JYU DISSERTATIONS 52

Petteri Juvonen

Essays on Labour Market Institutions and Macroeconomic Dynamics

JYVÄSKYLÄ UNIVERSITY
SCHOOL OF BUSINESS AND ECONOMICS

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ABSTRACT

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Labour market reforms play an important role in the public debate and policy recommendations. This thesis aims to find evidence on how labour market institutions are related to economic dynamics and adjustment. The thesis contains an introductory chapter and three essays. The first essay uses data of OECD countries to study whether differences in labour market institutions explain the differences in business cycle dynamics across OECD countries. The second and third essays use theoretical models to study centralized wage-setting and wage-setting coordination.

The results of the first essay suggest that labour market institution variables have explanatory power for the heterogeneity in the volatilities of macroeconomic variables and in shock adjustment. When assessing the scope that labour market reforms could achieve in changing the shock adjustment process of an economy, the results suggest only modest changes. Whether the relation between institutional variables and model parameters is assumed to be deterministic or stochastic is found to have a large impact on the statistical inference.

The second essay shows how centralized wage-setting can be modelled in a contemporary macroeconomic modelling framework and analyses how centralized wage-setting matters for monetary policy and what aggregate welfare consequences centralized wage setting can have. It is illustrated that when the economic environment contains imperfections, wage setting by a large large union that internalizes its actions, has possibility to lead to more optimal allocations than wage setting at the firm level.

The third essay studies wage-setting coordination. The modelling framework is an open economy model, and wage-setting coordination takes place between unions of tradable and non-tradable sectors. The results suggests that in an open economy large wage setters have possibility to increase aggregate welfare over market allocations through the exploitation of terms of trade externality. However, the strategic interaction between labour unions has tendency to bring the economy to a worse equilibrium. It is found that if non-tradable sector wages are pegged to wage developments at the tradable sector when the economy adjusts to shocks, it produces large welfare losses for the non-tradable sector, which speaks against the importance of wage norms set by the tradable sector.

Keywords: Labour market institutions, business cycles, centralized wage-setting, wage-setting coordination

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TIIVISTELMÄ (ABSTRACT IN FINNISH)

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Työmarkkinareformeilla on merkittävä rooli julkisessa keskustelussa ja toimenpidesuosituksissa, mihin pohjautuen väitöskirja tarkastelee, kuinka työmarkkinoiden institutionaaliset rakenteet vaikuttavat talouden sopeutumiskykyyn. Väitöskirja koostuu johdantoluvusta sekä kolmesta tutkimuksesta. Ensimmäisessä tutkimuksessa analysoidaan OECD-maiden aineistolla, selittävätkö erot työmarkkinainstituutioissa maiden välisiä eroja suhdannevaihteluiden dynamiikassa. Toinen ja kolmas tutkimus hyödyntävät teoreettisia malleja ja tutkivat keskitettyä palkanmuodostusta ja palkanmuodostuksen koordinaatiota.

Ensimmäisen tutkimuksen tulosten perusteella eroilla työmarkkinainstituutioissa voidaan selittää maiden välisiä eroja makrotaloudellisten muuttujien dynamiikassa ja sopeutumisessa sokkeihin. Tarkasteltaessa kuinka paljon työmarkkinareformeille voidaan muuttaa talouden sopeutumiskykyä, tulokset viittaavat vain pieniin muutoksiin. Tutkimuksessa havaitaan, että tilastolliseen päättelyyn vaikuttaa huomattavasti, oletetaanko institutionaalisten muuttujien ja mallin parametrien välinen yhteys deterministiseksi vai stokastiseksi.

Toisessa tutkimuksessa esitetään, kuinka keskitettyä palkanmuodostusta voidaan mallintaa nykyisen makrotaloustieteen mukaisessa mallissa sekä analysoidaan, mikä merkitys keskitetyllä palkanmuodostuksella on rahapolitiikalle sekä kokonaistaloudelliselle hyvinvoinnille. Mikäli taloudellinen ympäristö sisältää epätäydellisyyksiä, toimintansa kokonaistaloudelliset vaikutukset sisäistävän suuren ammattiliiton palkanmuodostuksella on mahdollisuus johtaa työpaikkakohtaista sopimista kokonaistaloudellisesti optimaalisempaan tulokseen.

Kolmannessa tutkimuksessa hyödynnetään pienen avoimen talouden mallia ja tutkitaan palkkakoordinaatiota avoimen ja suljetun sektorin ammattiliittojen välillä. Tulokset esittävät, että avoimessa taloudessa suurilla ammattiliitoilla on mahdollisuus palkanmuodostuksellaan saavuttaa markkinapohjaista lopputulosta suurempi kokonaistaloudellinen hyvinvointi. Kuitenkin havaitaan, että ammattiliittojen välisellä strategisella käyttäytymisellä on taipumus viedä talous huonompaan tasapainoon. Mikäli suljetun sektorin palkkakehitys sidotaan avoimen sektorin palkkakehitykseen, tämän havaitaan johtavan suuriin hyvinvointitappioihin suljetulla sektorilla, kun talous sopeutuu sokkeihin, ja näin tulos kyseenalaistaa avoimen sektorin asettaman palkkanormin hyödyllisyyden.

Avainsanat: Työmarkkinainstituutiot, suhdannevaihtelut, keskitetty palkanmuodostus, palkkakoordinaatio

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Helsinki, January 2019
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CONTENTS

ABSTRACT
TIIVISTELMÄ (ABSTRACT IN FINNISH)
ACKNOWLEDGEMENTS
CONTENTS

1 INTRODUCTION 11
1.1 Background and aims of this thesis 11
1.2 Definitions and measurement of labour market institutions 13
1.3 Theories and empirics of labour market institutions and the macroeconomy 17
1.3.1 Large wage setters in general equilibrium models 17
1.3.2 Macroeconomic modeling of institutions related to unemployment 20
1.3.3 Empirical research on labour market institutions and business cycles 21
1.4 Overview of the essays 24
1.4.1 Labour market institutions and business cycle dynamics, VAR analysis 24
1.4.2 Centralized wage setting in a New Keynesian model 24
1.4.3 Wage-setting coordination in a small open economy 25
1.5 Discussion 25
References 29
Appendix 1.A Recommendations to Finland by international organizations 32

2 LABOUR MARKET INSTITUTIONS AND BUSINESS CYCLE DYNAMICS, VAR ANALYSIS 33
2.1 Introduction 34
2.2 Methodology 37
2.3 Data 43
2.4 Results 45
2.4.1 Conditional business cycle statistics 45
2.4.2 Conditional impulse responses 49
2.5 Conclusions 55
References 58
Appendix 2.A Gibbs sampler algorithm for the restricted model 60
Appendix 2.B Gibbs sampler algorithm for the general model 62
Appendix 2.C Simulation of conditional business cycle statistics and impulse responses 66
Appendix 2.D Additional tables and figures 67

3 CENTRALIZED WAGE SETTING IN A NEW KEYNESIAN MODEL ... 76
3.1 Introduction 76

3.2 Model 78
3.3 Dynamics 82
3.4 Sticky wages 86
3.5 Conclusions 88
References 90

4 WAGE-SETTING COORDINATION IN A SMALL OPEN ECONOMY .. 91
4.1 Introduction 92
4.2 Model 93
4.3 Parameterization 103
4.4 Steady state allocations 103
4.4.1 Demand elasticity of exports, γ 106
4.4.2 Share of non-tradables in the production of exports, δ 106
4.4.3 Slopes of best response curves 108
4.4.4 Heterogenous productivities 109
4.5 Dynamics 109
4.5.1 Export demand shock 110
4.5.2 Domestic demand shock 112
4.5.3 Productivity shocks 113
4.6 Conclusions 115
References 117

YHTEENVETO (SUMMARY IN FINNISH) 118

1 INTRODUCTION

1.1 Background and aims of this thesis

The functioning of the labour market is an important determinant of an economy's adjustment to shocks. Labour is integral input of production, and wage income determines the majority of households' purchasing power. Hence, labour market developments matter for both the aggregate supply and demand in an economy. The majority of production costs depend on wages, and hence the cost competitiveness of an economy is ultimately linked to wages. Accordingly, equilibrium in the labour market is a crucial factor in how external demand is translated into demand for domestic production.

In policy recommendations, labour market institutions are seen as important determinants of economic adjustment.[1] Much of the policy discussion of labour market institutions and reforms has reflected the large gap between continental European and US unemployment rates. The gap emerged after the mid 1980s, before which the US unemployment rate was higher. The OECD Job Study in 1994 was a comprehensive survey of labour markets and provided a list of recommendations for governments. Recently, interest in labour market institutions has been renewed in both policy debate and academic research because countries' labour markets differed considerably in how they recovered from the financial crisis of 2008. In the years immediately following 2008, euro area and US unemployment rates were on equal levels, but since then, the US labour market has recovered whereas euro area unemployment has not yet fully recovered from crisis levels. Within the euro area, recovery has also been heterogeneous.

In Europe, labour market reforms have been on the agenda for both the European Commission and European Central Bank in recent years. Labour market reforms are part of the Euro plus pact that was signed in 2011. The pact calls for "reviewing the wage setting arrangements" and the degree of centralization of bargaining mechanisms and suggests labour market reforms that promote flexi-

1 See Blanchard, Jaumotte and Loungani (2013) for the importance of labour market reforms in IMF recommendations for crisis countries

curity in order to foster employment.[2] Structural reforms, including labour market reforms, have played a substantial role also in the communication of the ECB. The ECB sees structural reforms as important for increasing the resilience and the potential output of euro area economies. Monetary policy cannot be tailored to developments in specific countries in a monetary union, and for this reason the member countries should be similar in terms of resilience.[3]

Finland was among the weakest-performing advanced economies in the recent past. It is illustrative to review what recommendations related to its labour market Finland has received from international organizations (OECD, European Commission and IMF) in their country evaluations. For a list of recommendations from the years 2014-2017, see table 2 in the Appendix. The recommendations that Finland has obtained are related to wage bargaining, unemployment insurance, active labour market policies and the pension system. The recommendations aim at increasing flexibility in wage bargaining, aligning wages with productivity developments, and increasing the labour supply.

Given the background that labour market reforms play an important role in policy debate and recommendations, this thesis aims to find evidence on how labour market institutions are related to economic dynamics and adjustment. The thesis contains three essays. The first essay uses macroeconomic data of OECD countries to study whether differences in labour market institutions explain differences in business cycle dynamics across OECD countries. The second and third essays use theoretical models to study centralized wage-setting. The second essay shows how centralized wage-setting can be modelled in a contemporary macroeconomic modelling framework and analyses how centralized wage-setting matters for monetary policy and what aggregate welfare consequences centralized wage setting can have. The third essay studies wage-setting coordination. The modelling framework is an open economy model, and wage-setting coordination takes place between unions of tradable and non-tradable sectors. The essay analyses if and what sort of wage coordination is optimal for a small open economy when it is exposed to both external and domestic shocks.

Labour market reforms are typically advocated because of their impact on the macroeconomy and aggregate labour market. Hence, it is important that labour market institutions can be modelled using the methods that form the backbone of contemporary macroeconomic analysis. A common feature of the essays in this thesis is that in each essay, a relatively old research question is analysed with a novel methodology. In the first essay, the methodology is based on a time varying parameter vector autoregressive model and on a variant of Bayesian shrinkage. The second and third essays use dynamic stochastic general equilibrium (DSGE) models to study the wage-setting of large unions.

The rest of the introduction is structured as follows. Section 1.2 presents definitions and country comparisons for the most important labour market institutions in terms of the research in this thesis. The relevant research literature is

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2 Flexicurity refers to a combination of weak employment protection legislation and high level of unemployment benefits.

3 See Draghi (2015).

reviewed in section 1.3. Section 1.4. gives an overview of the essays of this thesis and section 1.5 concludes.

1.2 Definitions and measurement of labour market institutions

Labour market institutions can be defined as "system(s) of laws, norms, or conventions resulting from a collective choice and providing constraints or incentives that alter individual choices over labour and pay" (Boeri and van Ours, 2013). Unemployment benefits, employment protection, collective bargaining, working hours legislation and the design of income taxation are examples of labour market institutions that are often mentioned in policy recommendations and public debate.

Country comparisons and policy analysis of institutions require that institutions are conceptualized so that they are measurable. At the extreme, when comparisons and analysis are conducted using quantitative methods, this requires that institutional characteristics are mapped to numerical variables. A major actor in this field has been the OECD. Besides doing country comparisons, the OECD has collected data on labour market institutions. To illustrate how labour market institutions are measured and how much variation there is between countries with regard to their institutions, a few labour market institutions are introduced below.

Employment protection legislation (EPL) refers to rules governing the hiring and firing of workers. This legislation is captured in an index calculated by the OECD. The main index is aggregated from four subindexes (OECD 2013). Two of the subindexes measure the employment protection of regular workers against individual and collective dismissal and the other two measure the regulation of fixed term-contracts and employment agencies. The subindexes are calculated based on 21 measures that are obtained by analysing national laws and collective agreements. These measures include, for example, the lengths of notice periods for different tenures of employment and the number of additional notification requirements for collective dismissal compared to individual dismissal.

EPL-index for OECD countries in the 2013 is shown in Figure 1. Anglo-Saxon countries are clearly below the average both in terms of employment protection of permanent workers and regulation of temporary forms of employment. Otherwise, differences in the employment protection of permanent workers are relatively small, and most of the variability in the overall strictness stems from the regulation of temporary forms of employment.

All developed economies have a public unemployment insurance scheme, but the generosity of these schemes varies. There are differences in the eligibility criteria, lengths and monetary amounts of transfers. OECD collects and publishes statistics on monetary transfers to the unemployed by calculating replacement rates (REP). The replacement rate is the ratio of received unemployment benefits to income before unemployment. Since countries differ in the progression of tax-

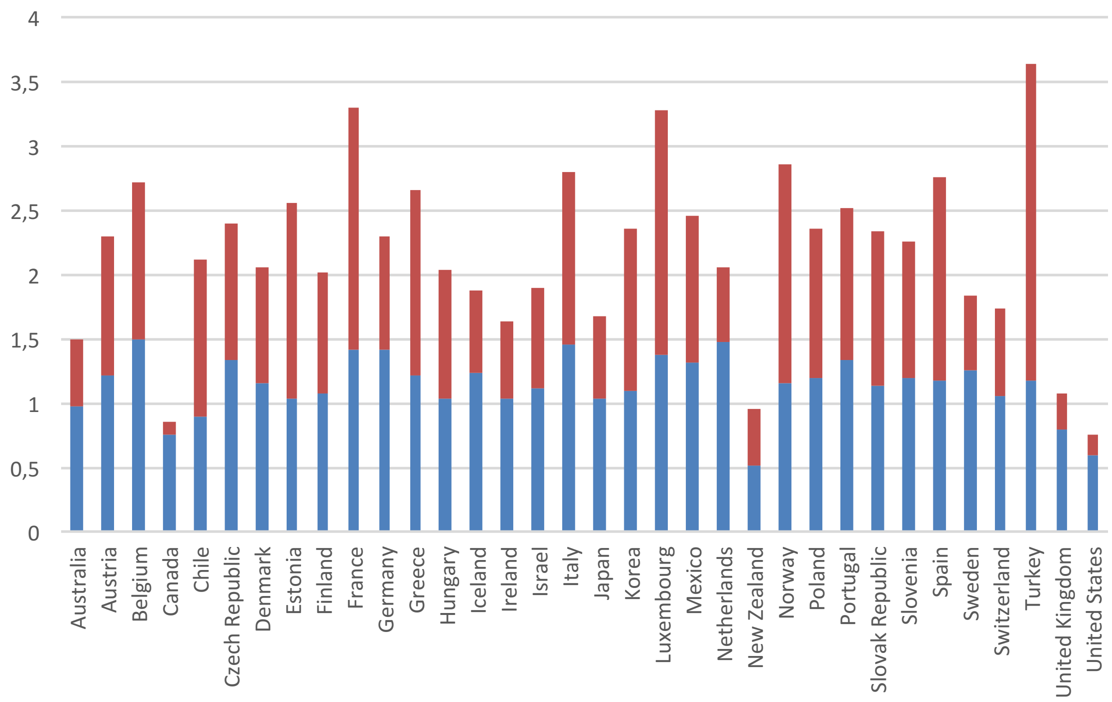

Figure 1. Employment protection index, OECD countries, 2013. Blue bars refer to protection of permanent workers against individual and collective dismissals; red bars refer to regulation of temporary forms of employment.

ation, the OECD calculates net replacement rates that measure after-tax benefits to after-tax income. Progression of taxation causes the net replacement rates of individuals to differ according to their income levels. Typically, the level of unemployment benefits depends somewhat but not completely on past income, and for this reason, replacement rates differ according to past income levels. Hence, the OECD publishes statistics for different income quintiles for each country. Figure 2 displays the average of net replacement rates over the income quantiles, for both the short-term unemployed and the long-term unemployed. Countries differ in their overall levels of replacement rates and also in the gap between the replacement rates of the short- and long-term unemployed.

An issue related to unemployment benefits is the coverage of public unemployment insurance. According to the calculations of Boeri and Van Ours (2013), in EU countries in 2010, the coverage of unemployment benefits schemes varied from 10 % (Greece) to 100 % (Denmark, Finland, Norway, Slovakia, UK).

A great deal of heterogeneity across countries is related to wage bargaining institutions. Wage bargaining systems are characterized by several measures, some of which are displayed in Table 1. The data on wage bargaining institutions is obtained from the ICTWSS database.[4] Wage setting centralization measures the level at which wages are predominately negotiated, measured on a five-level scale. The levels are firm, industry and national levels or mixtures of these main

[4] Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts.

