. Specifically, the solution of the Ramsey problem provides information only about the equilibrium behavior of the policy variables such as inflation, tax rates or interest rates which is of limited practical relevance for the real world policy maker. As pointed out by Schmitt-Grohe and Uribe (2007), the fact that the Ramsey equilibrium processes for the policy variables are function of all of the state variables and exogenous driving forces imposes serious problems for the practical monetary and fiscal policy conduct for at least two reasons. First, it is extremely difficult to extract the information regarding the state of those variables. Second, even if the policy maker had all of the information needed regarding the state of the economy, using the equilibrium processes of the policy variables to define a policy regime would not guarantee a Ramsey outcome as the competitive equilibrium, since such a regime can lead to equilibrium multiplicity.

It would be outside the scope of this chapter to resolve this implementability issue, but it is useful to compare the implications of the Ramsey plan with the simple implementable rules approximating real world policy conduct. Therefore, in this section we contrast the Ramsey policy with simple interest rate and tax rate rules whose simplicity lies in the fact that everything that is required by policy maker in order to implement them is contained in the information provided by several observable macroeconomic variables. We follow most of the literature to specify the Taylor type interest rate rule of the following form:

$$\log(\frac{R_t}{R^*}) = \phi_\pi \log(\frac{\pi_t}{\pi^*}) + \phi_y \log(\frac{y_t}{y^*}) \tag{4.61}$$

A simple fiscal rule following Schmitt-Grohe and Uribe (2007) and Chadha and Nolan (2007) can be written as:

$$T_t = T^* + \varkappa(d_{t-1} - d^*) \tag{4.62}$$

Superscript * denotes the Ramsey steady state value of the respective variable, whereas ϕ_π, ϕ_y and $\varkappa$ represent the response parameters. According to this interest rate rule, monetary policy adjusts the nominal interest rate in response to a log deviation of inflation and output from their respective Ramsey steady state values. Fiscal policy reacts by adjusting the tax revenues in response to a deviation of the real value of government liabilities from its Ramsey steady state. Based on the large empirical evidence showing that many central banks follow the policy of strong inflation targeting we set $\phi_\pi = 3$. Following Rotemberg and Woodford (1999b) ϕ_y is set to 0.125. Furthermore, we set $\varkappa$ to 0.5 which implies that in each period 50% of the real liabilities deviation is accommodated by the tax revenue change and insures that the real liabilities grow at the rate lower then the real interest rate.

Figure 4.3 shows the impulse responses of selected variable to a 1% neutral technology shock. Several observations are worthwhile pointing out. First, optimal Ramsey policy implies lower volatility of employment, interest rate and inflation but larger volatility of consumption relative to two other policy regimes. These results are consistent with Faia (2009) in a model with absent fiscal policy and are the consequence of the inflation-unemployment trade off. Second, the simple policy rule implies almost no volatility of the tax rate, whereas the Ramsey plan is characterized by significant volatil-

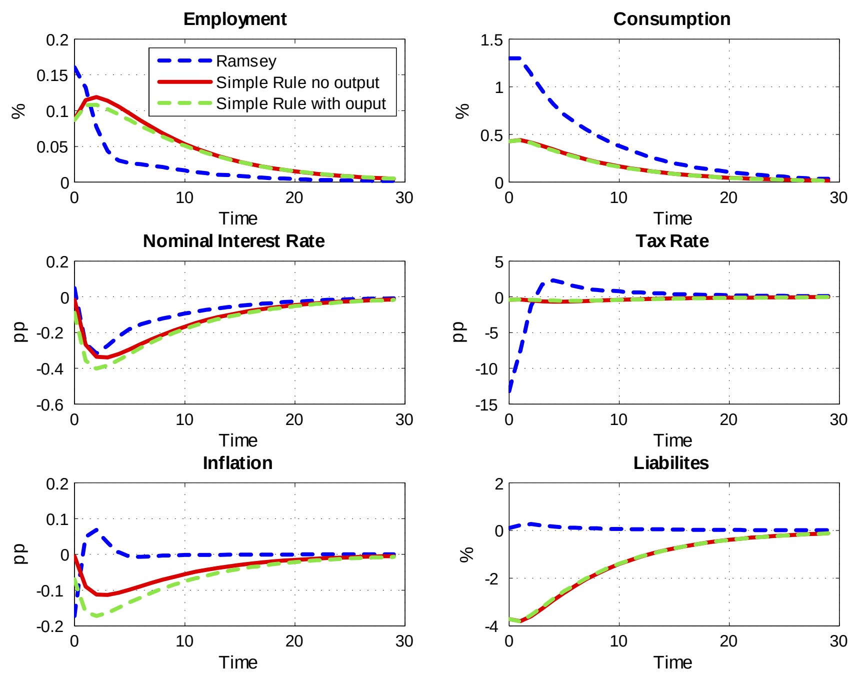


Fig. 4.3. Impulse responses of selected variables to a 1% positive productivity shock. All variables except the interest rate, the tax rate and the inflation rate are expressed as a percentage deviation from the Ramsey steady state. The interest rate, the tax rate and the inflation rate are expresed in terms of percentage points.

ity of the same. Moreover, in contrast to the Ramsey plan, the real level of government liabilities reacts strongly when simple policy rules are used. Somewhat similar results are obtained by Schmitt-Grohe and Uribe (2005) in the standard New-Keynesian setup. The non-responsiveness of the tax rate is the consequence of the expected increase in output which implies increase in the expected tax revenues. Inflation falls in order to support the increase in the consumption which translates into the fall of nominal interest rate. The decrease in the nominal interest rate and the inflation together with negligible response of the tax rate imply significant fall in the real level of government liabilities. The difference in responses between Ramsey plan and the simple rules is generated by the fact that the policy maker employing the simple rules react only to the subset of endogenous variables, while the Ramsey planner takes into account all of the endogenous variables plus the shocks. As a consequence, the Ramsey planner uses the tax volatility in addition to the inflation volatility in order to fully exploit the increase in productivity as well as to mitigate the inefficient employment fluctuations. Third, the overshooting effect is absent. This is so since the simple rules do not take into account the future effects of the current policy moves.

Figure 4.4 shows the impulse responses of selected variables to a 1% government spending shocks. Following a 1% positive increase in government spending the volatility of inflation and employment is again larger under simple rules relative to the Ramsey case, while the consumption volatility is smaller. Moreover, the response of the tax rate is again negligible while the liabilities reaction is large. Inflation goes up, as it is typical in response to the positive demand shock which in turn increases the interest rate. Larger

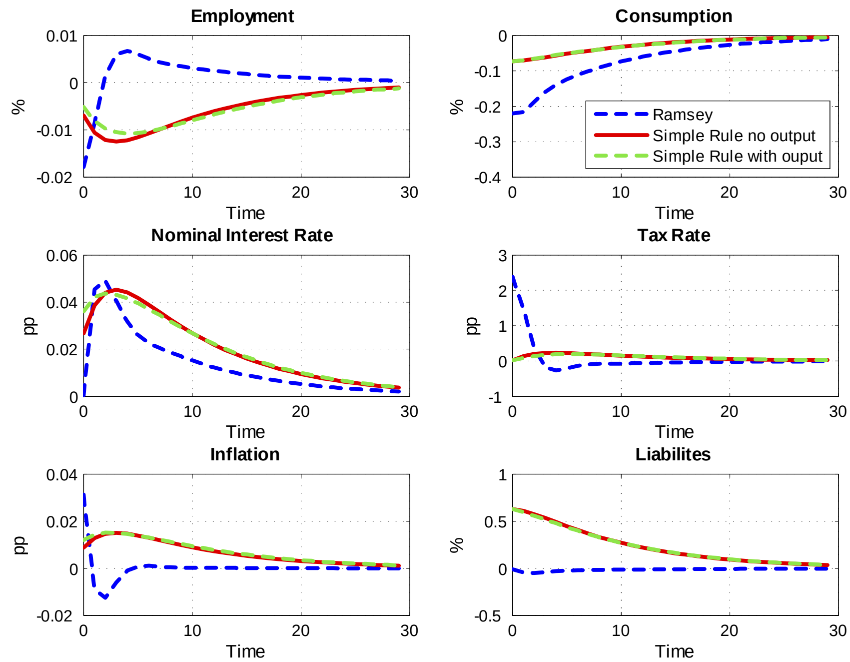


Fig. 4.4. Impulse responses of selected variables to a 1% positive government spending shock. All variables except the interest rate, the tax rate and the inflation rate are expressed as a percentage deviation from the Ramsey steady state. The interest rate, the tax rate and the inflation rate are expresed in terms of percentage points.

response of the interest rate relative to the inflation in addition to negligible response of the tax rate leads to the increase in the real level of government liabilities. We can conclude that in this case, same as it was under positive productivity shock, the difference between the Ramsey plan and the simple rules lies in the fact that simple rules do not react to all of the endogenous variables and the shocks. This in turn partially ignores the inefficient unemployment fluctuations as well as the future effects of the current policy.