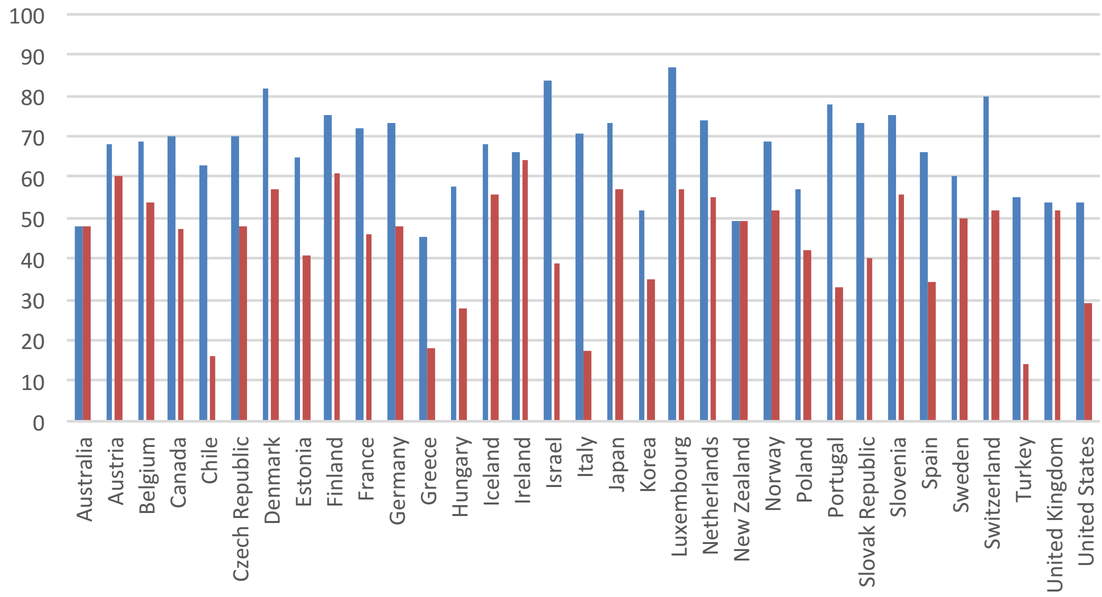

Figure 2. Net replacement rates, OECD countries, 2015. Calculated as net of unemployment benefits to net income before unemployment. Blue bars refer to unemployment benefits during the first month of unemployment, red bars to unemployment benefits during the 60th month of unemployment.

levels. Coordination is a measure of how the wage bargaining parties internalize the effect of their wage setting on the aggregate wage. Typically, coordination takes place through pattern bargaining. In pattern bargaining, the wages are bargained at the industry level but there exists an established ordering according to which the wages are bargained across sectors. Usually, the wage bargaining round is started by a union in the manufacturing sector. Since the union that starts the wage bargaining round knows that the wage agreement in its sector is taken as a reference by the following sectors, the union needs to account for how its wage bargaining affects the aggregate economy.

Table 1 displays data on centralization, coordination and type of coordination. In these institutional dimensions, countries also display considerable heterogeneity. In almost all continental European countries, the level of bargaining is higher than the firm level, whereas for other countries, the predominant bargaining level is the firm level. In most of the continental European countries, the predominant level of bargaining is sectorial. In addition, among these countries, wage-setting coordination through pattern bargaining is implemented in Austria, Germany, Denmark and Sweden.

	Level of bargaining					
	Firm		Sectorial	National	Coordination	Pattern bargaining
Austria			x		4	x
Belgium				x	5	o
Germany			x		4	x
Finland				x	5	o
France		x			2	o
Ireland	x				3	o
Italy			x		3	o
Netherlands			x		3	o
Portugal			x		3	o
Slovakia		x			2	o
Australia	x				2	o
Canada	x				1	o
Denmark			x		4	x
Japan	x				4	x
New Zealand	x				1	o
Norway			x		4	o
Sweden			x		4	x
Korea	x				3	
New Zealand	x				1	o
Poland	x				1	o
Switzerland			x		3	o
UK	x				1	o
USA	x				1	o

Table 1. Wage bargaining in OECD countries, 2013.

1.3 Theories and empirics of labour market institutions and the macroeconomy

1.3.1 Large wage setters in general equilibrium models

Theoretical macroeconomic models employs the concept of the representative agent. It is typically assumed that the model economy consists of an infinite number of agents, but agents are similar enough that their behaviour can be modelled by focusing on one average agent in each class. A model with an infinite number of firms and households reduces to a model of a single representative firm and a single household. The model is solved by solving the optimization problems of the representative firm and household. Typically, the representative firm maximizes profits by deciding on prices and/or labour and capital demand. The representative household maximizes utility by deciding on labour supply, consumption and savings. In addition, the model can include government that decides on taxation and public spending and a monetary authority that decides on money supply or interest rate.

In benchmark models, wages are determined between a household and a firm. Although a model consists of only one representative household and one firm, it is assumed that these agents are infinitesimally small and thus atomistic. This means that these agents do not consider their decisions to have an effect on each other's decisions and aggregate variables. For example, the representative household takes the aggregate wage rate as given and does not consider its own wage to have an effect on the aggregate wage rate.

This sort of modelling of the labour market is empirically appealing for economies where wages are actually negotiated mostly at the firm level, most notably the US and the UK among advanced economies. However, in several countries, labour unions have an influential role in wage formation. As labour unions represent the workers of an industry or industries, the labour unions cannot take economy-wide variables as given. Labour unions and employers' federations are non-atomistic, as opposed to households and firms that are atomistic. In terms of modelling, the non-atomicity of an agent makes a great difference. When a labour union makes an optimal wage decision, it cannot take aggregate variables as given. Instead it needs to take into consideration in its optimization problem how its wage decision affects the aggregate variables.

The macroeconomic modelling of large, non-atomistic labour unions was first introduced in Calmfors and Driffill (1989). They set up a model that explicitly consists of 64 industries. The industry site of the model features a tree structure where individual industries are aggregated to intermediate industries, which in turn are aggregated to a smaller number of industries. The hierarchical setting gives rise to five levels of wage-setting where the lowest level corresponds to firm-level wage formation and the highest to fully centralized wage formation. The main finding of Calmfors and Driffill (1989) is that the firm level and fully centralized wage formation produce lower real wages and smaller deviations from full employment than do the intermediate wage-formation regimes. This finding is known as the Calmfors-Driffill hypothesis.

In the model of Calmfors and Driffill (1989), the products of industries are imperfect substitutes and hence the elasticity of demand is not infinite. A single union has a tendency to set a higher real wage than the aggregate real wage. This will reduce the employment in that sector, but the utility loss due to lower employment is more than offset because of the higher consumption level for a given labour input. In the end, all unions act similarly. As all unions aim at setting a wage rate higher than the aggregate wage, the resulting aggregate, is higher. When unions are large, they anticipate the adverse effect of their wage setting, which disciplines wage setting at the more centralized levels. At the lower level, in turn, the unions have less monopoly power, which also disciplines wage-setting. In Garcia and Sorolla (2016) and Krusell and Rudanko (2016) the Calmfors and Driffill -hypothesis is obtained with models featuring search and matching frictions in the labour market.

Much of the literature that followed Calmfors and Driffill (1989) has focused on strategic interaction between the central bank and large unions. In Calmfors and Driffill (1989), the money supply is assumed to be constant, and the model does not feature a response of monetary authority to wage setting. Iversen and Soskice (2000), Cukierman and Lippi (1999) and Lippi (2003) set up general equilibrium models with endogenous monetary policy and large wage setters. What these studies discover is that monetary policy can have long-run real effects. This is a feature that the conventional models with atomistic wage and price setters do not have.

In the models with atomistic wage and price setters, monetary policy can only have short-run effects on employment and output, but for the long run, the monetary policy can influence only the nominal side of the economy, nominal price and wage levels. When wage setters (or price setters as in Iversen and Soskice (2000)) are non-atomistic, they anticipate how their own behaviour affects the response of monetary authority. Hence, the behaviour of large wage setters is conditional on the chosen monetary policy. If monetary policy is changed, the behaviour of wage setters is also altered permanently and monetary policy can therefore have permanent effects.

The models in Iversen and Soskice (2000), Cukierman and Lippi (1999) and Lippi (2003) are static, as opposed to the dynamic stochastic general equilibrium (DSGE) models that are used in the contemporary macroeconomic modelling and monetary policy analysis. Gnocchi (2009) brings non-atomistic wage setters to the DSGE modelling framework. In DSGE models, the agents are forward-looking, meaning that agents form expectations of the future paths of variables, and this affects their decision-making. DSGE models also feature stochastic component(s) in a form of shock processes. This means that the model is perturbed away from the steady state equilibrium allocation that would exist in the absence of shocks. As Gnocchi (2009) models non-atomistic wage setters in a DSGE model, this enables studying the influence of large wage setters on adjustment to shocks in addition to their influence on steady state allocations.

As in Iversen and Soskice (2000), Cukierman and Lippi (1999) and Lippi (2003), the main research aim in Gnocchi (2009) is to study the interaction between large wage setters and monetary policy and its implications for optimal monetary policy. In order to study monetary policy in a dynamic model, it is necessary to have a market imperfection that makes the responses of agents to shocks suboptimal. Gnocchi (2009) assumes that product markets are imperfect and prices are sticky, which is a typical assumption in the New Keynesian literature.[5]

Gnocchi (2009) assumes that the labour market is monopolistically competitive because of the differentiated labour force, which makes the steady state allocation suboptimal. In the case of an atomistic labour force, monetary policy would not have any effect on the steady state allocation. In the case of non-atomistic wage setters, the wage setters anticipate that their wage demands affect the aggregate wage and price level, which in turn affects the central bank response and real economic activity. Therefore, in the case of non-atomistic wage setters, the central bank can affect wage setting through its aggressiveness with regard to inflation stabilization. The interaction channel is more effective the more centralized the wage setting is. Hence, Gnocchi (2009) argues that if wage-setting centralization is not taken into account, the models for monetary policy can underestimate the welfare benefits of strict inflation stabilization in the context of countries with centralized wage setting. In terms of dynamics, Gnocchi (2009) does not find differences between models with non-atomistic and atomistic wage setters.

The studies reviewed above focus on the strategic interaction between unions and the central bank. In these studies, the unions take each other's actions as given. The only strategic interaction takes place between the monetary authority and the unions. One institutional feature among several countries with unionized wage setting is that there exists an established pattern in the bargaining. Typically, the pattern has been that a union in the manufacturing sector begins the bargaining round. The wage leader anticipates that the wage it sets affects the wage bargaining of other sectors. Calmfors and Seim (2013) set a model of a small open economy with non-tradable and tradable sectors. In both sectors, there exists a union that bargains the wage for its sector. Pattern bargaining is modelled as a Stackelberg game, and the results are also compared to uncoordinated bargaining, which is modelled as a Nash game. The results of Calmofs and Seim (2013) question the conventional wisdom that tradable sector wage leadership leads to wage moderation. The model in Calmfors and Seim (2013) is static, and hence the effect of the wage-bargaining regime on adjustment to shocks is not studied. Also, Vartiainen (2003) and Holden (2003) have modelled wage setting coordination in an open economy. In their setups, there are several unions in both sectors but the coordination takes place between unions in the same sector, not between sectors.

5 For a seminal contribution see Clarida, Galí and Gertler (1999).

1.3.2 Macroeconomic modeling of institutions related to unemployment

The benchmark DSGE models feature only the intensive margin of employment. The changes in labour inputs to production arise only from the hours worked by the employees. In benchmark models, unemployment is also neglected, and the models do not feature households who were willing to work but are unable to do so. Also, the changes in employment are frictionless. Firms are always able to use the amount of labour input that is optimal. To model institutions related to unemployment, the design of unemployment insurance and employment protection legislation, extensions to prototype DSGE models are needed in terms of the modelling of the labour market. Zanetti (2011) and Campolmi and Faia (2011) are the seminal studies to model unemployment benefits and employment protection in DSGE models. Both studies use the search and matching framework to model frictional labour markets and unemployment.

The search and matching framework of Mortensen and Pissarides (1994) models the labour market through flows in and out of unemployment (see e.g. Pissarides (2000)). In each period, some of the workers lose their jobs and start searching for new jobs. Firms post vacancies, and once an unemployed person and a vacant job are matched, the firm and the unemployed person bargain over the wage. Vacancies are not filled instantaneously, and the searching workers do not find vacant jobs iinstantaneously. Instead, these matches take place with certain probabilities, which creates frictional unemployment. There is a large literature that employs the search and matching framework within a DSGE model; the seminal contributions include Hall (2005), Trigari (2006) and Gertler, Sala and Trigari (2008). Still, relatively few studies have attempted to explicitly model labour market institutions in a DSGE model with search and matching frictions.

Zanetti (2011) models unemployment benefits and employment protection in a DSGE model with search and matching frictions. The firing costs are modelled as taxes that a firm needs to pay when a worker is dismissed. Unemployment benefits are modelled as a transfer that an unemployed person receives from the government. Higher firing costs decrease the profitability of layoffs and hence adjustment to negative shocks takes place more through prices and wages. In addition, firms anticipate that increasing current employment increases the risk of costly layoffs in the future. These channels make employment and unemployment less responsive to shocks, and their volatilities are decreased.

An increase in the replacement rate increases the value of unemployment, and the real wage needs to be higher so that a worker will be willing to accept the job that is offered. This increases the steady-state real wages. Zanetti (2011) assumes productivity distribution for the workers. Given the economic conditions, there is always a threshold level of productivity, and only workers who have higher productivity than this threshold are hired; or, if already employed, their jobs are not destroyed. Zanetti (2011) assumes log-normal distribution for the productivity distribution of the workers. When the productivity threshold increases, the number of workers near the critical threshold also increases because of the bell-shaped distribution. An increase in the replacement rate increases the real wages and threshold productivity. Then, fever workers are above the threshold and the employment rate is lower. In addition, more workers are closer to the threshold, and this increases the need for firms to adjust employment when shocks take place. This increases the volatilities of unemployment and employment as well as of flows into and out of employment.

Campolmi and Faia (2011) employ a similar model as in Zanetti (2011) but in an open economy setting, and they try to explain observed inflation rate differentials among EMU countries. Empirical analysis in Campolmi and Faia (2011) suggests that there exists a negative relationship between replacement rates and inflation volatility in a data set for EMU countries. A similar relationship is matched with the model in Campolmi and Faia (2011). Higher replacement rates imply higher steady-state wages, which in turn decrease the steady state profits of firms. For a given productivity shock, this implies higher percentage changes in firms' profits and hence the incentives to post vacancies and layoff workers are higher for firms if replacement rates are high.

In the literature cited above, the approach has been to compare the dynamics that different calibrations of a DSGE model produce. Cacciatore *et al.* (2016) study labour and product market reforms in an open economy DSGE model with search and matching frictions. Reforms are modelled as permanent changes in certain parameters, but in addition to comparisons of steady state equilibria, transitionary dynamics are also studied. In general, Cacciatore *et al.* (2016a) find the long-term effects of reforms to be welfare-enhancing, but in the short-term, there is a welfare cost that is amplified if the monetary policy is constrained at the zero lower bound. Similarly to Zanetti (2009), employment protection is modelled as firing costs and replacement rate as a transfer that unemployed workers receive. In addition, activation policies are modelled as simultaneous changes in the probability of an unemployed person finding a job and in the value of home production.

The analysis is taken one step further in Cacciatore *et al.* (2016b), in which the simulations are conditioned on the state of the economy. Compared to product market reforms, the effects of labour market reforms are more sensitive to the state of the economy. Employment protection reform during a recession delivers significantly larger and more persistent welfare costs than when the economy is at the steady-state equilibrium. Unemployment reform increases employment and output more when implemented in a recession than in normal times. Cacciatore, Fiori and Ghironi (2016) study optimal monetary policy in a monetary union when structural reforms are implemented and suggest that expansionary monetary policy is optimal during transitionary periods after structural reforms.

1.3.3 Empirical research on labour market institutions and business cycles

Literature on the relation between labour market institutions and business cycle dynamics has focused on two questions. First, are labour market institutions related to shock adjustment? Second, can labour market institutions explain cross-country heterogeneity in the business cycle statistics, in the volatilities and correlations of macroeconomic variables? These questions are interrelated, and several articles address both questions, but distinct methodologies are needed to answer these questions. To explain cross-country heterogeneity, country-specific business cycle statistics are first calculated, and then statistical relation to labour market institutions is analysed using regression or correlation coefficient analysis. To explain differences in the adjustment, a dynamic econometric model is specified to macro panel data. The variation in adjustment is implemented by allowing for parameter variation that depends on labour market institutions or by including interaction terms of macroeconomic and labour market institution variables.

A seminal paper in the study of adjustment is Blanchard and Wolfers (2000). They argue that neither labour market institutions nor adverse economic shocks alone can explain the high European unemployment of the 1990s. Instead, Blanchard and Wolfers (2000) provide evidence that the interaction of shocks and institutions explains high European unemployment. Adverse shocks have had an impact on unemployment, but adjustment has depended on labour market institutions. Blanchard and Wolfers (2000) focus on the adjustment of unemployment. They consider both unobserved and observed shocks. Unobserved shocks are identified as time fixed effects, a common fluctuation in the unemployment data. The observed shocks are total factor productivity, real interest rate and labour share shocks. The responses of unemployment to these shocks are simply obtained by regressing unemployment on the series of total factor productivity, real interest rate and labour share. Nickell, Nunziata and Ochel (2005) question the importance of interactions between shocks and institutions. Their results suggest that the evolution in European unemployment between 1960-1990 can largely be explained by changes in labour market institutions and that the interactions of shocks and institutions add very little explanatory power.

Both Blanchard and Wolfers (2000) and Nickell *et al.* (2005) rely on single equation models to explain the adjustment of unemployment. A central theme in contemporary macroeconomics has been to identify economically interpretable shocks and study the effects of these shocks on macroeconomic variables. This approach relies on vector autoregressive (VAR) models pioneered by Sims (1980). VARs are multi-equation systems typically consisting of three to twenty variables and equations. Each variable is explained with its own lags and the lags of all other variables in the system. The unexplained variation is assumed to be caused by structural shocks, and structural shocks can be recovered from the residuals through identification assumptions.

The early literature by Blanchard and Wolfers (2000) and Nickell *et al.* (2005) on the adjustment of unemployment and institutions is at odds with contemporary macroeconometric research in several ways. The shocks in these papers are observable variables that include the real interest rate, growth rate of the money supply, total factor productivity growth, and proxy for labour demand. The relation of shocks to unemployment is obtained by regressing unemployment to contemporaneous values of the shock variables. However, since the shock variables cannot be claimed to be fully exogenous, the link between shock variables and the dependent variable, unemployment, cannot be taken as a causal relation.[6] Hence, the regression estimates for the relation between shock variables and unemployment reflect co-movement of these variables more than causal relations. This endogeneity problem does not necessarily mean that the estimates for the interaction of labour market institution variables and shock variables was biased, but the interpretation is less clear. The coefficients for the interaction terms tell how labour market institution variables are linked to co-movement of macro variables, for example unemployment and real interest rate, and not how labour market institution variables are linked to the response of unemployment to real interest rate shocks.

The relation of labour market institutions to shock adjustment in the contemporary macroeconometric framework is studied in Abbritti and Weber (2010, 2018) and Georgiadis (2014).[7] In these papers, a VAR model is specified and the parameters of the VAR are assumed to depend on labour market institution variables. Abbritti and Weber (2018) include in the VAR unemployment rate, inflation and interest rate as endogenous variables. The results suggest that in countries where employment protection is high and the labour force is highly unionized, the responses of unemployment to external shocks (world demand and oil price shocks) are smoother but inflation responds more strongly. High unemployment benefits and high tax wedges in turn amplify the unemployment response to shocks. Some institutions amplify and others moderate unemployment responses, but if these institutions are highly correlated, the responses of unemployment can be similar in countries with weak and strong institutions. Georgiadis (2014) studies asymmetries in monetary transmission and finds that employment protection legislation has explanatory power.

A strand of literature has focused on estimating the link between business cycle statistics and labour market institution variables. In this literature, a typical approach is to calculate a set of business cycle statistics for a group of countries and then explain the variability of the estimated statistics with labour market institutions using regression or correlation coefficient analysis. Rumler and Scharler (2011) find that union density increases output volatility and coordination of wage bargaining lowers inflation volatility. Gnocchi, Lagerborg and Pappa (2015) study the relation between a large set of labour market institution variables and business cycle statistics by extracting factors from the labour market institution data. The main finding is that more flexible institutions are associated with lower business cycle volatility. In addition, Gnocchi *et al.* (2015) study the impact of labour market reforms with a differences-in-differences approach. The results suggest that wage-bargaining reforms increase the correlation of the real wage with labour productivity and the volatility of unemployment. Employment protection legislation reforms increase the volatility of employment and decrease the correlation of the real wage with labour productivity. Reforms reducing replacement rates make labour productivity more pro-cyclical.

6 E.g. the real interest rate and money supply growth could both depend on the unemployment rate if the monetary authority responded to real economic activity.

7 Also, Towbin and Weber (2010) and Sa, Towbin and Wieladek (2014) apply similar methodology but the subject is different

1.4 Overview of the essays

1.4.1 Labour market institutions and business cycle dynamics, VAR analysis

This essay studies how labour market institutions are related to business cycle dynamics. For a panel of OECD countries, I estimate a vector autoregressive (VAR) model in which the parameters are assumed to depend on labour market institution and control variables. I study how employment protection, generosity of unemployment benefits and degree of coordination and centralization in the wage setting are related to short run dynamics of wages, unemployment, GDP and labour productivity.

The methodology is based on the time-varying parameter VAR framework outlined originally in Cogley and Sargent (2005) and Primiceri (2005). I link the parameter variation to labour market institutions and control variables, but I allow for unexplained parameter variation. The model is very generous and hence over-parameterized. For this reason, Bayesian shrinkage is employed. I apply the Bayesian Lasso by Park and Casella (2008)[8] following Belmonte, Koop & Korobilis (2014), who provide an application to the time-varying parameter framework. The results are obtained by comparing the second moments (volatilities and correlations) and impulse response functions that the model implies conditional on certain values for labour market institution variables.

Results suggest that labour market institutions have explanatory power for the heterogeneity in the volatilities of macroeconomic variables and in shock adjustment. In countries with high coordination in wage bargaining, wages are less volatile and respond less to productivity shocks. In countries with strict employment protection legislation, wages are less volatile and unemployment is less responsive to external demand shocks. If unemployment benefits are generous, unemployment and wages are more responsive to productivity shocks. The explanatory power of labour market institutions for business cycle heterogeneity seems to be comparable to that of the control variables used (trade to GDP, government consumption to GDP and Euro dummy). When assessing the scope that labour market reforms could achieve in changing the shock adjustment process of an economy, the results speak to only modest changes. Whether the relation between institutional variables and VAR parameters is assumed to be deterministic or stochastic is shown to have a large impact on the statistical inference.

1.4.2 Centralized wage setting in a New Keynesian model

In this essay, centralized wage-setting is studied in a New Keynesian model. The essay aims to study the implications of national-level wage bargaining for aggregate dynamics and monetary policy. A single, large union sets the wages for the whole economy and takes into account the aggregate effects of its wage setting. A novel method to model the wage setting of a large union is developed. It is found

[8] LASSO is an acronym for least absolute shrinkage and selection operator

that when the union maximizes the utility of the representative household, optimal wage-setting stabilizes price the level, and monetary policy should put more weight on output gap stabilization. Wage stickiness is modelled in a way that is relevant in the context of centralized wage-setting. Contrary to Calvo-type staggered wage-setting, unions set the wages for a fixed period, and the length of the period is known when wages are set. Given the same average length of wage agreements, welfare losses are smaller when wages are set by large unions than atomistic (household) unions.

1.4.3 Wage-setting coordination in a small open economy

This essay studies wage-setting coordination in a two-sector open economy model. Wages are set by sector-specific non-atomistic unions that anticipate the effects of their wage demands on aggregate variables. A method to model the strategic interaction of large agents in a dynamic stochastic general equilibrium model is developed. It is found that in terms of steady state, large wage-setters can increase the aggregate welfare over competitive market allocation through the exploitation of the terms of trade externality. However this happens only when the strategic interaction is minimal, if unions play a Nash game, or if either of the unions sets the wage for both sectors. In pattern bargaining, a Stackelberg game, strategic behaviour eats the aggregate surplus and only the leader gains at expense of the follower. Hence, the steady state results of this paper do not support the importance of wage leadership of the tradable sector or pattern bargaining in general. In terms of dynamics, it is found that if non-tradable sector wages are pegged to wage developments at the tradable sector, this produces large welfare losses for the non- tradable sector. These results speak against the importance of wage norms set by the tradable sector.

1.5 Discussion

With the essays in this theses, I analyze how labour market institutions are linked to macroeconomic dynamics and adjustment. The research is motivated by the background that labour market reforms play an important role in policy recommendations and public debate. All the essays contain methodological development that was required to bring the analysis more in line with contemporary macroeconomic research.

In the first essay, the empirical analysis is conducted in a way that allows to take more consistently into account the estimation uncertainty when studying relations between institutional variables and macroeconomic dynamics. Compared to previous literature by Abbritti and Weber (2018) and Gnocchi *et al.* (2015), the results in this essay show weaker relations between labour market institution variables and macroeconomic dynamics. The methodology used in the first essay and that of Abbritti and Weber (2018) are similar, with the distinction that while

Abbritti and Weber (2018) assume a deterministic relation between labour market institution variables and the VAR parameters, I assume the relation to be stochastic. Using applications similar to mine, Western (1998) and Wieladek (2016) also show that assuming deterministic relations instead of stochastic relations leads to higher statistical significance. Still, the situation is not straightforward. A legitimate question is the following: is it possible to fully take into account all the estimation uncertainty in this kind of research without making the model so complex that the relations are already statistically insignificant from the moment of setup?

The modelling of large wage setters in a DSGE model required developing a new methodology. Previously, only Gnocchi (2009) has modelled large wage setters in a DSGE model. The approach in Gnocchi (2009) is to obtain the effect of union size on the macroeconomy by relating the number of unions to the average wage mark up. The approach is similar to that in the older literature, which used static models to analyse the implications of centralized wage-setting on monetary policy (e.g. Lippi (2003)). However, the approach in Gnocchi (2009) requires there to be more than one union and a closed-form solution to the relation between the mark up and number of unions, which is impossible to obtain with more complex models. The way the wage-setting of unions in this thesis is modelled borrows from how optimal monetary and fiscal policy are modelled in the DSGE literature, e.g. Schmitt-Grohé and Uribe (2007), as Ramsey optimal policies.

In the third essay, wage-setting coordination between large unions is studied. Previously, wage-setting coordination has been studied using static models (e.g., Calmfors and Seim (2013)). Hence, the implications of wage-setting coordination on dynamic adjustment on shocks have not been studied. In the third essay, wage setting coordination is studied as games between two Ramsey planners.

What can be credibly assessed with the methodologies that I have developed in this thesis? The first essay suggests that the relation between labour market institutions and macroeconomic dynamics is weaker than found in the previous literature. As the literature in this field is relatively limited and evidence is mixed, but the role of labour market reforms in the recommendations of international organizations is large, the situation is cumbersome and naturally calls for more research on this topic. Emphasis should be put on credible causal identification of the effects of labour market reforms.

The second essay suggests, contrary to the previous literature, that centralized wage-setting is non-trivial for the implementation and objectivities of monetary policy. It also shows that when the economy faces macroeconomic shocks, large wage-setters that do not take aggregate variables as given have the potential to enhance economic adjustment. As the same average length of wage agreements in models with centralized and decentralized wage-setting produced considerably different dynamics, the results of this essay illustrate how similar degrees of micro-level and macro-level rigidities can lead to fairly different aggregate dynamics when aggregate shocks are driving the economy. The results favour wage-setting centralization but still need to be viewed against the fact that by definition wage-setting in this essay is socially optimal. All more-realistic scenarios would be deviations towards less efficient outcomes.

The results of third essay question whether the large role of the tradable sector in wage-setting is actually optimal for the aggregate economy. The findings are consistent with Calmfors and Seim (2013). Most importantly, it is illustrated that if non-tradable sector wages are set to follow tradable sector wages as a norm, this produces inefficient aggregate outcomes. Since the economic environments that non-tradable and tradable sectors face are different, sector-specific adjustment is needed. Also, where the tradable sector is the wage leader, the results do not find pattern bargaining to be optimal for aggregate welfare. The results of a theoretical model are functions of assumptions. Given a different economic environment, the results might be reversed. According to conventional wisdom, tradable-sector-oriented wage bargaining is considered to produce efficient macroeconomic adjustment, but this raises the following question: assuming that the tradable sector union acts to maximize the welfare of the households that it represents, what aspects (that the model in this essay neglects) in the economic environment are needed in order to make the wage leadership or wage norm of the tradable sector optimal for the aggregate economy?

The main contribution of this thesis is methodological. The essays in thesis develop methodologies to analyse labour market institutions more credibly within the framework of contemporary macroeconomics. This is important because labour market reforms are advocated because of their potential effects on the macroeconomy and aggregate labour market, not on specific firms, sectors or groups of people. Hence, the analysis of labour market institutions requires evaluation through macroeconomic methodology. The first essay of this thesis develops methodology to study the relation of labour market institutions on macroeconomic adjustment. The methodology in the first essay allows us to study the relation of labour market institutions to macroeconomic adjustment in an econometrically more consistent manner. The second and third essays develop methodology to study the wage-setting and wage-setting coordination of large unions in a contemporary DSGE framework. Previously, only centralized but uncoordinated wage setting has been studied in a DSGE model (in Gnocchi (2009)), and that approach was restricted to a stylized model. By contrast, the approach in this thesis is extendable to larger models. The analysis of wage-setting coordination in the previous literature has been restricted to static models (Calmfors and Seim (2013), Vartiainen (2003) and Holden (2003)), and with static models, quantitative analysis of shock adjustment is not possible.

On the substance side, the results of this thesis are mixed when compared to the previous literature. The empirical analysis of the first essay suggests that the relation of labour market institutions to business cycle dynamics is weaker than found in the previous literature (Gnocchi *et al.* (2015) and Abbritti and Weber (2018)). On the other hand, the theoretical analysis in the second and third essays suggests that the degrees of centralization and coordination can change the dynamics of an economy considerably. It should be acknowledged that the theoretical analysis in this thesis employs relatively stylized models. Hence, in future research, wage-setting centralization and coordination should be studied in larger and empirically more relevant models to bridge the gap between purely empirical and theoretical results.

Although I have concluded that according to the results in the first essay, the relation of labour market institutions to business cycle dynamics is weaker than found in the previous literature, the relation still exists. Even if the evidence is relatively weak compared to the strong role of labour market institutions in the policy recommendations of international organizations, the results do not support simply ignoring labour market institutions. Instead, deeper analysis is required because the evidence on how labour market institutions shape the dynamics of economies is mixed in the literature.[9] The second and third essays show that the internal consistency of policy recommendations on wage setting can be evaluated using a DSGE model. As in Calmfors and Seim (2013), the results in the third essay question the conventional wisdom that the wage leadership of the export sector is optimal for the whole economy. This result illustrates that the way wage-setting coordination affects economic dynamics is relatively complex. Hence, the analysis of labour market institutions through carefully specified structural models is helpful in delineating the premises and the logic of policy recommendations on labour market institutions.

[9] Table 2 on page 45 summarizes the literature on labour market institutions and business cycle dynamics.

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Appendix 1.A Recommendations to Finland by international organizations

Table 2. Recommendations to Finland by international organizations

Report	Recommendation
OECD(2016)	"Reduce taxes on labour to improve work incentives and raise recurrent taxes on personal immovable property and indirect taxes." "Shorten the duration of unemployment benefits and reduce benefits over the spell." "Enforce mandatory job search." "Strengthen the role of state mediator and local level unions in the wage setting process to raise local flexibility without compromising competitiveness." "Negotiations should be sequenced such that trade-exposed industries settle before the others."
OECD(2014)	"Strengthen active labour market policies to improve the labour force participation of youth, women of childbearing age and the long-term unemployed."
European Commission (2017)	"Promote the further alignment of wages with productivity developments, fully respecting the role of social partners. Take targeted active labour market policy measures to address employment and social challenges, provide incentives to accept work and promote entrepreneurship."
European Commission (2016)	"While respecting the role of social partners, ensure that the wage setting system enhances local wage bargaining and removes rigidities, contributing to competitiveness and a more export industry-led approach. Increase incentives to accept work and ensure targeted and sufficient active labour market measures, including for people with a migrant background. Take measures to reduce regional and skills mismatches."
European commission (2015)	"Adopt the agreed pension reform and gradually eliminate early exit pathways Promote wage developments in line with productivity fully respecting the role of the social partners and in accordance with national practices."
European commission (2014)	"Improve the use of the full labour force potential in the labour market, including by improving the employment rate and the employability of older workers, and increasing the effective retirement age, by reducing early exit pathways and aligning the retirement age or pension benefits to changes in life expectancy. Improve the labour-market prospects of young people and the long-term unemployed, with a particular focus on vocational education and targeted activation measures."
IMF (2016)	"If the current (collective) agreement is not successful at better aligning wages with productivity at the firm level, other approaches should be considered, including legislative changes to the wage bargaining process." "Strengthening active labor market programs would help workers retrain and move between industries." "The recent reduction in the maximum duration of unemployment benefits is an important step and should help increase activation."
IMF(2015)	"The government's intention to increase the flexibility of the wage bargaining system and curb the long duration of unemployment benefits are also welcome and developing concrete proposals in these areas should be a priority. Such reforms should be paired with a strengthening of ALMP, so current plans to cut ALMP spending seem ill-advised"
IMF(2014)	"In addition, it is important that wage bargaining supports adjustment by steering real wages in line with overall productivity growth, while ensuring sufficient flexibility to accommodate variation at the firm and sectoral levels"

Note: The list is illustrative. ALMP refers to active labour market policies.

2 LABOUR MARKET INSTITUTIONS AND BUSINESS CYCLE DYNAMICS, VAR ANALYSIS

Abstract*
This paper studies how labour market institutions are related to business cycle dynamics. Using a panel of OECD countries, I estimate a vector autoregressive (VAR) model in which the parameters are assumed to depend on labour market institutions and control variables. I study how employment protection, generosity of unemployment benefits and degree of coordination and centralization in wage-setting are related to short run dynamics of wages, unemployment, GDP and labour productivity. Results suggest that labour market institutions have explanatory power for the heterogeneity in the volatilities of macroeconomic variables and in shock adjustment. In countries with high coordination in wage-bargaining, wages are less volatile and respond less to productivity shocks. In countries with strict employment protection legislation, wages are less volatile and unemployment is less responsive to external demand shocks. If unemployment benefits are generous, unemployment and wages are more responsive to productivity shocks. The explanatory power of labour market institutions for business cycle heterogeneity seems to be comparable to that of control variables (trade to GDP, government consumption to GDP and Euro dummy). When trying to quantify how much labour market reforms can change the shock-adjustment process of an economy, the results suggest only modest changes. It is illustrated that whether the relation between institutional variables and VAR parameters is assumed as deterministic or stochastic has a large impact on the inference.

Keywords: Labour market institutions, hierarchical Bayesian modeling

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2.1 Introduction

One major distinction across developed economies lies in labour market institutions. Countries differ in their degree and practices of collective bargaining, in their unemployment insurance schemes and in the strictness of their employment protection legislation. Labour market institutions are widely used as an explanation for differences in the economic performance of countries, and labour market reforms carry significant weight in the policy recommendations of international organizations.[1]

The relations of labour market institutions and long-run economic performance are intensively studied, but business cycle outcomes have received less attention in the academic literature.[2] A lesson from the modern business cycle literature is that economic fluctuations are not necessarily undesirable as such but that imperfections and rigidities may lead to suboptimal responses of an economy to driving shocks. Therefore, it is necessary to understand how labour market institutions shape the business cycle dynamics of economies in order to understand the aggregate welfare consequences of different labour market institutions. Additionally, the creation of the Euro area provides reasons to study the effects of labour market institutions on business cycle dynamics. Due to the euro area's common monetary policy, the member countries of monetary unions have fewer stabilization tools. Hence, it is important to know whether certain labour market institutions amplify or mitigate the responses of member countries to common shocks and hence potentially create asymmetric responses. In addition, given the limited ability of the member countries to introduce stabilization policies on country-specific shocks, it is useful to understand which labour market institutions are desirable and undesirable from this perspective. Certain labour market institutions might lessen the need for stabilization policies, while others might increase that need.

The introduction of a search and matching framework of the labour market into dynamic stochastic general equilibrium (DSGE) models has made it possible to model labour markets in contemporary macroeconomic models in more detail. There are studies that also incorporate labour market institutions into DSGE models with search and matching frameworks, most notably Zanetti (2011) and Campolmi and Faia (2011). One aim of this paper is to test the empirical implications of these models. In a recent study, Amaral and Tasci (2016) provide evidence that labour market-related business cycle statistics display significant heterogeneity among OECD countries, and this heterogeneity is difficult to match with a standard search and matching model of the labour market. One contribution of this paper is to assess whether labour market institution variables are so strongly linked to the heterogeneity of labour market dynamics that the inclusion

1 See Blanchard, Jaumotte and Loungani (2013) for the role of labour market institutions in IMF country recommendations

2 See Layard, Nickell and Jackman (2005) and Boeri and van Ours (2013) for a survey of the literature on labour market institutions and equilibrium unemployment

of relevant labour market institutions in theoretical models is needed to improve the empirical properties of these models.

In this study, I estimate a hierarchical Bayesian VAR model where the parameters are allowed to vary according to institutional characteristics of the countries in the sample. In the context of labour market institutions, a similar approach has been taken in Abbritti and Weber (2010, 2018) and Georgiadis (2014). Also, Towbin and Weber (2010) and Sa, Towbin and Wieladek (2014) apply a similar methodology, but the subject is different. Compared to existing studies that link the parameter variation of a VAR to institutional variables, two differences stand out. First, I allow *all* the parameters of the VAR to vary according to institutional variables. Georgiadis (2014) allows only the VAR coefficients (that is dynamic relations) to vary with institutional variables. Abbritti and Weber (2018), Towbin and Weber (2010), Sa, Towbin and Wieladek (2014) estimate the VAR in the recursive form and also allow the contemporaneous relations in the VAR to vary with institutional variables, but they keep the (diagonal) variance-covariance matrix of the errors fixed. In the estimation, I allow for variation for all the elements of the variance covariance matrix, including the diagonal elements. The difference is crucial because the analysis is based on comparing moments that are calculated from the VAR parameters and impulse response functions, both of which are functions of all the VAR parameters.