4.5 Concluding Remarks

In this chapter we have analyzed optimal monetary and fiscal policy in the New-Keynesian model with monopolistic competition, sticky prices, distortionary wage taxation and labour markets characterized by the search-matching frictions. In order to analyze the optimal policy maker's behavior we follow public finance approach used in the New-Keynesian literature, and construct a constrained Ramsey problem. Dynamic properties of the optimal responses are obtained by numerically solving for the equilibrium conditions under commitment. We find that, when search-matching frictions are present neither perfect price stability nor tax smoothing is optimal, though the required degree of deviation from price stability is reduced with a fiscal policy in hands of the policy maker, since deflation and tax reduction act as complements.

All of those results stand in contrast to the proposals in the New-Keynesian literature where the optimal policy maker's behavior requires either strict price stability or negligible deviations from it, as well as tax smoothing. Deviation from strict price stability is more in line with the flexible price perfect competition RBC optimal policy analysis, whereas the tax volatility stands in contrast to both of the approaches. Moreover, we find a certain degree of inflation and tax overshooting or undershooting, depending on the type of shock considered. This is a consequence of the assumed commitment in the policy maker's behavior which allows him to internalize the effects of his current actions on the future expectations.

4.A Appendix A to Chapter 4

4.A.1 The Firm's Profit Maximisation Problem

The Lagrangian for the firm's profit maximization is given by:

$$\begin{aligned} L \;=\; & \max_{\{n_{i,t}, v_{i,r}, P_{i,t}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left\{ \frac{P_{i,t}}{P_t} Y_{i,t} - w_{i,t} - c^h v_{i,t} - \Theta_t \right. \\ & \left. + mc_{i,t} \left[n_{i,t} A_t - \left(\frac{P_{i,t}}{P_t} \right)^{-\nu} Y_t \right] + \mu_{i,t} \left[(1-\rho^x) n_{i,t-1} + v_{i,t} g(\theta_t) - n_{i,t} \right] \right\} \end{aligned} \tag{4.A.1}$$

such that

$$Y_{i,t} = \left(\frac{P_{i,t}}{P_t} \right)^{-\nu} Y_t \tag{4.A.2}$$

$$\Theta_t = \frac{\Psi}{2} \left(\frac{P_{i,t}}{P_{i,t-1}} - \pi \right)^2 \tag{4.A.3}$$

The first order conditions of the above problem with respect to $\{n_{i,t}, v_{i,t}, P_{i,t}\}$ read as follows:

$$\frac{\partial L}{\partial n_{i,t}} = 0 \Rightarrow$$

$$-\beta^t \frac{\lambda_t}{\lambda_0} w_t + \beta^t mc_{i,t} \frac{\lambda_t}{\lambda_0} A_t - \beta^t \frac{\lambda_t}{\lambda_0} \mu_{i,t} + \beta^{t+1} E_t \left[\frac{\lambda_{t+1}}{\lambda_0} (1-\rho^x) \mu_{i,t+1} \right] \tag{4.A.4}$$

$$\frac{\partial L}{\partial v_{i,t}} = 0 \Rightarrow$$

$$-\beta^t \frac{\lambda_t}{\lambda_0} c^h + \beta^t g(\theta_t)\mu_{i,t} = 0 \tag{4.A.5}$$

$$\frac{\partial L}{\partial P_{i,t}} = 0 \Rightarrow$$

$$\begin{aligned} & \beta^t \frac{\lambda_t}{\lambda_0}\left[(1-\nu)(P_{i,t})^{-\nu}(P_t)^{-(1-\nu)}Y_t - \Psi\left(\frac{P_{i,t}}{P_{i,t-1}}-\pi\right)\frac{1}{P_{i,t-1}} + \nu\varepsilon_{i,t}(P_{i,t})^{-\nu}(P_t)^{-(1-\nu)}Y_t\right] \\ = & -\beta^{t+1}E_t\left[\frac{\lambda_{t+1}}{\lambda_0}\Psi\left(\frac{P_{i,t+1}}{P_{i,t}}-\pi\right)\frac{P_{i,t+1}}{P_{i,t}}\frac{1}{P_{i,t}}\right] \end{aligned}$$

$$\begin{aligned} & (1-\nu)\left(\frac{P_{i,t}}{P_t}\right)^{1-\nu}\frac{1}{P_{i,t}}Y_t - \Psi\left(\pi_t-\pi\right)\frac{1}{P_{i,t-1}} + \nu\varepsilon_{i,t}\left(\frac{P_{i,t}}{P_t}\right)^{1-\nu}\frac{1}{P_{i,t}}Y_t \\ = & -\beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\Psi\left(\pi_{t+1}-\pi\right)\pi_{t+1}\frac{1}{P_{i,t}}\right] \end{aligned} \tag{4.A.6}$$

In a symmetric equilibrium, which we subsequently consider, the aggregate price level equals the individual prices $(P_t = P_{i,t})$ which allows us to rewrite (4.A.6) as

$$(1-\nu)\frac{Y_t}{P_t} - \Psi\left(\pi_t-\pi\right)\frac{1}{P_{t-1}} + \nu mc_t\frac{Y_t}{P_t} + \beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\Psi\left(\pi_{t+1}-\pi\right)\pi_{t+1}\frac{1}{P_t}\right] = 0 \tag{4.A.7}$$

$$Y_t\left[(1-\nu)+\nu mc_t\right] = \Psi\left(\pi_t-\pi\right)\pi_t - \beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\Psi\left(\pi_{t+1}-\pi\right)\pi_{t+1}\right] = 0 \tag{4.A.8}$$

From (4.A.5) we have

$$\frac{c^h}{g(\theta_t)} = \mu_t \ \forall t \ \Rightarrow \frac{c^h}{g(\theta_{t+1})} = \mu_{t+1} \tag{4.A.9}$$

whereas (4.A.4) implies

$$\mu_t = -w_t + mc_tA_t + \beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}(1-\rho^x)\mu_{t+1}\right] \tag{4.A.10}$$

Combining (4.A.9) and (4.A.10) we get

$$\frac{c^h}{g(\theta_t)} = -w_t + mc_t A_t + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t}(1-\rho^x)\frac{c^h}{g(\theta_{t+1})} \right] \tag{4.A.11}$$

Rearranging (4.A.11) we can obtain the expression for the marginal costs as in the text, given by

$$mc_t = \frac{w_t}{A_t} + \frac{\frac{c^h}{g(\theta_t)} - \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t}(1-\rho^x)\frac{c^h}{g(\theta_{t+1})} \right]}{A_t} \tag{4.A.12}$$

4.A.2 The Bellman Equations

The marginal value of an employment for a firm reads as

$$\mathbf{J}^e_t = mc_t A_t - w_t + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) (1-\rho^x)\, \mathbf{J}^e_{t+1} \tag{4.A.13}$$

whereas the marginal value of a job for a worker is given by

$$\mathbf{W}^e_t = (1-\tau_t)w_t + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left[(1-\rho^x)\, \mathbf{W}^e_{t+1} + \rho^x \mathbf{U}_{t+1} \right]$$

This allows us to write:

$$\begin{aligned} \mathbf{W}^e_t &= (1-\tau_t)w_t \\ &\quad + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left[(1-\rho^x) \left(\mathbf{W}^e_{t+1} - \mathbf{U}_{t+1} \right) - (1-\rho^x)\mathbf{U}_{t+1} + \rho^x \mathbf{U}_{t+1} \right] \end{aligned}$$

$$\mathbf{W}^e_t = (1-\tau_t)w_t + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left[(1-\rho^x) \left(\mathbf{W}^e_{t+1} - \mathbf{U}_{t+1} \right) + \mathbf{U}_{t+1} \right] \tag{4.A.14}$$