The second difference from existing literature is that the relation between institutional variables and VAR parameters is assumed to be stochastic, whereas in Abritti and Weber (2010,2017) and Georgiadis (2014), it is assumed to be deterministic. This assumption is crucial for the statistical inference as emphasized also in Western (1998) and Wieladek (2016).

The variables that enter the VAR are real wages, unemployment rate, GDP and labour productivity. Existing studies that use the VAR approach to study the relation between labour market institutions and the business cycle, such as Abbritti and Weber (2010,2018) and Georgiadis (2014), have not included wages or labour productivity in their estimations.[3] I also include wages in the VAR because understanding the effects of labour market institutions on aggregate wage dynamics might be crucial, as collective bargaining institutions are directly linked to the wage setting and can influence the macroeconomy mainly through wages. Labour productivity is included because Amaral and Tasci (2016) show that the persistence of labour productivity varies greatly among OECD countries, and when calibrating a search and matching model, the persistence of labour productivity is a major determinant for the model's implied volatilities. Hence, it is of interest to see if the differences in the persistence of labour productivity are related to differences in labour market institutions.

The labour market institutions that are studied in this paper are the strictness of employment protection legislation, unemployment benefits replacement rate, and wage-setting coordination and centralization. The effects of the first two on business cycle dynamics in a DSGE model are studied in Zanetti (2011) and

3 The VAR in Abbritti and Weber (2010, 2018) includes unemployment rate, inflation and interest rate. Georgiadis (2014) includes GDP, price level and interest rate.

Campolmi and Faia (2011). Wage-setting coordination and centralization have not yet been studied in DSGE models but are included in the analysis because countries differ greatly in that institutional dimension and it is of importance in the policy discussion.[4] Other labour market institutions could have been studied, but already with these three institutional variables, the empirical model is relatively large. In Abbritti and Weber (2010) and Gnocchi, Lagerborg and Pappa (2015), a larger set of labour market institutions is studied, but the curse of dimensionality is addressed by constructing factors from labour market institution variables. I chose not to follow that approach in order to identify the relationship between business cycle dynamics and individual institutions directly. In addition, wage setting and coordination measures are not treated as continuous variables as in previous studies but instead as categorical variables.

The data consists of 23 OECD countries, and time period covers 1995-2013. Previous studies have used longer data sets but fewer countries. In particular, restricting the study to a shorter time period allows the inclusion of the Czech Republic, Hungary, Poland and Slovakia. This is beneficial because these countries have weaker labour market institutions than the majority of the older OECD countries that have longer data available. Including these countries increases the heterogeneity in the data set. Overall, the variation in the labour market institution data over time within a country is limited compared to the variation across countries. Hence, it is preferable to increase the cross-sectional dimension more than the time dimension.

Gnocchi *et al.* (2015) find that labour market institution variables are linked to differences in business cycle dynamics. They estimate business cycle statistics for 19 OECD countries and use rank correlation coefficient analysis to study the relation between labour market institution variables and business cycle statistics. Rank correlation analysis is robust, but it does not allow for quantitative evaluation of the magnitudes. In my paper, the aim is also to quantify how large differences in business cycle dynamics labour market institutions could potentially cause.

Abbritti and Weber (2018) obtain stronger results for the relation between labour market institutions and business cycle dynamics than the results that I obtain in this paper. The results in Abbritti and Weber (2018) are also stronger than in the previous literature. The methodology in this paper is close to the methodology in Abbritti and Weber (2018), but one large difference stands out. Abbritti and Weber (2018) assume the relation between labour market institutions and VAR parameters to be deterministic, whereas I assume it to be stochastic. This difference has a large impact on inference. Also, my results are much stronger if the relation is assumed to be deterministic, which is consistent with what Western (1998) and Wieladek (2016) have documented with their applications.

Results suggest that labour market institutions have explanatory power for the heterogeneity in the volatilities of macroeconomic variables and in shock adjustment. In countries with high coordination in wage bargaining, wages are

4 For the importance of wage setting institutions in the policy discussion, see, e.g., Blanchard *et al.* (2013)

less volatile and respond less to productivity shocks. In countries with strict employment protection legislation, wages are less volatile and unemployment is less responsive to external demand shocks. If unemployment benefits are generous, unemployment and wages are more responsive to productivity shocks. The explanatory power of labour market institutions for business cycle heterogeneity seems to be comparable to that of control variables (trade to GDP, government consumption to GDP and Euro dummy). When trying to quantify how much labour market reforms can change the shock-adjustment process of an economy, the results suggest only modest changes.

The rest of the paper is organized as follows. The next section explains the methodology used in the estimation. Section 3 presents the data used in this paper and section 4 reports the results. Section 5 concludes.

2.2 Methodology

The methodology is based on the time-varying parameter VAR framework outlined originally in Cogley and Sargent (2005) and Primiceri (2005). These studies estimate a TVP VAR model for the US economy and assume that the parameters of the VAR follow driftless unit root processes. Recently, Mumtaz and Zanetti (2015) have used a TVP VAR model to detect time-variation in the business cycle dynamics of US labour market variables. The aim of this paper is not to detect variation in VAR parameters *per se* but instead to link parameter variation to observable institutional variables. I specify a VAR model with a prior that parameters of the VAR are related to labour market institution variables. The data cover 23 OECD countries. Labour market institutions variable display relatively little variation over time. Hence, it is mostly the parameter variation across the cross-sectional units, countries, that labour market institution variables can be assumed to capture. The model includes error processes for the VAR parameters, and the error processes account for the parameter variation that is not captured by the institutional variables.

The model neglects potential interdependencies between countries. Taking this into account in a manner that still makes estimation feasible requires specific techniques, since modelling interdependencies between countries dramatically increases the number of parameters. Canova and Ciccarelli (2009) specify a panel VAR model to account for cross-country interdependencies, but applying it to the analysis in this paper would further encumber the already complex model. Since the cross-country interdependencies are neglected, the model is naturally misspecified. However, it does not seem reasonable to believe that this would affect the results systematically in favour of strengthening or decreasing the relation between labour market institutions and business cycle dynamics. Finally, cross-country interdependencies are also neglected in the previous literature.[5] To

[5] Neither Abbritti and Weber (2010, 2018) nor Georgiadis (2013) models cross-sectional interdependencies.

decrease these concerns, the largest economy, USA, is omitted from the sample, since fluctuations in the US economy can have large spillovers to the rest of the world (for a recent empirical documentation, see e.g. Feldkircher and Huber (2016)). Instead, the US GDP is included in the VAR as an exogenous variable to control for common shocks in the data. For each cross-section unit (country) i, the data generating process is assumed to be a vector autoregression of form

$$y_{\mathrm{i,t}} = X_{\mathrm{i,t}}\beta_{\mathrm{i,t}} + e_{\mathrm{i,t}}, \qquad e_{\mathrm{i,t}} \sim N(0, \Omega_{\mathrm{i,t}}) \tag{1}$$

where $X_{i,t}$ includes lags of dependent variables, a constant and exogenous variables. As is common in time-varying parameter VAR literature (e.g. Primiceri 2005), the variance-covariance matrix $\Omega_{\mathrm{i,t}}$ is decomposed with

$$A_{\mathrm{i,t}}\Omega_{\mathrm{i,t}}A'_{\mathrm{i,t}} = \Sigma_{\mathrm{i,t}}\Sigma'_{\mathrm{i,t}} \tag{2}$$

where $A_{\mathrm{i,t}}$ is a lower diagonal matrix with ones on the diagonal and $\Sigma_{\mathrm{i,t}}$ is a diagonal matrix. The evolution of the coefficients $\beta_{\mathrm{i,t}}$, and elements in $A_{\mathrm{i,t}}$ ($a_{i,t}$'s) and $\Sigma_{\mathrm{i,t}}$ ($\sigma_{\mathrm{i,t}}$'s) is given by the constants and the labour market institution and control variables in $Z_{i,t}$ and innovations $\eta_{\mathrm{i,t}}$

$$\begin{bmatrix} \beta_{\mathrm{i,t}} \\ a_{\mathrm{i,t}} \\ log(\sigma_{\mathrm{i,t}}) \end{bmatrix} = Z_{\mathrm{i,t}} \begin{bmatrix} \theta_\beta \\ \theta_a \\ \theta_\sigma \end{bmatrix} + \begin{bmatrix} \eta^{\beta*}_{\mathrm{i,t}} \\ \eta^{a*}_{\mathrm{i,t}} \\ \eta^{\sigma*}_{\mathrm{i,t}} \end{bmatrix} \tag{3}$$

Parameters of the VAR are assumed to vary over time and across countries. $Z_{i,t}\theta$ captures the variation that can be explained with institutional variables, and η captures all the remaining variation. If equation (3) is substituted to equations (1)-(2), this gives a model with interaction terms. This kind of approach with VAR is taken in Sa, Towbin and Wieladek (2014) and Abbritti and Weber (2010, 2018).[6] However, in those papers, the elements in $\Sigma_{i,t}$, the "volatilities", are not modelled to depend on institutional variables. This is an important extension since assuming constant, country specific σ_i's, as in Sa, Towbin and Wieladek (2014), leads to unintended restrictions for the terms in Ω. Given the decomposition in (2), terms in Ω are non-linear functions of terms in A and Σ. It is difficult to justify why some of these parameters would be related to labour market institutions whereas some would not be.[7]

A limitation of the models in the previous literature is that the η error term in (3) is neglected and hence it is assumed that the parameters of the VAR depend

6 Georgiadis (2014) assumes a nonlinear relationship between VAR coefficients and institutional variables.

7 Let a_1, a_2, a_3 be the non-constant elements in A and $\sigma_1, \sigma_2, \sigma_3$ be the non-zero elements in Σ. Then with a decomposition $A\Omega A' = \Sigma\Sigma'$ it leads to that $\Omega(1,1)$ element is σ_1^2, but $\Omega(3,3)$ is given by $(a_2 - a_1 a_3)^2\sigma_1^2 + a_3^2\sigma_2^2 + \sigma_3^2$. If a_1, a_2, a_3 are allowed to depend on institutional variables and $\sigma_1, \sigma_2, \sigma_3$ are not allowed, this leads to a restriction that the variance of errors of the first variable in the VAR is unrelated to institutional variables whereas that of the third (and second) variable is not restricted to be unrelated to institutional variables.

deterministically on the variables in $Z_{i,t}$ in equation (3). This is a strong assumption but allows for straightforward estimation. In the context of univariate models, there is a variety of studies that have used the interaction term approach to study the role of institutions on economic relations (e.g. Blanchard and Wolfers (2000) and Nunziata (2005) employ the interaction term approach).

I consider it important to allow for an error term in equation (3) because, given that one is ready to assume that the parameters of an econometric model vary according to some institutional variables, it is hard to justify why these variables could be the only variables causing the variation. Even if there were no omitted variables, there might be significant measurement errors, since mapping institutional structures on the numerical measures is not trivial. Hence, the data might easily differ from the theoretical variables. The inclusion of η also matters for the inference. As will be seen in Section 4, neglecting η implies a much stronger statistical relation between labour market institution variables and business cycle statistics than when η is included in the model.

The error term $\eta_{i,t}$ captures parameter variation in the data that is not explained by the institutional variables. If this residual variation originates from the institutional characteristics that are not included in $Z_{i,t}$, it suggests that $\eta_{i,t}$ should be a persistent process, since institutions display very little variation on quarterly frequencies. Also, there may be measurement errors in the institutional variables. Because both the true institutions and the variables measuring institutions are persistent are measurement errors of institutional variables likely to be repeated over time and for this reason persistent process too. Finally, if there are changes in the institutions or other country characteristics that are not captured in $Z_{i,t}$, it is probable that these changes are, in turn, persistent changes as well. A process that captures both of these features, persistence and persistent changes, is the unit root process. Hence, it is assumed that $\eta_{i,t}$ follow uncorrelated unit root processes:

$$\eta_{i,t}^* = \eta_{i,t-1}^* + u_{i,t}^*, \qquad u_{i,t}^* \sim N(0, \Omega_{u^*}) \tag{4}$$

where $\eta_{i,t}^* = \begin{bmatrix} \eta_{\mathrm{i,t}}^{\beta *} & \eta_{\mathrm{i,t}}^{a*} & \eta_{\mathrm{i,t}}^{\sigma *} \end{bmatrix}'$ and Ω_{u^*} is a diagonal matrix. This assumption is also in line with the original TVP VAR methodology in Primiceri (2005). If none of the parameter variation is explained by the variables in $Z_{i,t}$, the model reduces to an estimation of country-specific TVP VARs.

The model is very generous, as the parameters of the VAR are allowed to depend on observable institutional characteristics, and in addition country-specific time variation is allowed in order to make the estimation more robust. By omitting $\eta_{i,t}^*$, I would force all the variation in the parameters of the VAR to originate from labour market institution variables, and this could lead to spurious results. Also, the relation between VAR parameters and institutional variables would be deterministic without an error term in (3), which would mitigate the estimation uncertainty. The natural drawback is that the model has a large parameter set to be estimated and this could lead to estimation uncertainty to such a degree that meaningful inference is no longer possible.

Bayesian shrinkage offers a solution to circumvent a problem of this sort. The researcher has the option to start with a parameter-rich model, but the estimation proceeds in a data-driven manner towards a more parsimonious model. A recent contribution to Bayesian shrinkage estimation is the Bayesian Lasso by Park and Casella (2008).[8] Belmonte, Koop & Korobilis (2014) provide an application to the TVP framework. The approach in Belmonte *et al.* was chosen to induce shrinkage since it provides variable selection over time-varying and time-invariant parameters. Following Belmonte *et al.* (2014), shrinkage is applied to $\eta^*_{i,t}$ terms with a transformation that allows to decompose the time varying $\eta^*_{i,t}$ to the initial condition and to deviations from the initial condition. The initial condition captures the cross-sectional residual variation in parameters, and deviations from the initial condition capture the residual variation over time within a cross-sectional unit. Both the initial condition and time variation parts are shrunk towards zero.

To decompose the $\eta^*_{i,t}$ process to initial conditions and deviations from it, simply define $\eta_i = \eta^*_{i,0}$ and $\eta_{i,t} = \eta^*_{i,t} - \eta_i$, $\eta_{i,0} = 0$. Following Belmonte *et al.* (2014) and Frühwirth-Schnatter and Wagner (2010), a further transformation is implemented for $\eta_{i,t}$ terms. For a j'th element in $\eta_{i,t}$ vector, $\tilde{\eta}_{j,i,t} = \frac{\eta_{j,i,t}}{\omega_{j,i}}$, where $\omega_{j,i}$ is a diagonal element in Ω^*_u. Frühwirth-Schnatter and Wagner (2010) refer this as non-centred parameterization.

Then, equations (3) and (4) can be re-written as

$$\begin{bmatrix} \beta_{\mathrm{i,t}} \\ a_{\mathrm{i,t}} \\ log(\sigma_{\mathrm{i,t}}) \end{bmatrix} = Z_{\mathrm{i,t}} \begin{bmatrix} \theta_\beta \\ \theta_a \\ \theta_\sigma \end{bmatrix} + \omega_{\mathrm{i}}\tilde{\eta}_{\mathrm{i,t}} + \eta_{\mathrm{i}} \tag{5}$$

$$\tilde{\eta}_{i,t} = \tilde{\eta}_{i,t-1} + u_{i,t}, u_{i,t} \sim N(0, I) \tag{6}$$

$$\eta_{i,0} = 0 \tag{7}$$

Now the $\eta^*_{i,t}$ error terms are divided into unit-specific time-invariant η_i and unit-specific time-varying $\tilde{\eta}_{i,t}$ parts. The rationale for using the non-centred parameterization for η's is that one is able to assume inverted normal prior for ω's. Usually, the variances of the errors are assumed to be inverted Gamma distributions. Frühwirth-Schnatter and Wagner (2010) provide evidence that when working with shrinkage priors, the use of Normal priors leads to better performance.

To induce Lasso-type shrinkage, the following priors are assumed for the ω and η_i terms. The time-invariant unit-specific η_i terms are distributed as

$$\eta^k_i | \tau^2_{i,k} \sim N(0, diag(\tau^2_{i,k})) \tag{8}$$

where $k = (\beta, a, \sigma)$ Each term in vector $\tau_{i,k}$ is distributed as

$$\tau_{k,i} | \lambda_k \sim exp\left(\frac{\lambda^2_k}{2}\right) \tag{9}$$

[8] LASSO is an acronym for least absolute shrinkage and selection operator

To induce shrinkage for time-varying error terms following prior for ω_i is used

$$\omega_{i,k}|\xi^2_{i,k} \sim N(0, diag(\xi^2_{i,k})) \tag{10}$$

where $k = (\beta, a, \sigma)$ Each term in vector $\xi_{k,i}$ is distributed on prior as

$$\xi_{k,i}|\kappa_k \sim exp\left(\frac{\kappa_k^2}{2}\right) \tag{11}$$

λ_k, κ_k determine the degree of shrinkage. λ_k, κ_k are treated as random variables instead of fixed parameters in order to induce the degree of shrinkage in a data-driven manner. λ_k, κ_k require priors, and non-informative priors are used, as in Belmonte *et al.* (2014)(see Appendix for detail).

For θ's, independent Normal priors are assumed. θ's that are associated with the constants in Z give the average values of the VAR parameters over the sample. Prior means for these are obtained from the training sample. For other terms in θ, a zero mean is assumed. Priors for θ's are relatively diffuse, and hence these priors believes are dominated by the sample information.[9]

All model parameters have analytical conditional distributions, and the model can be estimated using the Gibbs sampler. The time-varying terms $\tilde{\eta}_{i,t}$ are estimated using the algorithm in Chan and Jeliazkov (2009) instead of the Kalman simulation smoother algorithm, which is the standard in the TVP-VAR literature. The reason for this is the computational efficiency of Chan and Jeliazkov's (2009) approach. Otherwise, the estimation closely follows Primiceri (2005). A detailed description of the estimation is provided in Appendix A.

The main methodological contribution of this paper over the existing studies that use institutional variables to explain parameter variation is that I allow the elements of $\Sigma_{i,t}$ to be linked to institutional variables. This is important for the analysis of this paper, since one aim is to study if there is a relation between labour market institutions and business cycle moments that are obtained from the VAR parameters. Hence, it is important that all the elements of the variance covariance matrix $\Omega_{i,t}$ are linked to institutional variables. This also matters for the impulse response analysis. Apart from the first cell in $\Omega_{i,t}$, all other elements are functions of elements in both $A_{i,t}$ and $\Sigma_{i,t}$.

Another methodological contribution is to inlude η error terms in equation (3). This is important since it increases the empirical performance of the model and is crucial for the inference. Allowing for error terms in (3) makes the relation between VAR parameters and institutional variables stochastic, whereas without error terms, it is deterministic. It should be highlighted that the situation is very different from usual econometric modelling, where the relations are always stochastic. Typically, a researcher is interested in the relation between dependent and explanatory variables that are both observed, whereas here, the interest lies in the relation between unobserved dependent variables (VAR parameters)

9 Prior variances of θ's are set to 10.

and observed explanatory variables (labour market institution and control variables). In standard regression analysis, the relation is stochastic by construction, since the estimation would not be possible without allowing for error terms in the regression equation. When the interest is in the relation between regression parameters and observed institutional variables, as in this study, the researcher has the option to decide whether the relation is stochastic or deterministic, since the dependent variables that are unobserved are constructed in the analysis.

One approach to model the effect of institutional variables on economic dynamics has been to simply augment a standard regression model with the interaction terms of institutional variables and explanatory variables. Essentially, the modelling procedure is the same as in this study, but the dependence between institutional variables and regression parameters is not modelled explicitly as in equation (3). Appendix A provides the details of the estimation, and in my approach, the estimation proceeds by substituting equation (3) for equation (1). This gives a model with interaction terms of explanatory variables and institutional variables. In addition, there are interaction terms of η error terms and explanatory variables that are typically neglected in the previous literature. This illustrates that if one uses the interaction terms approach, the maximum likelihood estimator is not the standard ordinary least squares estimator but rather the generalized least squares (GLS) type estimator because of the interaction terms between errors and explanatory variables. Canova (2008) shows the derivations for the GLS estimator in this context. However, in Canova (2008), the error terms of the second stage relation are country-specific constants. If the error terms are time-varying, as in this study, the derivations would be more cumbersome.

Although it seems decisive whether one assumes the relation of institutional variables and model parameters to be deterministic or stochastic, fairly little research has been done on this. Wieladek (2016) illustrates that if one assumes a deterministic relation for the VAR parameters and institutional variables, the distributions of impulse responses are significantly smaller than if stochastic relation is assumed. Further, according to Wieladek's (2016) results, more institutions are found to be statistically significantly related to shock transmission when a deterministic relation is assumed. Western (1998) finds that in the context of regression coefficients, the confidence bands are smaller when the relation to institutional variables is assumed to be deterministic. Similar results are obtained in this study and are discussed further in the next section.

Another methodological contribution is that Lasso-type shrinkage is applied to TVP VAR. Belmonte *et al.*(2014) work with a single equation model, and shrinkage is applied only on the coefficients of the model not on the variance.

Another approach to studying the relation between institutional variables and dynamics has been to estimate cross-section-specific VARs and obtain impulse responses and group impulse responses according to an institutional variable. Calza, Monacelli & Stracca (2013) apply this methodology to study the relation of mortgage market characteristics to the transmission of monetary policy. This approach is robust and transparent but has the limitation that when the time dimension for the data is only modest, as is the case in my analysis, crosssectionally estimated VARs can be poorly estimated. Grouping is also done one variable at a time, which, in the case of labour market institutions, would make comparisons difficult because labour market institution variables are highly correlated. Comparison would be less informative regarding the independent relations of each institution to the dynamics, and it would not be possible include additional control variables.

An appealing property of the methodology presented here is that it is in line with the likelihood principle. The model is estimated under the hypothesis and prior belief that the institutional variables are linked to the parameter variation of the VAR. Hence, all the prior information is included in the estimation.

2.3 Data

The data set consists of 23 OECD countries.[10]The time period covers 1995-2013 and the data are quarterly. For a subset of countries, a longer series exists, and pre-1995 data of these countries are used as a training sample to get prior means for the terms in θ that are associated with the constants in Z. Previous studies have used longer data, but the advantage of using shorter data is that it allows us to include more countries in the data set.[11]This is useful since most of the variation in labour market institutions is across countries, and time variation within a country is relatively limited. Hence, large N is preferable to large T. The majority of the countries that have long series are countries that have relatively strong labour market institutions. In turn, the countries that have shorter series are countries that have weaker labour market institutions than the majority of the old OECD countries. This further increases the heterogeneity in the labour market institutions compared to a data set that consists of long series of older OECD countries.

In addition, one difficulty in using long series is that although the variation in labour market institutions is only modest, the time variation in business cycle statistics is large and even larger than the cross-country variation (see e.g. the figures in Canova, Ortega and Ciccarelli (2012)). In general, the business cycle volatility decreased in OECD countries from the 1970s until the financial crisis of 2008. At the same time, the strictness of labour market institutions has slightly decreased in general. These common patterns might introduce difficulties into the estimation.

Unbalanced panel estimation would efficiently use all the data available and would be technically feasible. Unbalanced panel estimation was not chosen since the countries with shorter series have weaker labour market institutions than the

10 The countries are Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Poland, Portugal, Slovakia, Spain, Switzerland and the UK.

11 Czech Republic, Hungary, Poland and Slovakia have consistent data sets for both macro and labour market institution variables only from 1995 onwards.

average in the sample. This could introduce problems into the estimation, since countries with differing characteristics would have unequal weights in the sample.

The endogenous variables that enter the VAR are real wage growth, unemployment rate and GDP or labour productivity growth. Productivity is measured as GDP divided by employment, as in Amaral and Tasci (2016). GDP and productivity are included only in turns to keep the number of estimated parameters more compact. When results refer specifically to productivity, it is included in the VAR; otherwise, GDP is included. Data for these variables are from the OECD Economic Outlook.[12]GDP growth was chosen because it is a proxy for economic activity. Unemployment and real wage growth were chosen because labour market institutions should have relatively direct relations to these variables. Productivity growth was chosen since Amaral and Tasci (2016) highlight the importance of the persistence of labour productivity for differing labour market variable volatilities.

The USA is excluded from the sample since movements in US macro variables can potentially have large effects on other economies and cross-country correlations are not modelled in the estimation. Instead, the US GDP is used as an exogenous variable to control for common shocks in the data. In order to control for common shocks, the US GDP enters as a contemporaneous variable. With the exception of unemployment rate, all variables enter year-on-year growth rates. A lag length of two was chosen, but the robustness of the results was studied with four lags.

The labour market institution variables that are considered are strictness of employment protection legislation, unemployment benefits replacement rate and wage-setting coordination and centralization. An abundance of other indicators also exists. These indicators were chosen because they constitute the minimum set to be able to test the predictions of DSGE model studies on the relation between labour market institutions and business cycle dynamics.

The employment protection variable is constructed as an average of the OECD indicators for the legislation related to dismissal of workers in regular contracts and the regulation on temporary contracts. Replacement rate data is from van Vliet and Caminada (2012), and it measures the ratio of net unemployment benefits and net income for an average worker in the manufacturing sector.

For wage setting, two indicators are combined from the ICTWSS database.[13] The other indicator measures the centralization of wage-setting by defining the predominant level where wages are set (workplace, industry, national level or in between these levels), and the other measures the coordination in the wage-setting process. Both indicators are on the scale from 1 to 5. These two variables are highly correlated, and hence identifying their independent relations to macroeconomic dynamics in a relatively small sample is difficult. Although in the earlier literature, wage-setting coordination and centralization variables are

12 Except for Swiss wage data, which are from the Swiss statistical authority.

13 ICTWSS: Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts in 51 countries between 1960 and 2014, Visser (2016).

treated as continuous variables, it is not self-evident that this would be the correct approach. Thinking about wage-setting in a firm, sectorial or national level, it is difficult to see the differences as quantitative differences rather than mere qualitative or categorical differences. To circumvent these problems, high correlation between centralization and coordination variables and their categorical nature, I construct from these variables a single categorical variable. This allows me to combine information from both variables without expanding the parameter space and also takes into account the categorical nature of these variables. Also, according to Calmfors and Driffill's (1988) hypothesis, the relation of wage-setting centralization to the macroeconomy is hump-shaped, which can be captured with a three-category variable. A three-category variable is constructed as follows: uncoordinated/decentralized if both indicators are less than two, intermediate if either indicator is greater than two but less than four, coordinated/centralized if either of the indicators is four or five. In what follows, I refer to this variable as coordination for simplicity.

In addition to labour market institution variables, control variables are included in $Z_{\mathrm{i,t}}$. These are Euro dummy, openness to trade and the share of government spending of GDP. To model the global changes in business cycle dynamics during that sample period, volatility of US GDP growth is included as an explanatory variable in $Z_{i,t}$.[14]

2.4 Results

2.4.1 Conditional business cycle statistics

This section studies the relation between labour market institutions and business cycle dynamics by calculating moments from the VAR parameters conditional on specific values for the labour market institution variables. Given the posterior distribution for θ's, VAR parameters are obtained using equation (5). Using the formulas in the Appendix, moments are easily calculated from the VAR parameters. Because moments are simulated using the distribution of θ's instead of point estimates of the mean, the exact small sample distributions are automatically generated. Moments are calculated conditional on each degree of coordination and conditional on 20th, 50th and 80th sample percentiles of replacement rate and employment protection. Each institution is studied in turn, and other continuous variables in $Z_{i,t}$ are kept at a median value, coordination is kept at intermediate and the euro dummy is set to equal one.

Table 1 shows the variances, cross-correlations and autocorrelations of real wage growth, unemployment, GDP and productivity growth conditional on labour market institution variables. Overall, the medians of variances conditional on different values for labour market institution variables are different, but confidence bands are also large. In the case of coordination, volatilities of unemployment

[14] US GDP growth volatility is obtained from a TVP-AR(1) model with stochastic volatility

Table 1. Conditional business cycle statistics

	COORD			REP			EPL		
	Low	Intermed	High	Low	Intermed	High	Low	Intermed	High
var(w)	1,49′	1,36′	0,96	1,11	0,95	0,94	1,25*	0,96″	0,80
	1,02 2,64	1,03 1,87	0,77 1,23	0,81 1,64	0,76 1,21	0,75 1,21	0,92 1,81	0,77 1,22	0,65 0,99
var(u)	2,07	1,48	1,24	1,13	1,3	1,31	1,28	1,41	1,62
	0,8 10,59	0,87 3,04	0,7 2,89	0,52 4,09	0,72 2,85	0,74 2,94	0,61 4,25	0,77 3,04	0,92 3,55
var(y)	1,38	2,07′	1,55	2,07	1,73	1,59	1,84	1,91	2,02
	0,93 2,38	1,61 2,71	1,22 1,95	1,58 2,73	1,4 2,12	1,26 2,01	1,45 2,32	1,56 2,33	1,64 2,51
var(y/n)	2,02	1,35	1,30	1,76	1,47	1,37	1,63	1,58	1,59
	1,26 4,09	1,03 1,78	1,01 1,67	1,13 2,83	1,04 2,11	0,93 2,08	1,25 2,18	1,28 1,97	1,28 1,98
cor(y,u)	-0,27	-0,29′	-0,16	-0,25	-0,17	-0,13	-0,16	-0,18	-0,19
	-0,6 0,03	-0,38 -0,18	-0,26 -0,04	-0,38 -0,13	-0,27 -0,06	-0,24 0	-0,28 -0,02	-0,27 -0,07	-0,29 -0,07
cor(y,w)	0,24	0,03	0,05	-0,05	0,00	0,03	0,02	0,06	0,09
	0 0,48	-0,12 0,18	-0,05 0,15	-0,2 0,13	-0,11 0,1	-0,08 0,14	-0,12 0,16	-0,05 0,16	-0,01 0,2
cor(w,u)	-0,06	-0,21	-0,10	-0,17	-0,09′	0,00	-0,11	-0,1	-0,09
	-0,46 0,29	-0,41 -0,03	-0,28 0,04	-0,48 0,02	-0,26 0,06	-0,18 0,18	-0,39 0,08	-0,28 0,05	-0,28 0,06
cor(u,y/n)	-0,13	-0,01	0,07	-0,02	0,01	0,01	0,00	-0,01	-0,01
	-0,52 0,21	-0,13 0,14	-0,03 0,2	-0,14 0,12	-0,09 0,13	-0,11 0,16	-0,13 0,2	-0,1 0,12	-0,1 0,12
cor(w,y/n)	0,23	0,01	0,06	0,07	0,09	0,08	0,14	0,12	0,08
	-0,06 0,5	-0,14 0,17	-0,07 0,17	-0,09 0,22	-0,03 0,19	-0,03 0,19	-0,03 0,28	0 0,22	-0,02 0,18
acor(w)	0,74′	0,77*	0,62	0,66	0,62	0,61	0,65	0,62	0,6
	0,64 0,85	0,71 0,83	0,56 0,69	0,58 0,76	0,56 0,69	0,54 0,67	0,53 0,82	0,53 0,73	0,5 0,7
acor(u)	0,99	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,99
	0,97 1	0,96 0,99	0,97 0,99	0,96 0,99	0,97 0,99	0,97 0,99	0,96 0,99	0,97 0,99	0,98 0,99
acor(y)	0,79	0,77	0,71	0,7	0,71	0,72	0,7	0,72	0,73
	0,71 0,88	0,72 0,81	0,67 0,76	0,64 0,76	0,67 0,75	0,67 0,76	0,64 0,75	0,67 0,76	0,69 0,77
acor(y/n)	0,79*	0,65	0,59	0,55	0,59	0,62	0,59	0,60	0,61
	0,71 0,89	0,59 0,7	0,54 0,64	0,48 0,62	0,54 0,64	0,56 0,67	0,52 0,66	0,54 0,65	0,56 0,66

.5 *Note*: Intervals refer to 80% confidence set. The distributions of low and intermediate regimes are compared to that of high.′ refer to zero is not included to 80 % highest density region of distribution for the difference.″, * ,** refer to 90, 95 and 99 highest density regions.COORD, wage setting coordination, REP, replacement rate of unemployment benefits, EPL, employment protection

Table 2. Relations, business cycle statistics and labour market institutions

Study	Relation with REP					
	var(w)	var(u)	var(y)	var(y/n)	cor(y,w)	cor(w,y/n)
Zanetti	-	+	+		-	
Campolmi & Faia	-					
Gnocchi *et al.*	+	+*	-	-		+
Abbritti & Weber		+*				
Juvonen	-	+	-	-	+*	+
	Relation with EPL					
	var(w)	var(u)	var(y)	var(y/n)	cor(y,w)	cor(w,y/n)
Zanetti	+	-	-		-	
Gnocchi *et al.*	+	+*	-	+		-*
Abbritti & Weber		-*				
Juvonen	-*	+	+	-	+	-
	Relation with Coordination					
	var(w)	var(u)	var(y)	var(y/n)	cor(y,w)	cor(w,y/n)
Gnocchi *et al.*	+*	+	+*	+*		-*
Abbritti & Weber		+*				
Juvonen	-*	-*	+	-	-*	-

Note: * refers to a statistically significant relation. Campolmi & Faia (2011) and Zanetti (2011) are theoretical studies and results are obtained from simulations of DSGE models. REP, replacement rate, EPL, employment protection.

and wages are different between high and low coordination with 80 % confidence. (Meaning that the 80% highest density region of differences between $var(w)_{high}$ and $var(w)_{low}$ does not include zero). Also, the persistence of wages and labour productivity are both higher if wage-setting coordination is low.

The replacement rate of unemployment benefits seems to be relatively weakly related to business cycle dynamics. According to table 1, only the correlation of wages and unemployment seems to be related to the replacement rate. Employment protection is related to wage dynamics, implying higher volatility of wages if employment protection is low.

The persistence of labour productivity seems to be related to the degree of wage-setting coordination. It is difficult to reason what the link could be from wage coordination to labour productivity since wage coordination should affect primarily wage dynamics. Table 5 presents the results when η error terms are omitted. Then, the replacement rate and employment protection are also related to the persistence of labour productivity. Amaral and Tasci (2016) calibrate a search and matching model for a group of OECD countries and note that persistence in labour productivity has a significant impact on the model outcomes. The results here suggest that labour productivity persistence is related to labour market institutions. Hence, obtaining a better empirical fit for a search and matching model with cross-country data might require explicit modelling of labour market institutions.

In table 2, the results of this paper are compared with results from the earlier literature. Gnocchi *et al.* (2015) and Abbritti and Weber (2018) are empirical studies. Campolmi and Faia (2011) and Zanetti (2011) are theoretical studies, and their results are obtained by comparing simulations of DSGE models with changes in the values of parameters that can be interpreted to reflect the strictness of employment protection or replacement rate. Plus sign in table 2 indicates that higher value for a labour market institution variable implies greater value for the business cycle statistic.

Overall, the evidence is mixed. The results of this paper and Gnocchi *et al.* (2015) indicate similar relations for only half of the cases, and less than half of the implications of the theoretical papers are confirmed by empirical studies.

There seems to be a statistically significant relation for only a few business cycle statistics according to the results in table 1, and the statistically significant relations correspond to p-values of 0,05 or greater. This is in contrast to Abbritti and Weber (2018) and Gnocchi *et al.* (2015). Abbritti and Weber (2018) find statistically significant relations for the majority of cases and Gnocchi *et al.* (2015) for roughly half of the cases. Both studies are able to report p-values smaller than 0,05. [15]

The difference between the statistical significance of the results of this paper and the results of Gnocchi *et al.* (2015) and Abbritti and Weber (2018) is driven by the methodology. Table 5 in the Appendix displays the results when η error terms are omitted. There are much more statistically significant relations than in table 1, and overall the statistical significance is stronger. When η's are omitted, the dependence of VAR parameters on labour market institutions and control variables is deterministic and the methodology corresponds closely to that in Abbritti and Weber (2018). Gnocchi *et al.* (2015) study the relation between estimated business cycle statistics and labour market institution and control variables. As is usual when employing two-step approaches, the estimated business cycle statistics are treated as observed when doing inference on the relationship between labour market institutions and business cycle statistics, which limits the estimation uncertainty.

It is not self-evident which approach should be preferred. Arguably, the methodology I present here is closer to the data generating process than is the model in Abbritti and Weber (2018). This is by construction because I allow for parameter variation in VAR that is not explained by labour market institutions and controls, and the unexplained variation is captured by η's. On the other hand, there is a risk that the model is overly complex, and this could mitigate the statistical relationship between labour market institution variables and business cycle statistics, as the model complexity increases estimation uncertainty. This could suggest that the criterion for the statistical significance should be viewed in relation to model complexity. However, no formal procedure exists for this.

To balance between model robustness and over parameterization, I have used shrinkage priors for the η error terms, as explained in section 2. Figures 8-10 in Appendix D plot the η error terms for VAR parameters. It seems that the time-varying part of η is less important than the constant, country-specific part.

15 The comparison of frequentist p-values and Bayesian posterior distribution is not straightforward. However, the comparison here is only illustrative.

Most important seems to be allowing η error terms for the σ's. The majority of the η's are shrunk to very close to zero, which indicates that the used shrinkage procedure is working. This lessens the over parameterization concerns, since parameters that are shrunk tightly close to zero do not increase the overall estimation uncertainty. In this vein, the weak statistical relationship between labour market institutions and business cycle dynamics does not seem to be artificially constructed by estimating an overly complex model but instead stems from taking estimation uncertainty into account realistically.