Marginal value of an unemployment for a worker is given by

$$\mathbf{U}_t = b + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left[\theta_{t+1} g(\theta_{t+1})\,(1-\rho^x)\, \mathbf{W}^e_{t+1} + (1 - \theta_{t+1} g(\theta_{t+1})(1-\rho^x))\mathbf{U}_{t+1} \right] \tag{4.A.15}$$

which can be rewritten in a similar fashion as (4.A.14), to get

$$\begin{aligned}\mathbf{U}_t &= b+\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[\theta_{t+1}g(\theta_{t+1})\left(1-\rho^x\right)\left(\mathbf{W}^e_{t+1}-\mathbf{U}_{t+1}\right)\right. \\ &\quad \left.+(1-\theta_{t+1}g(\theta_{t+1})\left(1-\rho^x\right))\mathbf{U}_{t+1}+\theta_{t+1}g(\theta_{t+1})(1-\rho^x)\mathbf{U}_{t+1}\right]\end{aligned}$$

$$\mathbf{U}_t = b+\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[\theta_{t+1}g(\theta_{t+1})\left(1-\rho^x\right)\left(\mathbf{W}^e_{t+1}-\mathbf{U}_{t+1}\right)+\mathbf{U}_{t+1}\right] \quad (4.A.16)$$

It is also useful to obtain the expression for $\mathbf{W}^e_t - \mathbf{U}_t$ which is given by

$$\mathbf{W}^e_t-\mathbf{U}_t = (1-\tau_t)w_t-b+\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[\left(1-\rho^x\right)\left(1-\theta_{t+1}g(\theta_{t+1})\right)\left(\mathbf{W}^e_{t+1}-\mathbf{U}_{t+1}\right)\right] \quad (4.A.17)$$

4.A.3 Nash Bargaining Problem and wage equation

The wage is determined by Nash bargaining over the match surplus, which is assumed to be shared between firms and the workers according to the parameter η denoting workers' bargaining power. Formally the problem of a Nash product maximization can be stated as follows:

$$w_t(a_t) = \arg\max\left(\mathbf{W}^e_t-\mathbf{U}_t\right)^{\eta}\left(\mathbf{J}^e_t\right)^{1-\eta} \quad (4.A.18)$$

The first order condition for the above problem is given by:

$$\begin{aligned}&\eta\frac{\partial\mathbf{W}^e_t}{\partial w_t}\left(\mathbf{W}^e_t-\mathbf{U}_t\right)^{\eta-1}\left(\mathbf{J}^e_t\right)^{1-\eta} \\ =& -\left(1-\eta\right)\frac{\partial\mathbf{J}^e_t}{\partial w_t}\left(\mathbf{W}^e_t-\mathbf{U}_t\right)^{\eta}\left(\mathbf{J}^e_t\right)^{-\eta}\end{aligned} \quad (4.A.19)$$

Using

$$\frac{\partial\mathbf{W}^e_t}{\partial w_t} = 1-\tau_t \text{ and } \frac{\partial\mathbf{J}^e_t}{\partial w_t} = -1$$

substituting into (4.A.19), dividing by $\left(\mathbf{W}_t^e - \mathbf{U}_t\right)^{\eta}\left(\mathbf{J}_t^e\right)^{1-\eta}$ and rearranging we obtain a sharing rule as the solution of the Nash bargaining problem, which is in our case given by:

$$\mathbf{W}_t^e - \mathbf{U}_t = \frac{\eta}{1-\eta}(1-\tau_t)\mathbf{J}_t^e$$

Substituting this solution into (4.A.17) we get

$$\begin{aligned}\mathbf{W}_t^e - \mathbf{U}_t &= (1-\tau_t)w_t - b \\ &+\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[(1-\rho^x)\left(1-\theta_{t+1}g(\theta_{t+1})\right)\left(\frac{\eta}{1-\eta}\right)(1-\tau_{t+1})\mathbf{J}_{t+1}^e\right]\end{aligned} \tag{4.A.20}$$

Since $\mathbf{J}_t^e = \mu_t$ and $\frac{c^h}{g(\theta_t)} = \mu_t$ we can write:

$$\begin{aligned}&(1-\tau_t)w_t - b + \beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[(1-\rho^x)\left(1-\theta_{t+1}g(\theta_{t+1})\right)\left(\frac{\eta}{1-\eta}\right)(1-\tau_{t+1})\frac{c^h}{g(\theta_{t+1})}\right] \\ &= \frac{\eta}{1-\eta}(1-\tau_t)\left[mc_tA_t - w_t + \beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)\frac{c^h}{g(\theta_{t+1})}\right]\end{aligned}$$

It than follows that:

$$\begin{aligned}&(1-\tau_t)w_t(1-\eta) - b\,(1-\eta) + \eta\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)\left(1-\theta_{t+1}g(\theta_{t+1})\right)(1-\tau_{t+1})\frac{c^h}{g(\theta_{t+1})} \\ &= \eta(1-\tau_t)mc_tA_t - \eta(1-\tau_t)w_t + \eta(1-\tau_t)\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)\frac{c^h}{g(\theta_{t+1})}\end{aligned}$$

$$\begin{aligned}&(1-\tau_t)w_t + \eta\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)\left[(1-\theta_{t+1}g(\theta_{t+1}))(1-\tau_{t+1}) - (1-\tau_t)\right]\frac{c^h}{g(\theta_{t+1})} \\ &= \eta(1-\tau_t)mc_tA_t + b\,(1-\eta)\end{aligned}$$

$$
\begin{aligned}
w_t &= \eta mc_t A_t + b\frac{(1-\eta)}{(1-\tau_t)} \\
&+\frac{\eta}{(1-\tau_t)}\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)\left[(1-\tau_t)-(1-\theta_{t+1}g(\theta_{t+1}))(1-\tau_{t+1})\right]\frac{c^h}{g(\theta_{t+1})}
\end{aligned}
$$

$$
\begin{aligned}
w_t &= \eta mc_t A_t + b\frac{(1-\eta)}{(1-\tau_t)} \\
&+\frac{\eta}{(1-\tau_t)}\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-\rho^x)\left[\tau_{t+1}-\tau_t+\theta_{t+1}g(\theta_{t+1})(1-\tau_{t+1})\right]\frac{c^h}{g(\theta_{t+1})}
\end{aligned}
\tag{4.A.21}
$$

4.A.4 Derivation of the evolution of labour market tightness equation

Using job creation condition given by

$$
\frac{c^h}{g(\theta_t)} = -w_t + mc_t A_t + \beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}(1-\rho^x)\frac{c^h}{g(\theta_{t+1})}\right] \tag{4.A.22}
$$

as well as the solution for the wage equation (4.A.21) we can obtain equation defining the evolution of labour market tightness which is given by:

$$
\begin{aligned}
\frac{c^h}{g(\theta_t)} &= (1-\eta)mc_t A_t - b\frac{(1-\eta)}{(1-\tau_t)} \\
&+\beta E_t\frac{\lambda_{t+1}}{\lambda_t}(1-\rho^x)\frac{c^h}{g(\theta_{t+1})}\left[1-\frac{\eta}{(1-\tau_t)}(\tau_{t+1}-\tau_t+\theta_{t+1}g(\theta_{t+1})(1-\tau_{t+1}))\right]
\end{aligned}
\tag{4.A.23}
$$

4.B Appendix B to Chapter 4

The numerical solving of the Ramsey optimal policy problem is not an easy task to accomplish. There is no guarantee that the equilibrium exists, and the set of good initial conditions is of crucial importance. As already stated in the description of the Ramsey problem, we have derived a minimum number of necessary conditions for this problem in order to reduce its numerical complexity. Specifically, by performing this system reduction we are left with six equations in eight unknowns, whereby our system now comprises of equations given by (4.22), (4.23)and (4.52)-(4.56), to be solved for $\{c_t, \lambda_t, n_t, v_t, mc_t, \pi_t, R_t, \tau_t, l_t\}_{t=0}^{\infty}$. If in addition to the previous 7 equations, we had two more equations describing monetary and fiscal policy rules, we could solve for our 9 endogenous variables. But, when solving the Ramsey optimal problem one is not endowed with them unfortunately. In this case, the system can be augmented with the first order conditions associated with a Lagrangian representation of the Ramsey optimal policy problem. This is precisely what we do which expands our system by 7 additional endogenous variables defining the set of Ramsey Lagrangian multipliers. They are represented by 1×7 row vector $\Lambda_t = \{\Lambda_t^{R1}, \Lambda_t^{R2}, \Lambda_t^{R3}, \Lambda_t^{R4}, \Lambda_t^{R5}, \Lambda_t^{R6}, \Lambda_t^{R7}\} \vee t \in [0, \infty]$. We implement our solution algorithm by using both symbolic and numerical features of the MATLAB package. In what follows we will briefly describe our implementation strategy.