Another aspect of the importance of labour market institutions to business cycle dynamics is how much the differences in labour market institutions explain the variability of business cycle statistics. Aside from Faccini *et al.* (2012), this has not been addressed in the literature. Faccini *et al.* (2012) regress estimated ratios of unemployment volatility to GDP volatility on labour market institution and control variables. By comparing the fit of the models with and without labour market institution variables, they conclude that labour market institutions explain roughly one fourth of the explained variability. Quantifying the explanatory power of labour market institutions is of importance for the purpose of policy recommendations. Even if there existed a statistically significant relation between labour market institutions and business cycle statistics, but the explanatory power of labour market institutions was negligible, then structural reforms should be targeted more to the other aspects of the economy than to labour market institutions.

Let G be one of the business cycle statistics in Table 1. To analyse the relative importance of the labour market institution variables for the variability of G calculate

$$|[G(Z_{i,t}^{LMIs}, Z_{i,t}^{controls}, \eta_{i,t}, \theta) - G(0, Z_{i,t}^{controls}, \eta_{i,t}, \theta)]/G(Z_{i,t}^{LMIs}, Z_{i,t}^{controls}, \eta_{i,t}, \theta)|$$

for each data point. This gives relative predictive absolute errors for each data point when labour market institution (LMI) variables are omitted. Similar analysis is carried for the control variables in Z and for η error terms. Table 3 represents the sample medians of this summary statistic. The explanatory power of labour market institution variables seems to be comparable to the explanatory power of control variables.The control variables include trade-to-GDP ratio, government consumption-to-GDP ratio and a euro dummy, which all capture important characteristics of the macroeconomic environment. As the explanatory power of labour market institution variables is comparable to these variables, this suggests that differences in labour market institutions are related to business cycle variability across countries.

2.4.2 Conditional impulse responses

The results from the previous section suggest that there is a relation between business cycle heterogeneity and labour market institution variables. Still, the inter-

Table 3. Measures of relative explanatory powers

	Z_{LMIs}	$Z_{controls}$	η
var(w)	0,29	0,54	0,58
var(u)	0,49	0,59	0,67
var(y)	0,27	0,28	0,41
var(y/n)	0,46	0,23	0,32
cor(y,u)	0,84	1,19	1,21
cor(y,w)	0,77	1,01	1,01
cor(w,u)	0,77	1,04	1,00
cor(u,y/n)	1,55	2,81	7,90
cor(w,y/n)	2,89	0,90	1,77
acor(w)	0,06	0,26	0,26
acor(u)	0,01	0,01	0,01
acor(y)	0,03	0,09	0,10
acor(y/n)	0,17	0,12	0,15

Note: Median relative errors for business cycle statistics when either labour market institution variables, control variables or parameter error terms are omitted.

pretation of the results was not clear since business cycle statistics are reduced-form statistics. To obtain more insight on how labour market institutions are related to shock adjustment, impulse responses conditional on labour market institution variables are calculated. A productivity shock is identified using sign restrictions. An external demand shock is proxied by an unexpected change in the US GDP growth rate, which is treated as an exogenous variable in the VAR. Similarly to the simulation of business cycle moments, VAR parameters are first simulated conditional on specific values for labour market institution variables, and then impulse responses functions are generated. Additional details on the procedure are provided in Appendix C.

Figure 1 displays impulse responses to productivity shock conditional on different categories for labour market institution variables. Identifying assumptions for productivity shock are that real wages (W) and labour productivity (Y/N) respond positively and unemployment U responds negatively. In principle, this is a neutral technology shock and identifying assumptions are in line with those in Mumtaz and Zanetti (2015). Impulse responses are normalized to give a unitary increase in labour productivity on impact in order to make impulse responses across categories measurable. [16]

The first three rows of impulse responses in Figure 1 show the impulse responses to a productivity shock conditional on different degrees of wage-setting coordination. Real wages seem to be more responsive in economies with firm-level bargaining than in economies with high wage-setting coordination. Also, unemployment is more responsive if wage setting coordination is high. Interestingly, adjustments through wages, a price, and unemployment, a quantity, do not

16 The unnormalized impulse responses show only mild differences for labour productivity across categories for labour market institution variables, and the qualitative conclusions are the same with unnormalized impulse responses.

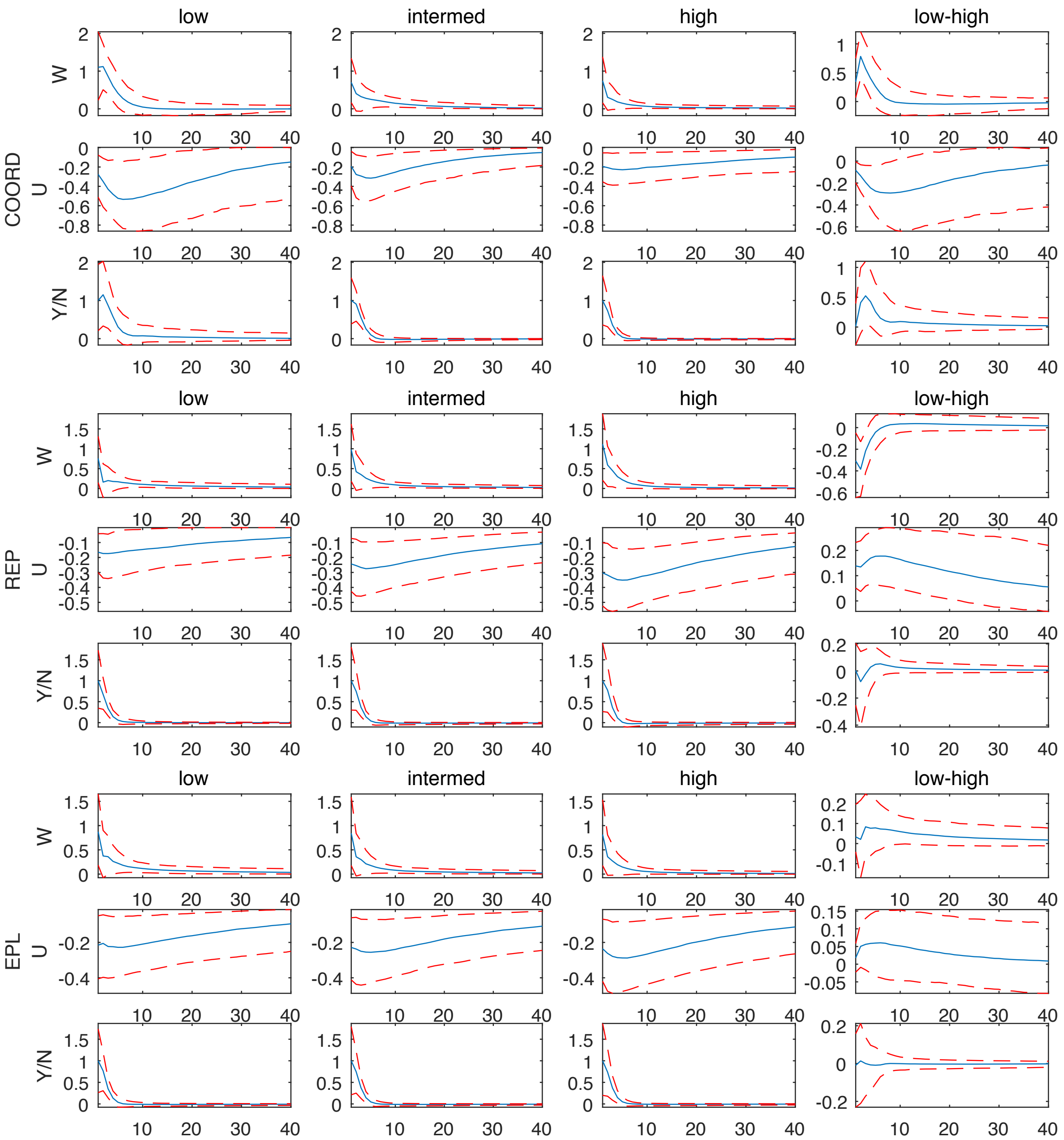

Figure 1. Impulse responses on productivity shock conditional on three categories for wage-setting coordination (COORD), replacement rate (REP) and employment protection (EPL). 80% confidence bands that take into account both identification and parameter uncertainty. Impulse responses are normalized to give unitary response on impact for labour productivity Y/N.

seem to be substitutes, since both wages and unemployment are more responsive the higher is the degree of wage setting coordination. This could be rationalized by the fact that wages that are more responsive to positive productivity shock create higher aggregate demand effects due to higher disposable income, which in turn lowers unemployment.

Impulse responses conditional on different values for the replacement rate suggest that in economies with generous unemployment benefits, real wages and unemployment rate are more responsive. In their DSGE model analysis, Campolmi and Faia (2011) find that higher replacement increases the responses of unemployment and decreases the responses of real wages. Their argument for the responses of unemployment is that a high replacement rate increases steady-state wages and hence firm profits are smaller. For a given increase in productivity, this results in a higher percentage increase in profits compared to an economy with a lower replacement rate, and hence in a high replacement rate economy, firms have higher incentives to post new vacancies, ultimately reducing unemployment. Contrary to Campolmi and Faia (2011, real wages are also more responsive when the replacement rate is higher, which is difficult to rationalize. One explanation could be that once again, this is due to general equilibrium effects. If unemployment is more responsive, more people move from unemployment to employment, which increases their disposable income. Then, through greater aggregate demand, this increases the labour demand further and hence amplifies the response of the real wage.

Impulse responses conditional on different values for employment protection do not display significant differences in Figure 1. Unemployment is slightly more responsive when employment protection is high, though the difference is not statistically significant. This suggests that stricter employment protection does not create a rigidity that limits the flows from unemployment to employment after a positive shock. On the other hand, according to these results, it seems that given a negative productivity shock, stricter employment protection legislation does not significantly reduce the ability of employers to adjust their labour demand and offers employees only a limited degree of protection against firings.

Analysis of impulse responses to productivity shock reveals how labour market institutions are related to adjustment to domestic shocks. To understand how labour market institutions are related to adjustment to external shocks, I obtain impulse responses to a temporary increase in US GDP growth. US GDP enters the VAR as an exogenous variable. The identification is assumed to capture movements in external demand. Naturally, US GDP growth can only capture a fraction of external demand faced by the countries in the sample. However, this is a relatively transparent way of obtaining economically interpretable impulse responses, and no additional identifying assumptions are required.

Figure 2 displays impulse responses to a temporary unit increase in US GDP growth. In terms of coordination, there are significant differences only in responses of output, which is more responsive if coordination is high. If anything, wages are slightly more responsive if coordination is low, as was the case with

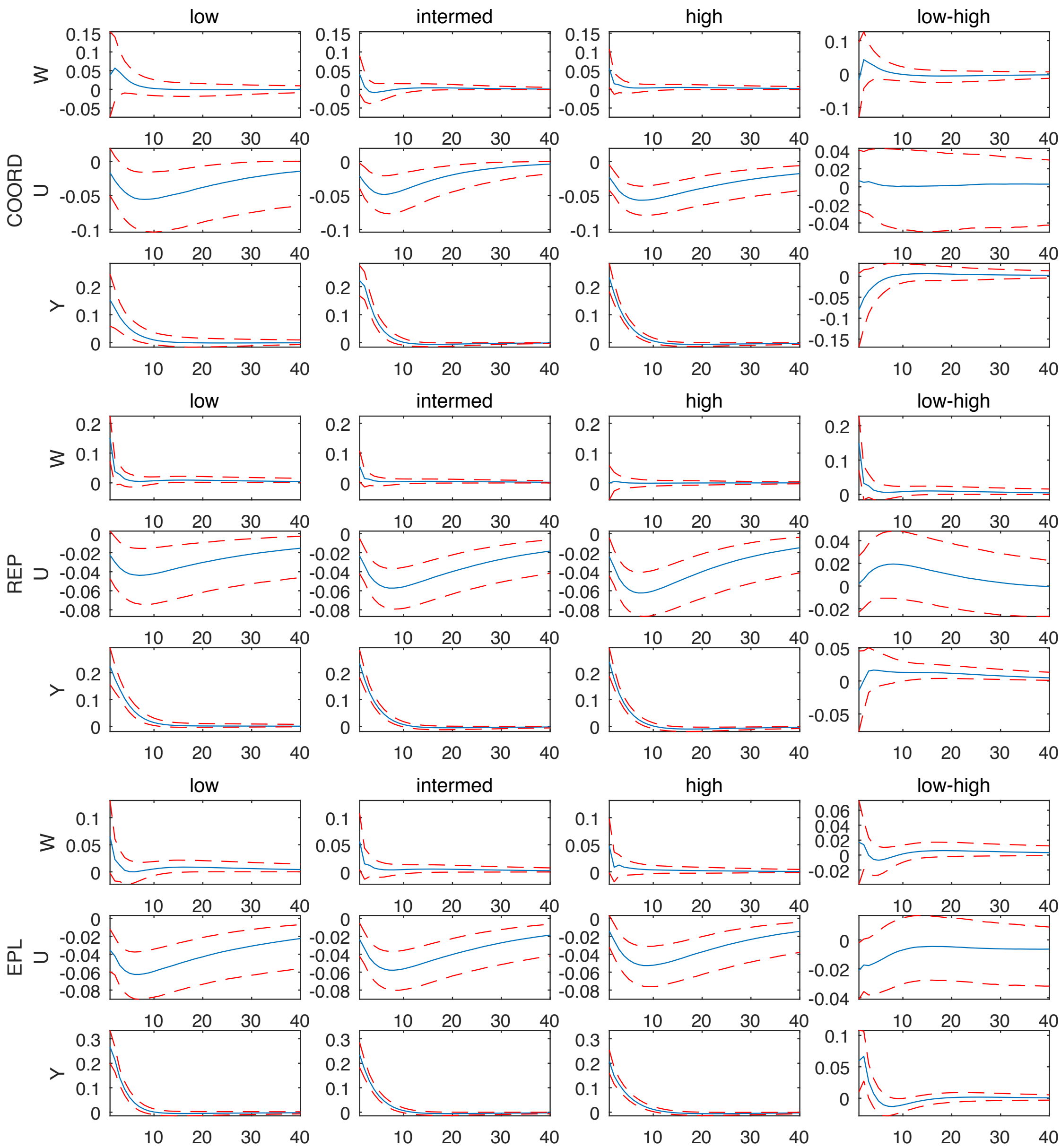

Figure 2. Impulse responses on temporary unit increase in US GDP growth conditional on three categories for wage-setting coordination (COORD), replacement rate (REP) and employment protection (EPL). 80% confidence bands.

the responses to a productivity shock.

If the replacement rate is high, Figure 2 shows that real wages are unresponsive to movements in US GSP growth, whereas with low replacement, real wages show a positive response. Low employment protection is associated with higher responses from unemployment on impact, indicating that stricter employment protection does limit flow in and out of unemployment in the context of external demand shock. These results are in line with the results obtained in Abbritti and Weber (2018), who argue for a dichotomy in which some labour market institutions restrict wages adjustment whereas others restrict unemployment adjustments. In their classification, employment protection is related to unemployment rigidities and the replacement rate is related to wage rigidities, consistent with what impulse response analysis implies here.

Impulse response analysis suggests that differences in labour market institutions are related to heterogeneity in shock adjustment. Still, further analysis is needed to assess the quantitative importance of labour market institutions. To evaluate the quantitative importance of labour market institutions, counterfactual simulations are run. In the simulations, values for labour market institution variables are altered to reflect labour market reforms. In the context of one country's TVP VAR, Primiceri (2005) and Canova and Gambetti (2009) have employed counterfactual analysis to simulate data under counterfactual monetary policy rules.

The procedure to implement the counterfactual analysis is the following. For a given country, parameters of the VAR are obtained from equations (5) and (6), given the values for institutional variables ,$Z_{i,t}$, for this country. Another set of parameters for the VAR are obtained by changing the values of labour market institution variables. Then, conditional forecasts are run with both sets of parameters. The conditioning variable is US GDP growth, which enters the VAR as an exogenous variable. The difference between the paths of conditional forecasts are driven by the difference in labour market institution variables.

Figure 3 displays the actual data and the conditional forecasts, which are based on the actual path of data in $Z_{i,t}$ and the reform scenarios where the values of labour market institution variables are altered. The country in this analysis is Finland, and the conditional forecasts start in 2008Q4. The time period starts from the beginning of the financial crisis. In 2009Q1, the Finnish GDP dropped 9 % compared to 2008Q1. At the same time, wage increases that had already been decided were implemented, and real wages grew rapidly in 2009 despite the weakening economic conditions. The counterfactual simulation tries to assess whether the adjustment would have been different if Finland had had different labour market institutions.

In the first panel, the wage-setting coordination variable is changed from high coordination to low coordination. In the second panel, the value for the replacement rate variable is changed. The actual value for Finland for the replacement rate in 2009 corresponds to the 42nd sample percentile, which is changed to the 22nd percentile in the sample. In the third panel, the value for employment protection is changed from the actual value, which corresponds to the 50th sample percentile, to the 30th sample percentile. In the fourth panel, all three reforms are implemented simultaneously.

One difference in this counterfactual analysis with impulse response analysis is that in this analysis, the changes in the intercepts also matter. The unconditional means that VARs under different parameter values imply are different, and this underlies the biggest level shifts. According to Figure 3, it seems that employment protection reforms change the dynamics of an economy only modestly, whereas wage-setting coordination and unemployment benefit reforms have more scope. The results suggest that given a decentralized wage setting system, the initial impact of real wages would have been more favourable and GDP would have declined slightly less.

According to Figure 3, the rise in unemployment would have been smaller if the replacement rate had been lower. However, this is not associated with a change in GDP developments. One explanation for this finding would be that given a lower replacement rate, workers are willing to accept jobs with lower wages and lower productivity. This would reduce the unemployment but would have a smaller effect on GDP.

When all reforms are implemented, as in the last row in Figure 3, an interesting result emerges. Real wages adjust in the beginning similarly as in the coordination reform scenario. However, afterwards, the real wage growth is more modest. This suggests that the interaction effects of labour market institutions are important. Switching to firm-level wage-setting from centralized wage-setting in an economy where replacement rates are high could lead to high wage demands, since a high replacement rate provides a better outside option and hence increases the bargaining power of a worker.

One way of seeing Figure 3 is that although the counterfactuals do seem to differ from the actual conditional forecasts, the differences are small compared to the fluctuations that the data display. This suggests that labour market reforms can change the average dynamics of an economy over time, but these results do not back up the suggestion that labour market reforms should be used as a cure for a crisis country. The results suggest that the changes that reforms can potentially bring are small compared to the fluctuations that a country experiences during a crisis.

2.5 Conclusions

The relation of labour market institutions to business cycle dynamics was studied using a TVP VAR estimated on a panel of countries. Results suggest that labour market institutions have explanatory power for the heterogeneity in the volatilities of macroeconomic variables and in shock adjustment. In countries with high coordination in wage-bargaining, wages are less volatile and respond less to productivity shocks. In countries with strict employment protection legislation, wages are less volatile and unemployment is less responsive to external

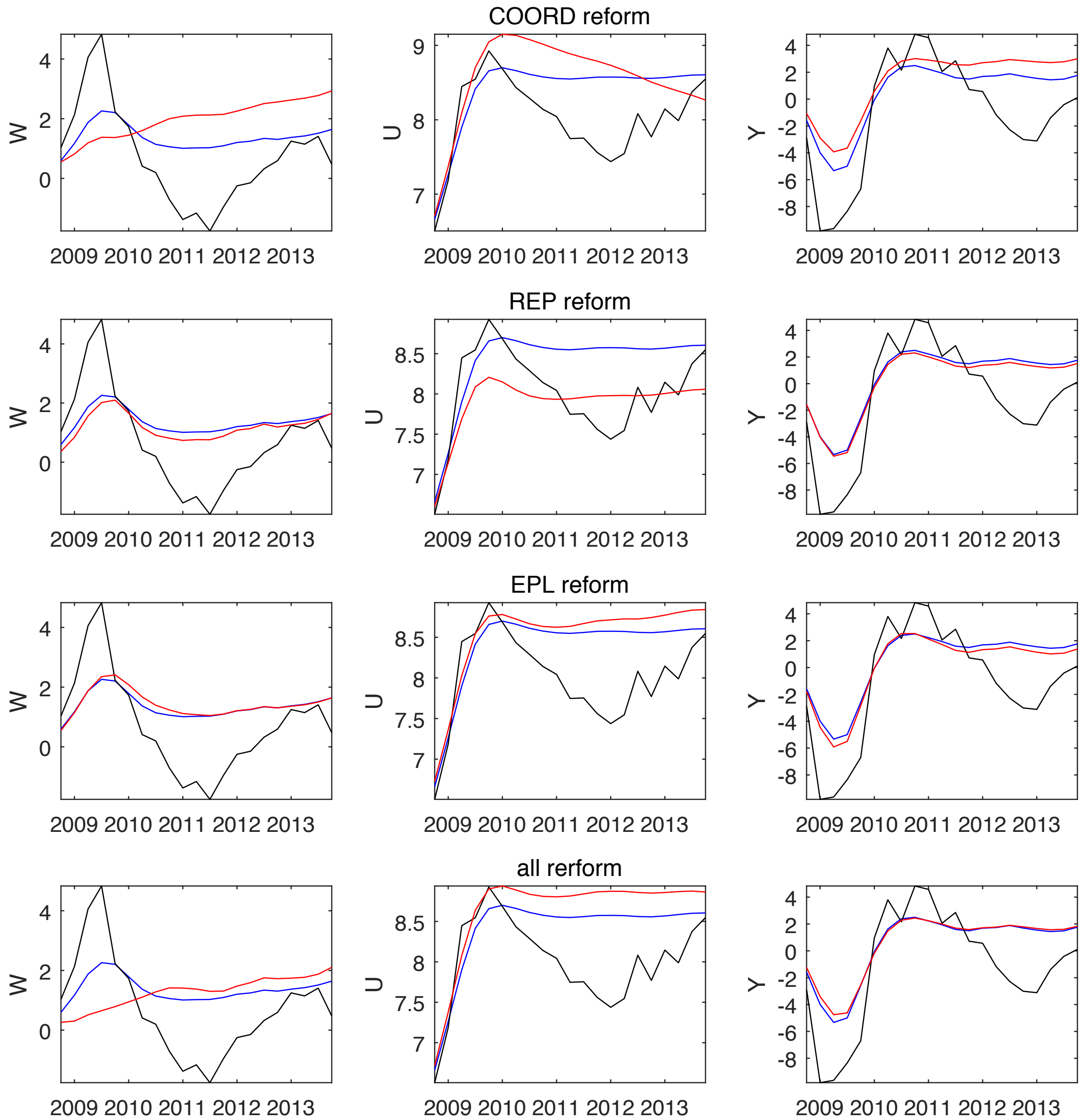

Figure 3. Conditional forecasts. Black line:data (Finland), blue line: conditional forecast, red line: conditional forecast with a reform. W: real wage growth, U: unemployment, Y: GDP growth

demand shocks. If unemployment benefits are generous, unemployment and wages are more responsive to productivity shocks. The explanatory power of labour market institutions for business cycle heterogeneity seems comparable to that of the control variables used (trade to GDP, government consumption to GDP and Euro dummy). When trying to assess the scope that labour market reforms could achieve in changing the shock adjustment process of an economy, the results speak to only modest changes.

A growing number of papers have studied the relation of institutions and macroeconomic characteristics to macroeconomic dynamics. For many countries, the series for institutions and macroeconomic characteristics have not been sufficiently long for consistent estimation, and hence, better data availability in the near future might increase the attractiveness of this approach. In this paper, I have presented a Bayesian hierarchical estimation procedure that explicitly models the dependence of VAR parameters on institutional variables while allowing for unexplained parameter variation. Essentially, allowing for unexplained parameter variation makes the relation between institutional variables and VAR parameters stochastic, whereas neglecting the unexplained parameter variation makes the relation deterministic. I have illustrated that the assumption of deterministic or stochastic relations is crucial for the inference. Another distinction across studies is whether the comparison criteria, a business cycle statistic or an impulse response, are estimated first and then linked to institutional variables or, as I have done, a (VAR) model is first estimated with a relation between model parameters and institutional variables, and then a comparison is made between model-implied business cycle statistics and impulse responses conditional on institutional variables. Further research is needed to develop an established way of modelling heterogenous dynamics with institutional variables in order to make the results across studies more comparable and to understand the merits and pitfalls of different approaches.

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Appendix 2.A Gibbs sampler algorithm for the restricted model

Model is given by

$$y_{\mathrm{i,t}} = X_{\mathrm{i,t}}\beta_{\mathrm{i,t}} + e_{\mathrm{i,t}}, \qquad e_{\mathrm{i,t}} \sim N(0, \Omega_{\mathrm{i,t}}) \tag{12}$$

where $X_{i,t}$ includes lags of depended variables and a constant and exogenous variables. The variance-covariance matrix $\Omega_{\mathrm{i,t}}$ is decomposed with

$$A_{\mathrm{i,t}}\Omega_{\mathrm{i,t}}A'_{\mathrm{i,t}} = \Sigma_{\mathrm{i,t}}\Sigma'_{\mathrm{i,t}} \tag{13}$$

where $A_{\mathrm{i,t}}$ is a lower diagonal matrix with ones on the diagonal and $\Sigma_{\mathrm{i,t}}$ is a diagonal matrix. The evolution of the coefficients $\beta_{\mathrm{i,t}}$, and elements in $A_{\mathrm{i,t}}$ ($a_{i,t}$'s) and $\Sigma_{\mathrm{i,t}}$ ($\sigma_{\mathrm{i,t}}$'s) is given by the constants and the labour market institution variables in $Z_{i,t}$.

$$\begin{bmatrix} \beta_{\mathrm{i,t}} \\ a_{\mathrm{i,t}} \\ log(\sigma_{\mathrm{i,t}}) \end{bmatrix} = Z_{\mathrm{i,t}} \begin{bmatrix} \theta_\beta \\ \theta_a \\ \theta_\sigma \end{bmatrix} \tag{14}$$

A model that allows for error terms in (14) is introduced in section B.

In what follows, a stacked form of (12) is used in it is given as

$$Y = X\beta + E \qquad E \sim N(0, \Omega) \tag{15}$$

where $Y = \left[y'_{1,1}, y'_{1,2} \dots y'_{N,T}\right]'$, $\beta = \left[\beta'_{1,1}, \beta'_{1,2} \dots \beta'_{N,T}\right]$, $E = \left[e_{1,1}, e_{1,2} \dots e_{N,T}\right]$ and

$$X = \begin{bmatrix} X_{1,1} & & & \\ & X_{1,2} & & \\ & & \ddots & \\ & & & X_{N,T} \end{bmatrix}, \Omega = \begin{bmatrix} \Omega_{1,1} & & & \\ & \Omega_{1,2} & & \\ & & \ddots & \\ & & & \Omega_{N,T} \end{bmatrix}$$

Parameters in (14) do not have analytical joint distributions but conditional distributions can be derived following Primiceri (2005) and posterior sampling can be done using Gibbs sampler. Namely, the parameters are sampled block by block conditional on a draw of all other parameters. Rest of this section shows these steps.

Drawing θ_β

Substitute $\beta_{i,t} = Z_{i,t}\theta_\beta$ and with appropriately defined block diagonal matrices

$$Y = XZ\theta_\beta + E \tag{16}$$

(16) is essentially a normal linear regression model. Given Ω, the posterior distribution of θ_β is (see e.g.)

$$V_{\theta_\beta} = (D_{\theta_\beta}^{-1} + Z'X\Omega XZ)^{-1} \tag{17}$$

$$\bar{\theta}_\beta = V_{\theta_\beta}(D_{\theta_\beta}^{-1}\underline{\theta}_\beta + Z'X'\Omega y) \tag{18}$$

$$\theta_\beta| \sim N(\bar{\theta}_\beta, V_{\theta_\beta}) \tag{19}$$

D_{θ_β} is the prior variance-covariance matrix and $\underline{\theta}_\beta$ is the prior mean.

Drawing θ_a

Equations (12) and (13) can be combined to yield

$$y_{i,t} = X_{i,t}\beta_{i,t} + A_{i,t}^{-1}\Sigma_{i,t}\epsilon_{i,t} \tag{20}$$

where $\epsilon_{i,t} \sim N(0,1)$. Rearrange to get

$$A_{i,t}(y_{i,t} - X_{i,t}\beta_{i,t}) = A_{i,t}\hat{y}_{i,t} = \Sigma_{i,t}\epsilon_{i,t} \tag{21}$$

$A_{i,t}$ is lower diagonal matrix and (21) can be written as

$$\begin{bmatrix} 1 & 0 & 0 \\ a_{i,t}^1 & 1 & 0 \\ a_{i,t}^2 & a_{i,t}^3 & 1 \end{bmatrix} \begin{bmatrix} \hat{y}_{i,t}^1 \\ \hat{y}_{i,t}^2 \\ \hat{y}_{i,t}^3 \end{bmatrix} = \Sigma_{i,t}\epsilon_{i,t} \tag{22}$$

Omit the first equation from (22) and rewrite it as

$$\begin{bmatrix} \hat{y}_{i,t}^2 \\ \hat{y}_{i,t}^3 \end{bmatrix} = \begin{bmatrix} a_{i,t}^1 & 0 \\ a_{i,t}^2 & a_{i,t}^3 \end{bmatrix} \begin{bmatrix} -\hat{y}_{i,t}^1 \\ -\hat{y}_{i,t}^2 \end{bmatrix} + \begin{bmatrix} \sigma_{i,t}^2 & 0 \\ 0 & \sigma_{i,t}^3 \end{bmatrix} \begin{bmatrix} \epsilon_{i,t}^1 \\ \epsilon_{i,t}^2 \end{bmatrix} \tag{23}$$

And more compactly as

$$\ddot{y}_{i,t} = \tilde{A}_{i,t}\tilde{y}_{i,t} + \tilde{\Sigma}_{i,t}\tilde{\epsilon}_{i,t} \tag{24}$$

Conditionally on $\tilde{y}_{i,t}$ and $\tilde{\Sigma}_{i,t}$,the elements of $A_{i,t}$ can be sampled using results for normal linear regression. Although $\tilde{A}_{i,t}$ is a reduced matrix of $A_{i,t}$ it contains all the unknown elements of $A_{i,t}$. Substitute $\tilde{A}_{i,t} = Z_{i,t}\theta_a$ to (26) and with appropriately defined block diagonal matrices one gets

$$\ddot{Y} = \tilde{Y}Z\theta_a + \tilde{\Sigma}\tilde{\epsilon} \tag{25}$$

θ_a can be sampled with

$$V_{\theta_a} = (D_{\theta_a}^{-1} + Z'\tilde{Y}'\tilde{\Sigma}\tilde{\Sigma}\tilde{Y}Z)^{-1} \tag{26}$$

$$\bar{\theta}_a = V_{\theta_a}(D_{\theta_a}^{-1}\underline{\theta}_a + Z'\tilde{Y}'\tilde{\Sigma}\tilde{\Sigma}\ddot{y}) \tag{27}$$

$$\theta_a| \sim N(\bar{\theta}_a, V_{\theta_a}) \tag{28}$$

Drawing θ_σ

Given $A_{i,t}$

$$A_{i,t}(y_{i,t} - X_{i,t}\beta_{i,t}) = y^*_{i,t} = \Sigma_{i,t}\epsilon_{i,t} \tag{29}$$

Equation (29) is nonlinear but can be linearized by squaring and taking logs yielding

$$y^{**}_{i,t} = 2h_{i,t} + \epsilon^{**}_{i,t} \tag{30}$$

where $h_{i,t} = log(\sigma_{i,t})$; $\epsilon^{**}_{i,t} = log(\epsilon^2_{i,t})$; $y^{**}_{i,t} = log[(y^*_{i,t})^2 + \bar{c}]$. $\bar{c}$ is an offset constant to avoid numerical problems in the estimation since squared $y^*_{i,t}$ can be very small. (32) is linear but not Gaussian. $\epsilon_{i,t}$ is distributed Normally with unitary variance. Hence $\epsilon^{**}_{i,t}$ is distributed as a log $\chi^2(1)$. To transform (30) into Gaussian, a mixture of normals approximations of the log χ^2 is used, as is described Kim, Shepard and Chip (1998). Denote var($\epsilon^{**}_{i,t}$)= $S_{i,t}$ when the distribution of $\epsilon^{**}_{i,t}$ is approximated with a mixture of normal distributions.

Substitute $h_{i,t} = Z_{i,t}\theta_\sigma$ to (30) and with appropriately defined block diagonal matrices one gets[17]

$$Y^{**} = \mathbf{2}Z\theta_\sigma + \epsilon^{**} \tag{31}$$

θ_σ can be sampled with

$$V_{\theta_\sigma} = (D_{\theta_\sigma}^{-1} + Z'\mathbf{2}'S\mathbf{2}Z)^{-1} \tag{32}$$

$$\bar{\theta}_\sigma = V_{\theta_\sigma}(D_{\theta_\sigma}^{-1}\underline{\theta}_\sigma + Z'\mathbf{2}'SY^{**}) \tag{33}$$

$$\theta_\sigma| \sim N(\bar{\theta}_\sigma V_{\theta_\sigma}) \tag{34}$$

---

[17] **2** refers to a diagonal matrix with diagonal entries equaling 2.

Appendix 2.B Gibbs sampler algorithm for the general model

This section specifies Gibbs sampler algorithm for a model which allows for unit specific and time varying error terms in the VAR parameters. VAR model is given in (12) and (13) but instead of (14), VAR parameters are assumed to follow

$$\begin{bmatrix} \beta_{\mathrm{i,t}} \\ a_{\mathrm{i,t}} \\ log(\sigma_{\mathrm{i,t}}) \end{bmatrix} = Z_{\mathrm{i,t}} \begin{bmatrix} \theta_\beta \\ \theta_a \\ \theta_\sigma \end{bmatrix} + \omega_{\mathrm{i}}\tilde{\eta}_{\mathrm{i,t}} + \eta_{\mathrm{i}} \tag{35}$$

$$\tilde{\eta}_{i,t} = \tilde{\eta}_{i,t-1} + u_{i,t}, u_{i,t} \sim N(0, I) \tag{36}$$

$$\tilde{\eta}_{i,0} = 0 \tag{37}$$

Start by substituting (37) to (12) and obtain

$$y_{i,t} = X_{i,t}Z_{i,t}\theta_\beta + X_{i,t}\omega_i^\beta \tilde{\eta}_{i,t}^\beta + X_{i,t}\eta_i^\beta + e_{i,t} \tag{38}$$

In what follows, β subscripts are omitted to simplify the notation. Conditional on $\omega_i\eta_{i,t}, \eta_i$ and $\Omega_{i,t}$ posterior for θ is given by

$$\bar{\theta} = V_\theta(D_\theta^{-1}\underline{\theta} + Z'X'\Omega(y - X\omega\tilde{\eta} - X\eta)) \tag{39}$$

$$\theta| \sim N(\bar{\theta}, V_\theta) \tag{40}$$

The posterior of η can be sampled with

$$V_\eta = (D_\eta^{-1} + X'\Omega X)^{-1} \tag{41}$$

$$\bar{\eta} = V_\eta(D_\eta^{-1}\underline{\eta} + X'\Omega(y - X\omega\tilde{\eta} - XZ\theta)) \tag{42}$$

$$\eta| \sim N(\bar{\eta}, V_\eta) \tag{43}$$

Conditional on ω, η, θ and Ω the simulation of $\tilde{\eta}$ could be carried out using the standard procedure in TVP-model literature, which uses Kalman filtering. However, when working with a macro panel data, this results that the Kalman filtering loops are not of size T but of size NT, which increases the computation time. Hence I use alternative simulation approach by Chan and Jeliazkov (2009), which simulates the latent states of a TVP model without the need for loops and with one step.

The law of motion for $\tilde{\eta}$ in (36) and (37) can be written compactly as

$$H\tilde{\eta} = u, \qquad u \sim N(0, S_u) \tag{44}$$

where

$$H = \begin{bmatrix} I & & & & \\ -I & I & & & \\ & -I & I & & \\ & & \ddots & \ddots & \\ & & & -I & I \end{bmatrix}, S_u = \begin{bmatrix} 0 & & & & \\ & 1 & & & \\ & & 1 & & \\ & & & \ddots & \\ & & & & 1 \end{bmatrix} \tag{45}$$

(45) implies that prior for η is $\tilde{\eta} \sim N(0, K^{-1})$ where $K = H' S_u^{-1} H$

The posterior simulation of η uses again the fact that conditional on other parameters (40) is simply a normal linear regression model.

$$V_\eta = (K + X'\omega'\Omega X\omega) \tag{46}$$

$$\bar{\tilde{\eta}} = V_\eta^{-1}(\omega'\Omega(y - XZ\theta - X\eta_i)) \tag{47}$$

$$\eta \sim N(\bar{\tilde{\eta}}, V_\eta^{-1}) \tag{48}$$

The merit of the approach by Chan and Jeliazkov (2009) is that instead of inverting the very large matrix V_η , the simulation can be implemented using only Cholesky factors of V_η.[18] This is efficient since V_η is sparse matrix, containing non-zero elements only close to diagonal.

Given $\eta, \eta, \theta, \Omega$ ω can be sampled with

$$V_\omega = (K + X'\tilde{\eta}'\Omega X\tilde{\eta}) \tag{49}$$

$$\bar{\omega} = V_\omega^{-1}(\tilde{\eta}'\Omega(y - XZ\theta - X\eta)) \tag{50}$$

$$\omega \sim N(\bar{\omega}, V_\omega^{-1}) \tag{51}$$

Update prior variances

The prior variance for η_i is a diagonal matrix, D_η and each element is distributed individually as

$$\tau_i^2 \sim exp\left(\frac{\lambda^2}{2}\right) \tag{52}$$

and the posterior is given by inverse Gaussian:

$$\tau_i^2 \sim IG\left(\sqrt{\frac{\lambda^2}{\eta_i^2}}, \lambda^2\right) \tag{53}$$

and λ is updated with

$$\lambda \sim Gamma\big(n_\eta + a_1, \frac{1}{2}\sum_{j=1}^{n_\eta} \tau_j + a_2\big) \tag{54}$$

where n_η is the length of η vector.