Let Ξ_t denoted the set of endogenous variables in a dynamic model whose cardinality is given by N. Let the agents equilibrium conditions be represented by $N-2$ equations given by

$$E_t f(\Xi_t, \Xi_{t+1}) = 0 \tag{4.B.1}$$

where $E_t\{\cdot\}$ denotes conditional expectation operator such that, if $s^t = (s_t, s_{t-1}...s_0)$ is the particular set of historical events up to and including time t then, $E_t\{\cdot\} = \sum_{s^{t+1}} p(s^{t+1} \mid s^t)$. Here p_t denotes date zero probability of observing a history s^t, and the initial event s_0 is assumed to have occurrence probability equal to one. $f(\Xi_t, \Xi_{t+1})$ denotes $N-2\times 1$ column vector of the agents' first order conditions. Let the preferences over Ξ_t be implicitly given by

$$E_0 \sum_{t=0}^{\infty} \beta^t U(\Xi_t) \tag{4.B.2}$$

Then the Ramsey problem consist of choosing every $\epsilon_t \in \Xi_t$ subject to (4.B.1). Formally, we can write this problem as

$$\max_{\{\Xi_t, \Lambda_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left\{ U(\Xi_t) + \Lambda_t f(\Xi_t, \Xi_{t+1}) \right\} \tag{4.B.3}$$

The first order conditions of the above problem can than be written as

$$U_1(\Xi_t) + \Lambda_t E_t f_1(\Xi_t, \Xi_{t+1}) + \beta^{-1} \Lambda_{t-1} f_2(\Xi_{t-1}, \Xi_t) = 0 \tag{4.B.4}$$

where U_1 is $1 \times N$, Λ_t is $1 \times N - 2$ and 0 is $1 \times N$ row vector and $f' \in \{f_1, f_2\}$ is $N - 2 \times N$ matrix. Thus, our system comprises of (4.22), (4.23), (4.52)-(4.56) and N equations represented by (4.B.4). which makes total of $N + 7$ equations in 13 unknowns, out of which 7 are the Lagrangian multipliers. We solve for the N first order conditions of the Ramsey problem by using MATLAB's symbolic solver. The complete system defined by $N + 7$ equations is then solved for the rational expectation equilibrium by using the perturbation method implemented in algorithm developed by Schmitt-Grohe and Uribe (2004c).

As the perturbation methods are local approximations they need to be supplied with the point around which the approximation will be performed. In our case this point is the Ramsey equilibrium deterministic steady state, comprising from the steady state values of the 7 Lagrangian multipliers in addition to the steady state values of 9 endogenous variables. The complexity of the problems lies in the fact that we need to determine the steady state values of the Lagrangian multipliers. In order to accomplish this task we use nonlinear search algorithm implemented in MATLAB's *fminsearch* function.[57] Roughly speaking we proceed in two steps. First, we start our nonlinear optimization by providing the initial guess for two policy parameters, namely the interest rate R and the wage tax rate τ. We then solve for the remaining $N-2$ endogenous variables. Because of the inherent nonlinearity in the labour market tightness conditions which makes it impossible to obtain the closed form solution for θ, we incorporate additional numerical nonlinear solver within the *fminsearch* procedure and solve in every numerical search iteration for the new value of labour market tightness, vacancies and employment. This task is accomplished by employing MATLAB's *fsolve* function, which uses *trust-region-dogleg* algorithm to find the zeros of the nonlinear system. In each iteration, and after obtaining the values for the endogenous variables, we solve for the values of Lagrangian multipliers by exploiting the properties of the steady state version of (4.B.4).

In order to formally describe the procedure let us first rewrite the steady state version of (4.B.4) as

$$U_1(\Xi) + \Lambda\left(f_1(\Xi) + \beta^{-1} f_2(\Xi)\right) = 0 \tag{4.B.5}$$

[57] *fminsearch* is the version of Nelder-Mead Simplex Method which is slower but more reliable relative to the other nonlinear unconstrained optimisation routines.

It is easy to notice that this system can be rewritten in a form of a standard OLS minimization problem. Letting $Y = U_1(\Xi)^T$, $X = \left(f_1(\Xi) + \beta^{-1} f_2(\Xi)\right)^T$ and $\Omega = -\Lambda^T$ we can rewrite (4.B.5) in the standard OLS notation as $Y = X\Omega$ where the dimensionality of Y and Ω is $N \times 1$, and the dimensionality of X is $N \times N - 2$. Our problem is then to minimize the distance Γ, defined as $Y - X\Omega$, with respect to Ω, by searching over the pair of values (R, τ) until $\min \digamma \leqslant \delta$. The solution for Ω is the standard OLS estimator defined as $(X^T X)^{-1} X^T Y$; $\digamma$ denotes the sum of $\mathbf{1} \left\| \Gamma \right\|$, G^1 and G^2, and δ denotes the termination tolerance on the function value. More precisely, G^1 represents the relatively large penalty value to the objective function to be minimized in case the algorithm drifts away from the values of interest rate R which are larger than one. G^2 is the additional constraint measure defined as the difference between the steady state version of the liabilities condition and the imposed steady state value of the liabilities. Formally,

$$\mathbf{1} = \left\{ \begin{array}{l} 0 \; if \; R < 1 \\ 1 \; otherwise \end{array} \right. \; ; \; G^1 = \left\{ \begin{array}{l} 10 \; if \; R < 1 \\ 0 \; otherwise \end{array} \right.$$

and

$$G^2 = \left| \frac{l}{4Ry} - 0.44 \right|$$

Chapter 5

Summary and Future Work

The need for product market liberalization and labour market deregulation, which should improve the overall economic performance in Europe, is widely accepted among policy makers. As an additional issue, labour tax reforms continue to be an important item on the policy agenda in many European countries. However, surprisingly little formal academic analysis has been conducted in order to provide insights into the effects of particular tax, labour and product market reforms. The scarce literature, mostly conducted within the partial equilibrium setup, focuses on the labour market reforms and their effects on long-run labour market performance, thereby abstracting from potentially important general equilibrium effects. Moreover, the role of product market reforms is absent. On the other hand, very few exception in the literature conducted the reform analysis within the general equilibrium setup, but fully neglected the importance of the fiscal issues, although at least as much effort has gone into arguing for reforms that reduce the distortionary effects of taxation, as has gone into advocating other deregulation programmes.

As pointed out in the introduction, the main aim of this thesis is to shed new light on the effects that various labour and product market reforms have on the overall economic performance, and to explicitly consider the taxation issues largely neglected in previous research. Chapter 1 provides a review of the main empirical and theoretical literature and identifies the gaps and drawbacks which serve as the motivation for the remainder of the thesis. In Chapter 2 we start by analyzing the benefits (or costs) of tax reform and address the question of its effectiveness relative to product market or other labour market institutional reforms. We contribute by showing how tax reforms can contribute to the reforms process; how the composition of the price mark-up determines the long run effects of structural reforms and how the effectiveness of different reform instruments varies depending on the policy maker's ultimate objective. We find the difference between the short and the long run consequences of reforms and identify the existence of short run costs in employment and welfare, but potential gains in the long run. We also show the importance of the choice of the reform instrument. More specifically, we find that tax reforms are most effective for raising welfare, whereas labour market deregulation will be a better choice for employment creation if product markets are "competitive", but the product market liberalization will be better if they are not. We also show the differences in the effects of wage and payroll taxes on wages, employment and output which contradicts the widely used assumption in the public finance literature.

The framework used in Chapter 2 allowed us to gain useful insights about the reform process, but is abstracting from several important empirical regularities and theoretical considerations. Specifically, it is based on the so called stock approach and was therefore unable to capture large flows in the labour market characterized by high rates of hires by firms and large number of separations from firms evident in the data. Moreover, the dynamic implications were based on the clear cut difference between the short and the long run, induced by entry and exit, and therefore rather limited. In order to correct for these drawbacks, we have employed a new modelling strategy in Chapter 3, based on a fully fledged microfounded dynamic stochastic general equilibrium framework in line with the recent New-Keynesian macroeconomic models. More precisely, we have abandoned the widely used assumption of Walrasian labour markets and have them replaced with labour markets characterized by a search-matching process which results in involuntary equilibrium unemployment. Moreover, we have introduced the endogenous job destruction and costly firing decisions, as well as explicit fiscal considerations by enriching the model with two types of distortionary taxes, a progressive wage tax and a flat payroll tax. This allowed us to explicitly consider not only the long-run effects of tax changes as well as product market reforms, but also the effects they have on the fluctuations of macroeconomic aggregates such as inflation, output and consumption. We confirm the detrimental effects of the marginal tax distortions on the overall economic performance within a general equilibrium model characterized by the search-matching process with endogenous job destruction and costly firing decisions. We find a positive effect of an increase in the degree of wage tax progressivity which implies that promoting income equality leads to positive employment, output and consumption effects. We also identify positive effects of product market liberalization on the economy as a whole. We have also analyzed the effect of a particular tax and product market reform on the behavior of the economy following a technology or a government spending shock. Following a positive technology shock we find that the tax reforms aiming to decrease the tax distortions, as well as product market reforms aiming to increase competition, lead to a reduction in the volatility of employment, consumption and output. On the other, inflation response is in both cases more pronounced on impact, but subsequently becomes quickly dampened. On the contrary, following a positive government spending shock, inflation response under both reforms is larger relative to the benchmark case along the whole adjustment path. However, employment, output and consumption are less volatile in the reformed economy. We complete the analysis by considering the effect of a reduction in the marginal payroll tax which is partially offset by an increase in the marginal wage tax rate, such that the marginal tax wedge is unchanged. We find a detrimental long run effect of this type of reform on employment, output and consumption. Moreover, if the reform is anticipated one period in advance, we identify the negative effects of this tax reform on employment, output and consumption along the whole transition path.

In Chapter 4 we have studied the optimal monetary and fiscal policy implications of the New-Keynesian setup where Walrasian labour markets are replaced with search-matching framework, and the policy maker has only distortionary taxes at his disposal. To our knowledge this is the first attempt in the literature to study those issues within the New-Keynesian framework enriched with search-matching frictions. By replacing Walrasian labour markets with the search-matching setup, we were able to analyze an important inflation-unemployment trade-off arising from real labour market frictions induced by costly search-matching process. We were also interested in testing the robustness of the conclusions from former widely used setup which abstracts from real labour market frictions in more realistic environments in which economies are subject to multiple distortions. We find that, following a positive technology shock, Ramsey planner can reduce both inflation and tax rate in order to fully exploit the benefits of this productivity increase which is the consequence of the increase in employment and consumption. Moreover, the optimal policy features deviation from strict price stability which somewhat contrast the standard New-Keynesian predictions. We also identify an additional channel through which Ramsey planner can influence efficiency, and that is the expectational dynamic effects that tax rates have on wages. Moreover, we find that the optimal tax rate and government liabilities inherit the time series properties of the underlying shock. We also identify a certain degree of overshooting in inflation and tax rates following a positive productivity shock, and undershooting following a positive government spending shock. It is the consequence of the assumed commitment which allows the policy maker to internalize the effects of its current decisions on future expectations.

5.1 Future work

To conclude this chapter and the thesis, we provide an outline of the several issues that have not been addressed in this thesis but would represent interesting extensions of the research work conducted here. In each of the chapters we have considered the outcomes of the Nash bargaining. It would certainly be useful to compare the results from this setup to the alternative wage setting mechanisms, such as efficiency wages or monopoly union, in order to determine how much difference it makes when different mechanisms are used to evaluate the impact of a particular policy. As pointed out by Pissarides (1998), the analysis of alternative wage setting mechanisms can be justified by the lack of a definitive model for the European labour market. Moreover, as argued by Rochetau (2001), both bargain and efficiency wage mechanisms may coexist, whereby the tightness of the labour markets determines which one will be binding. Additionally, it would be interesting to analyze the dynamic effects of different wage setting mechanisms on aggregate macroeconomic outcomes.

In Chapters 3 and 4 labour supply decisions were exogenous, which implies that the labour market frictions affect mainly labour demand. An interesting extension would be to endogenize labour supply decisions along the extensive margin which would allow us to study taxation issues taking into account both the supply and demand side of the labour market. Alternatively, it would be useful to extend the models by incorporating intensive margin via the hours of work, and to compare the policy implications of this setup to the one where labour supply decisions are exogenous. When decisions over intensive margin are introduced, the efficiently bargained wage will depend on the hours of work. In this case changes in marginal tax could generate scale effects which would potentially reinforce the negative marginal tax effects on wages, but the effects on unemployment will be ambiguous and dependent on the labour supply elasticity. The general equilibrium effects of tax changes in this setting have not been analyzed yet.

Moreover, we have assumed that households are able to perfectly insure against the unemployment risk. It would be interesting to relax this assumption and to consider distributional consequences of various policy reforms. The main methodological challenge in solving this type of model would be related to the interaction of nontrivial and time dependent distribution of wealth among consumers, which would influence prices and aggregate quantities, and the distribution of wage solutions which would in turn influence workers and firms decisions. A potential promising avenue would be to combine the Aiyagary (1994) and Huggett (1993) modelling framework with search-matching setup.

Regarding the optimal monetary and fiscal policy analysis, it would be certainly important to analyze the implications of alternative wage setting mechanisms, as well as the implications generated by the removal of the perfect consumption insurance assumption.

Bibliography

ABEL, A. B. (1990): "Asset Prices under Habit Formation and Catching Up with the Joneses," *American Economic Review*, 80(2), 38–42.

ABOWD, J. M., AND F. KRAMARZ (2003): "The costs of hiring and separations," *Labour Economics*, 10(5), 499–530.

ABRAHAM, K. G., AND S. N. HOUSEMAN (1993): "Does Employment Protection Inhibit Labor Market Flexibility? Lessons from Germany, France, and Belgium," NBER Working Papers 4390, National Bureau of Economic Research, Inc.

ADDISON, J. T., AND J.-L. GROSSO (1996): "Job Security Provisions Employment: Revised Estimates," *Industrial Relations: A Journal of Economy and Society*, 35(4), 585Ű603.

AIYAGARI, S. R. (1994): "Uninsured Idiosyncratic Risk and Aggregate Saving," *The Quarterly Journal of Economics*, 109(3), 659–84.

AIYAGARI, S. R., A. MARCET, T. J. SARGENT, AND J. SEPPALA (2002): "Optimal Taxation without State-Contingent Debt," *Journal of Political Economy*, 110(6), 1220–1254.

ANDOLFATTO, D. (1996): "Business Cycles and Labor-Market Search," *American Economic Review*, 86(1), 112–32.

ARSENEAU, D. M., AND S. K. CHUGH (2008): "Optimal fiscal and monetary policy with costly wage bargaining," *Journal of Monetary Economics*, 55(8), 1401–1414.

BASU, S., AND J. G. FERNALD (1997): "Returns to Scale in U.S. Production: Estimates and Implications," *Journal of Political Economy*, 105(2), 249–83.

BAUER, T., AND R. T. RIPHAHN (2002): "Employment Effects of Payroll Taxes–An Empirical Test for Germany," *Applied Economics*, 34(7), 865–76.

BAYOUMI, T., D. LAXTON, AND P. PESENTI (2004): "Benefits and spillovers of greater competition in Europe: a macroeconomic assessment," International Finance Discussion Papers 803, Board of Governors of the Federal Reserve System (U.S.).

BEAN, C. (2006): "Globalization and Inflation," *Bank of England Quarterly Bulletin*, 46(4), 468–487.

BELOT, M., AND J. C. VAN OURS (2001): "Unemployment and Labor Market Institutions: An Empirical Analysis," *Journal of the Japanese and International Economies*, 15(4), 403–418.

BENIGNO, P., AND M. WOODFORD (2003): "Optimal Monetary and Fiscal Policy: A Linear Quadratic Approach," NBER Working Papers 9905, National Bureau of Economic Research, Inc.

BENTOLILA, S., AND G. BERTOLA (1990): "Firing Costs and Labour Demand: How Bad Is Eurosclerosis?," *Review of Economic Studies*, 57(3), 381–402.

BLANCHARD, O., AND J. GALI (2008): "Labor Markets and Monetary Policy: A New-Keynesian Model with Unemployment," NBER Working Papers 13897, National Bureau of Economic Research, Inc.

BLANCHARD, O., AND F. GIAVAZZI (2003): "Macroeconomic Effects Of Regulation And Deregulation In Goods And Labor Markets," *The Quarterly Journal of Economics*, 118(3), 879–907.

BLANCHARD, O., AND P. PORTUGAL (2001): "What Hides Behind an Unemployment Rate: Comparing Portuguese and U.S. Labor Markets," *American Economic Review*, 91(1), 187–207.

BLANCHARD, O., AND J. WOLFERS (2000): "The Role of Shocks and Institutions in the Rise of European Unemployment: The Aggregate Evidence," *Economic Journal*, 110(462), C1–33.

BOERI, T., G. NICOLETTI, AND S. SCARPETTA (2000): "Regulation And Labour Market Performance," CEPR Discussion Papers 2420, C.E.P.R. Discussion Papers.

BOIVIN, J., AND M. P. GIANNONI (2006): "Has Monetary Policy Become More Effective?," *The Review of Economics and Statistics*, 88(3), 445–462.

BOKAN, N., AND A. HUGHES HALLETT (2006): "Labour and Product Market Reforms in the Economy with Distortionary Taxation," CEPR Discussion Papers 5431, C.E.P.R. Discussion Papers.

——— (2008): "The Impact of Tax and Market Distortions on the Phillips Curve and the Natural Rate of Unemployment," *Economics - The Open-Access, Open-Assessment E-Journal*, 2(27), 1–28.

BRUNO, M. (1986): "Aggregate Supply and Demand Factors in OECD Unemployment: An Update," *Economica*, 53(210(S)), S35–52.

BRUNO, M., AND J. SACHS (1985): *Economics of worldwide stagflation*, vol. 1. Harvard University Press.

BURDA, M. C. (1992): "A Note on Firing Costs and Severance Benefits in Equilibrium Unemployment," *Scandinavian Journal of Economics*, 94(3), 479–89.

CAHUC, P., AND A. ZYLBERBERG (2004): *Labor Economics*, vol. 1 of *MIT Press Books*. The MIT Press.

CALVO, G. A. (1983): "Staggered prices in a utility-maximizing framework," *Journal of Monetary Economics*, 12(3), 383–398.

CALVO, G. A., AND P. E. GUIDOTTI (1993): "On the Flexibility of Monetary Policy: The Case of the Optimal Inflation Tax," *Review of Economic Studies*, 60(3), 667–87.

CAMPBELL, J. Y., AND J. COCHRANE (1999): "Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behavior," *Journal of Political Economy*, 107(2), 205–251.

CHADHA, J. S., AND C. NOLAN (2007): "Optimal simple rules for the conduct of monetary and fiscal policy," *Journal of Macroeconomics*, 29(4), 665–689.

CHARI, V. V., L. J. CHRISTIANO, AND P. J. KEHOE (1991): "Optimal Fiscal and Monetary Policy: Some Recent Results," *Journal of Money, Credit and Banking*, 23(3), 519–39.

CHEN, H. A., D. LEVY, S. RAY, AND M. BERGEN (2008): "Asymmetric price adjustment in the small," *Journal of Monetary Economics*, 55(4), 728–737.

CHRISTOFFEL, K., K. KUESTER, AND T. LINZERT (2005): "The Impact of Labor Markets on the Transmission of Monetary Policy in an Estimated DSGE Model," IZA Discussion Papers 1902, Institute for the Study of Labor (IZA).

——— (2009): "The role of labor markets for euro area monetary policy," Working Paper Series 1035, European Central Bank.

CHRISTOFFEL, K., AND T. LINZERT (2005): "The role of real wage rigidity and labor market frictions for unemployment and inflation dynamics," Working Paper Series 556, European Central Bank.

CLARIDA, R., J. GALI, AND M. GERTLER (1999): "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, 37(4), 1661–1707.

COE, D. T., AND D. J. SNOWER (1996): “Policy Complementarities: The Case for Fundamental Labor Market Reform,” IMF Working Papers 96/93, International Monetary Fund.

COENEN, G., P. MCADAM, AND R. STRAUB (2008): “Tax reform and labour-market performance in the euro area: A simulation-based analysis using the New Area-Wide Model,” *Journal of Economic Dynamics and Control*, 32(8), 2543–2583.

CONSTANTINIDES, G. M. (1990): “Habit Formation: A Resolution of the Equity Premium Puzzle,” *Journal of Political Economy*, 98(3), 519–43.

DAVERI, F., AND G. TABELLINI (2000): “Unemployment, growth and taxation in industrial countries,” *Economic Policy*, 15(30), 47–104.

DAVIS, S. J., AND J. HALTIWANGER (1999): “Gross job flows,” in *Handbook of Labor Economics*, ed. by O. Ashenfelter, and D. Card, vol. 3 of *Handbook of Labor Economics*, chap. 41, pp. 2711–2805. Elsevier.

DELLAS, H., AND G. TAVLAS (2005): “Wage Rigidity and Monetary Union,” *Economic Journal*, 115(506), 907–927.

DEMERTZIS, M., AND A. H. HALLETT (1998): “Asymmetric transmission mechanisms and the rise in European unemployment: A case of structural differences or of policy failures?,” *Journal of Economic Dynamics and Control*, 22(6), 869–886.

DEN HAAN, W. J., G. RAMEY, AND J. WATSON (2000): “Job Destruction and Propagation of Shocks,” *American Economic Review*, 90(3), 482–498.

DIAMOND, P. A. (1982): “Wage Determination and Efficiency in Search Equilibrium,” *Review of Economic Studies*, 49(2), 217–27.

DIXIT, A. K., AND J. E. STIGLITZ (1977): “Monopolistic Competition and Optimum Product Diversity,” *American Economic Review*, 67(3), 297–308.

DOBBELAERE, S. (2004): “Estimation of price-cost margins and union bargaining power for Belgian manufacturing,” *International Journal of Industrial Organization*, 22(10), 1381–1398.

DUCA, J. V., AND D. D. VANHOOSE (2000): “Has Greater Competition Restrained U.S. Inflation?,” *Southern Economic Journal*, 66(3), 729–741.

ECB (2002): “Labour Market Mismatches in the Euro Area Countries,” Report, European Central Bank, Frankfurt am Main, Germany.

ELMESKOV, J., J. P. MARTIN, AND S. SCARPETTA (2009): “Key Lessons For Labour Market Reforms: Evidence From OECD Countries’ Experience,” *Swedish Economic Policy Review*, 5(2), 205–252.

ELSBY, M. W. L., R. MICHAELS, AND G. SOLON (2009): “The Ins and Outs of Cyclical Unemployment,” *American Economic Journal: Macroeconomics*, 1(1), 84–110.

ERCEG, C. J., D. W. HENDERSON, AND A. T. LEVIN (2000): “Optimal monetary policy with staggered wage and price contracts,” *Journal of Monetary Economics*, 46(2), 281–313.

FAIA, E. (2008): “Optimal monetary policy rules with labor market frictions,” *Journal of Economic Dynamics and Control*, 32(5), 1600–1621.

——— (2009): “Ramsey monetary policy with labor market frictions,” *Journal of Monetary Economics*, 56(4), 570–581.

FANG, L., AND R. ROGERSON (2007): “Product Market Regulation and Market Work: A Benchmark Analysis,” NBER Working Papers 12891, National Bureau of Economic Research, Inc.

FARBER, H. S. (1997): “Job Creation in the United States: Good Jobs or Bad?,” Working Papers 764, Princeton University, Department of Economics, Industrial Relations Section.

FIORI, G., G. NICOLETTI, S. SCARPETTA, AND F. SCHIANTARELLI (2007): “Employment Outcomes and the Interaction Between Product and Labor Market Deregulation: Are They Substitutes or Complements?,” Boston College Working Papers in Economics 663, Boston College Department of Economics.

GALI, J. (2008): *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton University Press.

GALÍ, J. (2002): “New Perspectives on Monetary Policy, Inflation and the Business Cycle,” CEPR Discussion Papers 3210, C.E.P.R. Discussion Papers.

GALÍ, J., J. D. LÓPEZ-SALIDO, AND J. VALLÉS (2002): “Understanding the Effects of Government Spending on Consumption,” Economics Working Papers 911, Department of Economics and Business, Universitat Pompeu Fabra.

GERTLER, M., L. SALA, AND A. TRIGARI (2008): “An Estimated Monetary DSGE Model with Unemployment and Staggered Nominal Wage Bargaining,” *Journal of Money, Credit and Banking*, 40(8), 1713–1764.

GIANNONI, M. P., AND M. WOODFORD (2003): "Optimal Interest-Rate Rules: II. Applications," NBER Working Papers 9420, National Bureau of Economic Research, Inc.

GOLOSOV, M., AND R. E. L. JR. (2007): "Menu Costs and Phillips Curves," *Journal of Political Economy*, 115, 171–199.

GOODFRIEND, M., AND R. G. KING (2001): "The Case for Price Stability," NBER Working Papers 8423, National Bureau of Economic Research, Inc.

GRIFFITH, R., AND R. HARRISON (2004): "The link between product market reform and macro-economic performance," Discussion paper, European Commission.

GRUBER, J. (1994): "Payroll Taxation in the United States: Assessing the Alternatives," in *Enterprise Economics and Tax Reform Working Papers Volume III*, ed. by R. Shapiro. Washington, D.C.: Progressive Foundation.

GRUBER, J. (1997): "The Incidence of Payroll Taxation: Evidence from Chile," *Journal of Labor Economics*, 15(3), S72–101.

HALL, R. E. (2003): "Wage Determination and Employment Fluctuations," NBER Working Papers 9967, National Bureau of Economic Research, Inc.

——— (2005): "Employment Fluctuations with Equilibrium Wage Stickiness," *American Economic Review*, 95(1), 50–65.

HALLETT, A. H., S. E. H. JENSEN, AND C. RICHTER (2005): "The European economy at the cross roads: Structural reforms, fiscal constraints, and the Lisbon Agenda," *Research in International Business and Finance*, 19(2), 229–250.

HANSEN, G. D. (1985): "Indivisible labor and the business cycle," *Journal of Monetary Economics*, 16(3), 309–327.

HEIJDRA, B., AND J. LIGTHART (2009): "Labor tax reform, unemployment, and search," *International Tax and Public Finance*, 16(1), 82–104.

HOLMLUND, B., AND A. KOLM (1995): "Progressive Taxation, Wage Setting, and Unemployment , Theory and Swedish Evidence," Papers 1995-15, Uppsala - Working Paper Series.

HOSIOS, A. J. (1990): "On the Efficiency of Matching and Related Models of Search and Unemployment," *Review of Economic Studies*, 57(2), 279–98.

HUGGETT, M. (1993): “The risk-free rate in heterogeneous-agent incomplete-insurance economies,” *Journal of Economic Dynamics and Control*, 17(5-6), 953–969.

HØJ, J., V. GALASSO, G. NICOLETTI, AND T.-T. DANG (2006): “The Political Economy of Structural Reform: Empirical Evidence from OECD Countries,” OECD Economics Department Working Papers 501, OECD, Economics Department.

KHAN, A., R. G. KING, AND A. L. WOLMAN (2003): “Optimal Monetary Policy,” *Review of Economic Studies*, 70(4), 825–860.

KOEDIJK, K., AND J. KREMERS (1996): “Market Opening, Regulation and Growth in Europe,” *Economic Policy*, 23(11), 445–467.

KOSKELA, E., AND R. SCHOB (1999a): “Alleviating unemployment:: The case for green tax reforms,” *European Economic Review*, 43(9), 1723–1746.

——— (1999b): “Does the composition of wage and payroll taxes matter under Nash bargaining?,” *Economics Letters*, 64(3), 343–349.

KOSKELA, E., AND J. VILMUNEN (1996): “Tax progression is good for employment in popular models of trade union behaviour,” *Labour Economics*, 3(1), 65–80.

KRAUSE, M., AND T. A. LUBIK (2007a): “Does intra-firm bargaining matter for business cycle dynamics?,” Discussion Paper Series 1: Economic Studies 2007,17, Deutsche Bundesbank, Research Centre.

KRAUSE, M. U., D. J. LOPEZ-SALIDO, AND T. A. LUBIK (2008): “Do search frictions matter for inflation dynamics?,” *European Economic Review*, 52(8), 1464–1479.

KRAUSE, M. U., AND T. A. LUBIK (2007b): “The (ir)relevance of real wage rigidity in the New Keynesian model with search frictions,” *Journal of Monetary Economics*, 54(3), 706–727.

LAMBERTINI, L., N. GIAMMARIOLI, AND L. ONORANTE (2008): “Is U.S. Fiscal Policy Optimal?,” *SSRN eLibrary*.

LAYARD, R., AND S. NICKELL (1990): “Is Unemployment Lower if Unions Bargain over Employment?,” *The Quarterly Journal of Economics*, 105(3), 773–87.

——— (1999): “Labor market institutions and economic performance,” in *Handbook of Labor Economics*, ed. by O. Ashenfelter, and D. Card, vol. 3 of *Handbook of Labor Economics*, chap. 46, pp. 3029–3084. Elsevier.

LAYARD, R., S. NICKELL, AND R. JACKMAN (1991): *Unemployment: Macroeconomic Performance and the Labour Market*, vol. 1. Oxford University Press.

LAZEAR, E. P. (1990): "Job Security Provisions and Employment," *The Quarterly Journal of Economics*, 105(3), 699–726.

LOCKWOOD, B., AND A. MANNING (1993): "Wage setting and the tax system theory and evidence for the United Kingdom," *Journal of Public Economics*, 52(1), 1–29.

LUCAS, R. J., AND N. L. STOKEY (1983): "Optimal fiscal and monetary policy in an economy without capital," *Journal of Monetary Economics*, 12(1), 55–93.

MANKIW, N. G. (1990): "A Quick Refresher Course in Macroeconomics," *Journal of Economic Literature*, 28(4), 1645–60.

MANNING, A. (1993): "A Dynamic Model of Union Power, Wages and Employment," *Scandinavian Journal of Economics*, 95(2), 175–93.

MARTINS, J. O., S. SCARPETTA, AND D. PILAT (1996): "Mark-Up Ratios in Manufacturing Industries: Estimates for 14 OECD Countries," OECD Economics Department Working Papers 162, OECD, Economics Department.

MCCALL, J. J. (1970): "Economics of Information and Job Search," *Quarterly Journal of Economics*, 84, 113–126.

MERZ, M. (1995): "Search in the labor market and the real business cycle," *Journal of Monetary Economics*, 36(2), 269–300.

MILLARD, S. P., AND D. T. MORTENSEN (1995): "The Unemployment and Welfare Effects of Labour Market Policy: A comparison of the U.S. and U.K," Discussion paper, Northwestern University.

MORTENSEN, D. T. (1982): "The Matching Process as a Noncooperative Bargaining Game," in *The Economics of Information and Uncertainty*, NBER Chapters, pp. 233–258. National Bureau of Economic Research, Inc.

——— (1994a): "The cyclical behavior of job and worker flows," *Journal of Economic Dynamics and Control*, 18(6), 1121–1142.

——— (1994b): "Reducing supply-side disincentives to job creation," *Proceedings*, (Jan), 189–237.

MORTENSEN, D. T., AND C. A. PISSARIDES (1994): "Job Creation and Job Destruction in the Theory of Unemployment," *Review of Economic Studies*, 61(3), 397–415.

MORTENSEN, D. T., AND C. A. PISSARIDES (1999): "New developments in models of search in the labor market," in *Handbook of Labor Economics*, ed. by O. Ashenfelter, and D. Card, vol. 3 of *Handbook of Labor Economics*, chap. 39, pp. 2567–2627. Elsevier.

NELSON, E. (2001): "UK Monetary Policy 1972-97: A Guide Using Taylor Rules," CEPR Discussion Papers 2931, C.E.P.R. Discussion Papers.

NICKEL, S., AND L. NUNZIATA (2007): "Labour Market Institutions Database," .

NICKELL, S. (1997): "Unemployment and Labor Market Rigidities: Europe versus North America," *Journal of Economic Perspectives*, 11(3), 55–74.

NICKELL, S., L. NUNZIATA, AND W. OCHEL (2005): "Unemployment in the OECD Since the 1960s. What Do We Know?," *Economic Journal*, 115(500), 1–27.

NICKELL, S., L. NUNZIATA, W. OCHEL, AND G. QUINTINI (2003): "The Beveridge Curve, Unemployment and Wages in the OECD from the 1960s to the 1990s," in *Knowledge, Information and Expectations in Modern Macroeconomics: In Honor of Edmund S. Phelps*, ed. by P. Aghion, R. Frydman, J. Stiglitz, and M. Woodford, chap. 19, pp. 394–432. Princeton University Press, Princeton.

NICOLETTI, G., A. BASSANINI, E. ERNST, S. JEAN, P. SANTIAGO, AND P. SWAIM (2001): "Product and Labour Markets Interactions in OECD Countries," OECD Economics Department Working Papers 312, OECD, Economics Department.

NICOLETTI, G., AND S. SCARPETTA (2005): "Product Market Reforms and Employment in OECD Countries," OECD Economics Department Working Papers 472, OECD, Economics Department.

OECD (1994a): *Jobs Study: Evidence, and Explanations. Part I: Labor Market Trends and Underlying Forces of Change*. Organization for Economic Co-operation and Development, Paris, France.

——— (1994b): *Jobs Study: Evidence, and Explanations. Part II: The Adjustment Potential of the Labor Market*. OECD, Paris, France.

——— (2007): *Taxing Wages*. OECD, Paris, France.

OGAKI, M., AND C. M. REINHART (1998a): "Intertemporal substitution and durable goods: long-run data," *Economics Letters*, 61(1), 85–90.

——— (1998b): "Measuring Intertemporal Substitution: The Role of Durable Goods," *Journal of Political Economy*, 106(5), 1078–1098.

OSWALD, A. (1997): "The Missing Piece of the Unemployment Puzzle," Discussion paper, Inaugural Lecture, University of Warwick.

PAIN, N., I. KOSKE, AND M. SOLLIE (2006): "Globalisation and Inflation in the OECD Economies," OECD Economics Department Working Papers 524, OECD, Economics Department.

PAPADAKI, E., M. MARETTE, Y. LAU, AND J. HERNANDEZ (2004): "International Trade Model, Version 1," Discussion paper, Department of Foreign Affairs and Trade, Government of Canada, Ottawa.

PETRONGOLO, B., AND C. A. PISSARIDES (2001): "Looking into the Black Box: A Survey of the Matching Function," *Journal of Economic Literature*, 39(2), 390–431.

PHELPS, E. S. (1968): "Money-Wage Dynamics and Labor-Market Equilibrium," *Journal of Political Economy*, 76, 678.

——— (1994): *Structural Slumps: The Modern Equilibrium Theory of Employment, Interest and Assets*, vol. 1. Harvard University Press.

PISSARIDES, C. A. (1998): "The impact of employment tax cuts on unemployment and wages; The role of unemployment benefits and tax structure," *European Economic Review*, 42(1), 155–183.

——— (2000): *Equilibrium Unemployment Theory, 2nd Edition*, vol. 1 of *MIT Press Books*. The MIT Press.

——— (2007): "The Unemployment Volatility Puzzle: Is Wage Stickiness the Answer?," CEP Discussion Papers dp0839, Centre for Economic Performance, LSE.

PRESCOTT, E. C. (2004): "Why do Americans work so much more than Europeans?," *Quarterly Review*, (Jul), 2–13.

PRZYBYLA, M., AND M. ROMA (2005): "Does product market competition reduce inflation? Evidence from EU countries and sectors," Working Paper Series 453, European Central Bank.

RAVN, M. O., S. SCHMITT-GROHE, AND M. URIBE (2004): “The Macroeconomics of Subsistence Points,” NBER Working Papers 11012, National Bureau of Economic Research, Inc.

RAZIN, A., AND A. BINYAMINI (2007): “Flattening of the Short-run Trade-off between Inflation and Domestic Activity: The Analytics of the Effects of Globalization,” Kiel Working Papers 1363, Kiel Institute for the World Economy.

ROBERTS, J. M. (2006): “Monetary Policy and Inflation Dynamics,” *International Journal of Central Banking*, 2(3).

ROCHETEAU, G. (2001): “Equilibrium unemployment and wage formation with matching frictions and worker moral hazard,” *Labour Economics*, 8(1), 75–102.

ROGERSON, R. (1988): “Indivisible labor, lotteries and equilibrium,” *Journal of Monetary Economics*, 21(1), 3–16.

ROGERSON, R., R. SHIMER, AND R. WRIGHT (2005): “Search-Theoretic Models of the Labor Market: A Survey,” *Journal of Economic Literature*, 43(4), 959–988.

ROMER, D. (1993): “The New Keynesian Synthesis,” *Journal of Economic Perspectives*, 7(1), 5–22.

ROTEMBERG, J. J. (1983): “Aggregate Consequences of Fixed Costs of Price Adjustment [Sticky Prices and Disequilibrium Adjustment in a Rational Model of the Inflationary Process],” *American Economic Review*, 73(3), 433–36.

ROTEMBERG, J. J. (2006): “Cyclical Wages in a Search-and-Bargaining Model with Large Firms,” NBER Working Papers 12415, National Bureau of Economic Research, Inc.

ROTEMBERG, J. J., AND M. WOODFORD (1992): “Oligopolistic Pricing and the Effects of Aggregate Demand on Economic Activity,” *Journal of Political Economy*, 100(6), 1153–1207.

ROTEMBERG, J. J., AND M. WOODFORD (1999a): “The cyclical behavior of prices and costs,” in *Handbook of Macroeconomics*, ed. by J. B. Taylor, and M. Woodford, vol. 1 of *Handbook of Macroeconomics*, chap. 16, pp. 1051–1135. Elsevier.

——— (1999b): “Interest Rate Rules in an Estimated Sticky Price Model,” in *Monetary Policy Rules*, NBER Chapters, pp. 57–126. National Bureau of Economic Research, Inc.

SAPIR, A., P. AGHION, G. BERTOLA, M. HELLWIG, J. PISANI-FERRY, D. ROSATI, J. VIÑALS, AND H. WALLACE (2004): "An Agenda for a Growing Europe," Discussion paper, Oxford University Press, Oxford.

SCARPETTA, S. (1996): "Assessing the Role of Labour Market and Social Policies on Unemployment: A Cross-Country Study," Discussion Paper 26, OECD.

SCHMITT-GROHE, S., AND M. URIBE (2004a): "Optimal fiscal and monetary policy under imperfect competition," *Journal of Macroeconomics*, 26(2), 183–209.

——— (2004b): "Optimal fiscal and monetary policy under sticky prices," *Journal of Economic Theory*, 114(2), 198–230.

——— (2004c): "Solving dynamic general equilibrium models using a second-order approximation to the policy function," *Journal of Economic Dynamics and Control*, 28(4), 755–775.

——— (2005): "Optimal Fiscal and Monetary Policy in a Medium-Scale Macroeconomic Model: Expanded Version," (11417).

——— (2007): "Optimal simple and implementable monetary and fiscal rules," *Journal of Monetary Economics*, 54(6), 1702–1725.

SHIMER, R. (2005): "The Cyclical Behavior of Equilibrium Unemployment and Vacancies," *American Economic Review*, 95(1), 25–49.

SINKO, P. (2007): "Labour taxation, job creation and job destruction-Focusing on the role of wage setting," *International Tax and Public Finance*, 14(5), 583–604.

SIU, H. E. (2004): "Optimal fiscal and monetary policy with sticky prices," *Journal of Monetary Economics*, 51(3), 575–607.

SMETS, F., AND R. WOUTERS (2007): "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, 97(3), 586–606.

SPECTOR, D. (2004): "Competition and the capital-labor conflict," *European Economic Review*, 48(1), 25–38.

STIGLER, G. J. (1961): "The Economics of Information," *Journal of Political Economy*, 69, 213–225.

STOCK, J. H., AND M. W. WATSON (2005): "Understanding Changes In International Business Cycle Dynamics," *Journal of the European Economic Association*, 3(5), 968–1006.

TAYLOR, J. B. (1993): "Discretion versus policy rules in practice," *Carnegie-Rochester Conference Series on Public Policy*, 39(1), 195–214.

——— (1999): "Introduction to Monetary Policy Rules," in *Monetary Policy Rules*, NBER Chapters, pp. 1–14. National Bureau of Economic Research, Inc.

THOMAS, C. (2008): "Search and matching frictions and optimal monetary policy," *Journal of Monetary Economics*, 55(5), 936–956.

TRIGARI, A. (2004a): "Equilibrium unemployment, job flows and inflation dynamics," Working Paper Series 304, European Central Bank.

——— (2004b): "Labour Market Search, Wage Bargaining and Inflation Dynamics," Working Papers 268, IGIER (Innocenzo Gasparini Institute for Economic Research), Bocconi University.

——— (2006): "The Role of Search Frictions and Bargaining for Inflation Dynamics," Working Papers 304, IGIER (Innocenzo Gasparini Institute for Economic Research), Bocconi University.

——— (2009): "Equilibrium Unemployment, Job Flows, and Inflation Dynamics," *Journal of Money, Credit and Banking*, 41(1), 1–33.

VANHALA, J. (2006): "Labor Taxation, Matching and Shocks in the New Keynesian Model," Computing in Economics and Finance 2006 346, Society for Computational Economics.

WALSH, C. E. (2005): "Labor Market Search, Sticky Prices, and Interest Rate Policies," *Review of Economic Dynamics*, 8(4), 829–849.

WEBER, A. (2000): "Vacancy Durations–A Model for Employer's Search," *Applied Economics*, 32(8), 1069–75.

WILLIAMS, J. C. (2006): "The Phillips Curve in an Eta of Well Anchored Inflation Expectations," Discussion paper, unpublished working paper, Federal Reserve Bank of San Francisco.

WOODFORD, M. (2003a): *Interest and Prices*. Princeton University Press.

——— (2003b): "Optimal Interest-Rate Smoothing," *Review of Economic Studies*, 70(4), 861–886.

ZANETTI, F. (2009): "Effects of product and labor market regulation on macroeconomic outcomes," *Journal of Macroeconomics*, 31(2), 320–332.