The prior variance for ω_i is a diagonal matrix, D_ω and each element is distributed individually as

$$\xi_i^2 \sim exp\left(\frac{\kappa^2}{2}\right) \tag{55}$$

18 The columns and rows of V_η are of length NT times the number of coefficients, over 30 000 in the application of this study.

and the posterior is given by inverse Gaussian:

$$\xi^2 \sim IG\Big(\sqrt{\frac{\kappa^2}{\omega_i^2}}, \kappa^2\Big) \tag{56}$$

and κ is updated with

$$\kappa \sim Gamma\big(n_\omega + b_1, \frac{1}{2}\sum_{j=1}^{n_{\beta_i}} \xi_j + b_2\big) \tag{57}$$

This section has presented how to simulate conditional posterior distributions for the parameters related to VAR coefficients. Similar logic applies to the posterior simulation of parameters related to $a_{i,t}$'s and $\sigma_{i,t}$'s. Hence these steps are not reported here but are available upon a request.

Appendix 2.C Simulation of conditional business cycle statistics and impulse responses

This section explains how business cycle statistics and impulse responses are obtained conditional on institutional variables. Given distributions for θ's and η's VAR parameters can be simulated using equations (35) after specific values are given for variables in $Z_{i,t}$.

After VAR parameters are obtained, moments from the VAR can be computed according to following formulas. Omit the intercepts, separate endogenous and exogenous variables (US GDP) and rewrite the VAR in companion form as

$$Y_{i,t} = B_y Y_{i,t-1} + B_x X_{i,t} + E_{i,t} \qquad E_{i,t} \sim N(0, \Sigma_{E_{i,t}})) \tag{58}$$

where $Y_{i,t} = \begin{bmatrix} y_{i,t} & y_{i,t-1} & \dots & y_{t-q+1} \end{bmatrix}$.

The unconditional variances and covariances of $Y_{i,t}$ are given by

$$\begin{aligned} & E[(Y_{i,t} - E(Y_{i,t}))(Y_{i,t} - E(Y_{i,t}))] \\ = {} & E[((B_y Y_{i,t-1} + B_x X_{i,t} + E_{i,t}) - E(B_y Y_{i,t-1} + B_x X_{i,t})) \\ & \times((B_y Y_{i,t-1} + B_x X_{i,t} + E_{i,t}) - E(B_y Y_{i,t-1} + B_x X_{i,t}))] \end{aligned} \tag{59}$$

Given fixed values in Z and η, VAR parameters are constant and covariance stationarity can be safely assumed. Together with assuming the exogeneity of $X_{i,t}$, $cov(Y_{i,t-1}, X_{i,t}) = 0$,(59) leads to

$$\Sigma_y = B_y \Sigma_y B_y' + B_x \Sigma_x B_x' + \Sigma_E \tag{60}$$

Σ_y can be solved with formula (see Canova (2007) for closer details):

$$vec(\Sigma_Y) = [I - B_y \otimes B_y]^{-1} vec(B_x \Sigma_x B_x' + \Sigma_E) \tag{61}$$

Auto covariances can be obtained with $ACF(\tau) = B_y^\tau \Sigma_Y$

The sign-identified impulse responses are obtained as in Rubio-Ramírez, Waggoner and Zha (2010). Given variance-covariance matrix of the residuals, Ω obtain Cholesky decomposition $PP' = \Omega$. Draw N times N matrix J, from N(0,1) distribution. Take QR decomposition for J, that is J=QR. A candidate impact matrix is given as $M = PQ$. If this satisfies the restrictions, it is stored. In the application of this study there is always three Ω's, corresponding to three regimes, high, intermediate and low. It is required that all $P_{high}Q$, $P_{intermed}Q$ and $P_{low}Q$ satisfy the sign-restrictions.

Appendix 2.D Additional tables and figures

Table 4. Conditional business cycle statistics, pre-2009 data

	COORD			REP			EPL		
	Low	Intermed	High	Low	Intermed	High	Low	Intermed	High
var(w)	1,9''	1,05	0,97	1,07	0,98	0,98	1,11	0,97	0,91
	1 4,27	0,74 1,61	0,7 1,35	0,77 1,57	0,77 1,26	0,74 1,32	0,78 1,62	0,77 1,25	0,71 1,19
var(u)	1,56	1,02	0,98	1,42	1,1	1,01	1,04	1,13	1,32
	0,63 7,54	0,61 2,02	0,59 2,06	0,69 4,74	0,66 2,15	0,59 2,23	0,53 3,45	0,67 2,23	0,81 2,42
var(y)	1,45	1,12	1,12	1,59	1,42	1,38	1,31	1,42'	1,66
	0,84 2,92	0,85 1,51	0,85 1,45	1,12 2,37	1,05 1,95	0,97 2,03	0,98 1,74	1,13 1,8	1,31 2,14
var(y/n)	3,21*	1,13	1,14	1,51	1,28	1,24	1,22	1,33'	1,55
	1,62 8,84	0,88 1,48	0,88 1,49	0,84 2,95	0,78 2,17	0,69 2,37	0,92 1,66	1,04 1,7	1,23 1,99
cor(y,u)	-0,15	-0,19''	-0,03	-0,07	-0,06	-0,07	-0,07	-0,06	-0,05
	-0,53 0,21	-0,31 -0,06	-0,15 0,1	-0,2 0,11	-0,18 0,06	-0,19 0,07	-0,21 0,1	-0,17 0,06	-0,17 0,08
cor(y,w)	-0,11	-0,01	-0,04	-0,05	-0,07	-0,08	-0,08	-0,05	0
	-0,41 0,19	-0,18 0,15	-0,15 0,07	-0,2 0,11	-0,18 0,04	-0,2 0,04	-0,24 0,09	-0,16 0,07	-0,11 0,11
cor(w,u)	0	-0,05	0,01	-0,05	0,02	0,05	0,02	0,01	-0,01
	-0,33 0,29	-0,25 0,14	-0,16 0,16	-0,34 0,16	-0,15 0,18	-0,14 0,22	-0,25 0,24	-0,16 0,17	-0,18 0,16
cor(u,y/n)	-0,16	-0,11''	0,05	-0,05	-0,02	0,02	-0,07'	-0,02'	0,05
	-0,53 0,19	-0,21 0	-0,06 0,16	-0,17 0,07	-0,13 0,1	-0,11 0,17	-0,21 0,07	-0,13 0,09	-0,06 0,17
cor(w,y/n)	-0,06	-0,02	0,04	0,1	0,05	0,01	0,1	0,07	0,01
	-0,49 0,33	-0,17 0,12	-0,07 0,15	-0,03 0,25	-0,05 0,16	-0,11 0,13	-0,05 0,25	-0,04 0,18	-0,1 0,11
acor(w)	0,66'	0,67''	0,54	0,55	0,55	0,55	0,57	0,54	0,53
	0,53 0,83	0,56 0,77	0,44 0,64	0,44 0,67	0,47 0,62	0,47 0,63	0,47 0,68	0,47 0,62	0,45 0,61
acor(u)	0,97	0,97	0,97	0,98	0,97	0,97	0,97	0,97	0,98
	0,94 0,99	0,96 0,98	0,95 0,99	0,96 0,99	0,96 0,99	0,95 0,99	0,95 0,99	0,96 0,99	0,97 0,99
acor(y)	0,79''	0,69	0,67	0,61'	0,67''	0,7	0,65	0,67	0,7
	0,7 0,89	0,62 0,75	0,62 0,72	0,54 0,69	0,62 0,72	0,65 0,76	0,58 0,72	0,62 0,72	0,64 0,75
acor(y/n)	0,83**	0,58	0,6	0,54'	0,6'	0,64	0,58	0,6'	0,64
	0,68 0,98	0,47 0,69	0,52 0,69	0 0	0 0	0 0	0,51 0,65	0,55 0,66	0,59 0,7

Note: The distributions of low and intermediate regimes are compared to that of high.′ refer to zero is not included to 80 % highest density region of distribution for the difference.″, * ,** refer to 90, 95 and 99 highest density regions.

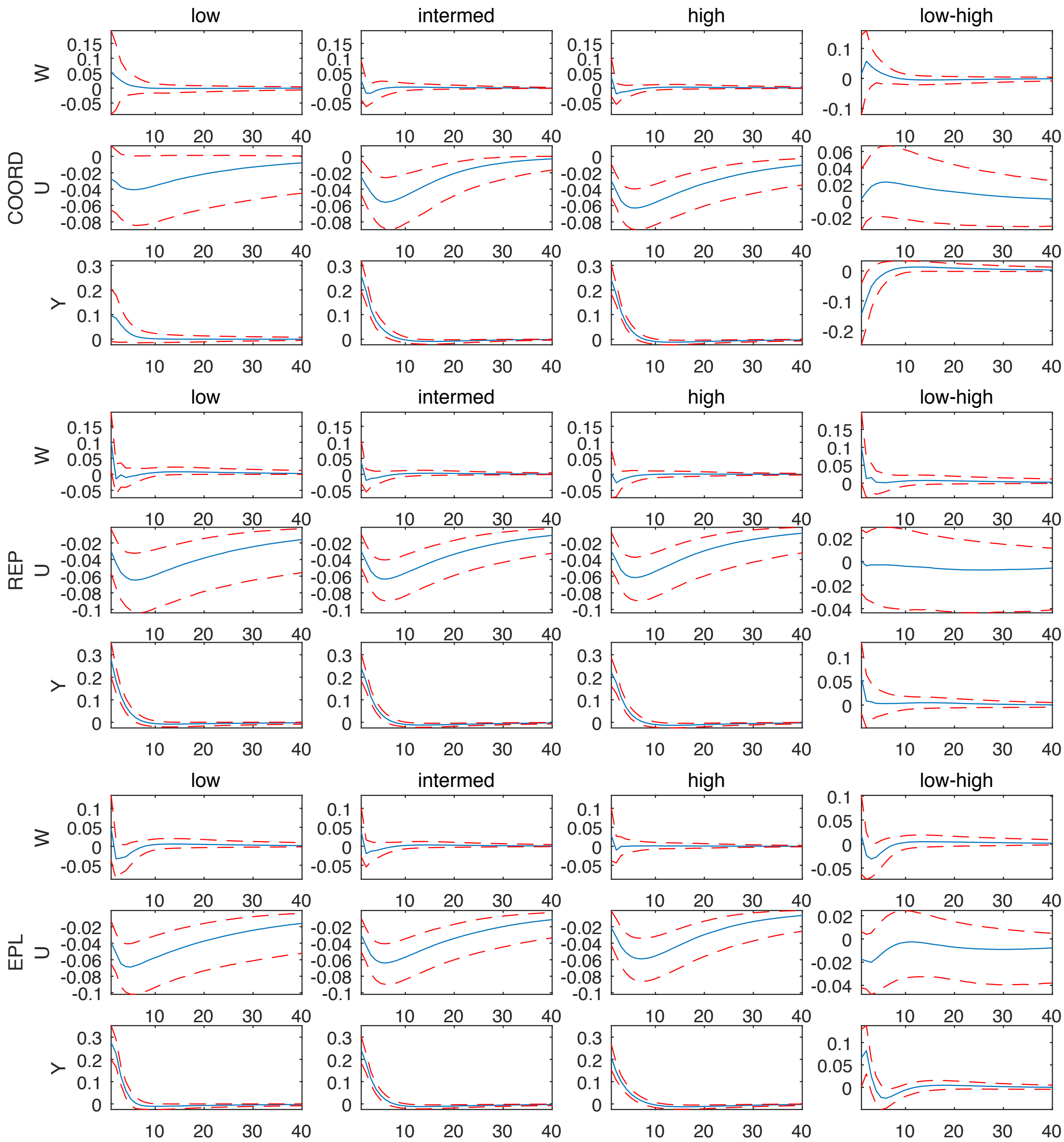

Figure 4. Impulse responses on temporary unit increase in US GDP growth conditional on three categories for wage setting coordination (COORD), replacement rate (REP) and employment protection (EPL), pre-2009 data. 80% confidence bands.

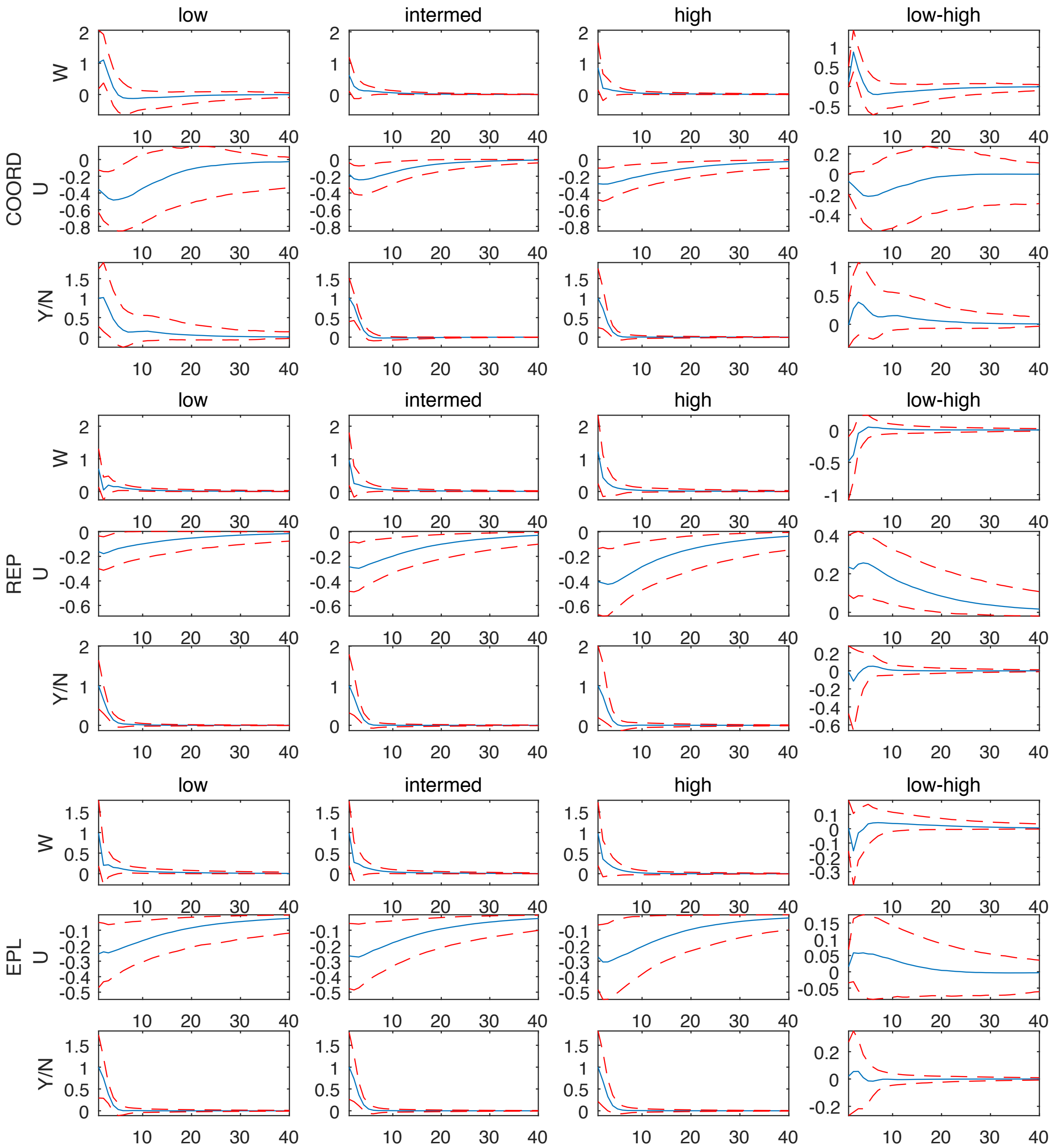

Figure 5. Impulse responses on productivity shock conditional on three categories for wage setting coordination (COORD), replacement rate (REP) and employment protection (EPL),pre-2009 data. 80% confidence bands that take into account both identification and parameter uncertainty. Impulse responses are normalized to give unitary response on impact for labour productivity Y/N.

Table 5. Conditional business cycle statistics, model without error terms for the VAR parameters

	COORD			REP			EPL		
	Low	Intermed	High	Low	Intermed	High	Low	Intermed	High
var(w)	2,07**	1,42''	1,02	1,39**	1,03*	0,92	0,73**	1,03**	1,55
	1,53 2,98	1,1 1,92	0,9 1,18	1,04 1,92	0,84 1,29	0,74 1,16	0,6 0,92	0,9 1,19	1,37 1,79
var(u)	1,28''	1,04	0,46	1,21**	0,55**	0,38	0,39*	0,56**	0,85
	0,46 16,62	0,61 2,14	0,32 0,79	0,84 1,99	0,41 0,77	0,28 0,55	0,22 0,86	0,36 0,98	0,56 1,49
var(y)	0,92	1,21	1,16	2,43**	1,51*	1,25	1,48'	1,59''	1,8
	0,58 1,65	0,97 1,52	0,99 1,39	1,91 3,18	1,17 2	0,88 1,81	1,14 1,98	1,24 2,09	1,37 2,45
var(y/n)	0,91	1,2	1,08	2,11**	1,35**	1,11	1,35	1,41'	1,58
	0,58 1,79	0,99 1,47	0,92 1,29	1,62 2,8	1,03 1,81	0,78 1,62	1,12 1,63	1,19 1,68	1,28 1,95
cor(y,u)	0	-0,13''	0	-0,01	-0,06	-0,09	-0,09	-0,07	-0,04
	-0,32 0,4	-0,22 -0,03	-0,08 0,09	-0,11 0,09	-0,14 0,03	-0,18 0	-0,17 0	-0,15 0,02	-0,14 0,07
cor(y,w)	-0,38''	0,08	-0,06	-0,1	-0,07	-0,06	-0,12	-0,07	-0,03
	-0,6 -0,14	-0,08 0,23	-0,16 0,03	-0,25 0,04	-0,2 0,06	-0,21 0,08	-0,26 0,03	-0,18 0,03	-0,12 0,07
cor(w,u)	-0,03	0,05	0,1	0,08	0,12	0,11	0,18	0,12	0,06
	-0,28 0,18	-0,13 0,21	0,02 0,19	-0,07 0,21	0,02 0,21	0,02 0,21	0,04 0,31	0,02 0,21	-0,03 0,15
cor(u,y/n)	-0,12	-0,08*	0,13	0,04	0,01	0	-0,06*	0,00*	0,11
	-0,45 0,26	-0,19 0,04	0,03 0,23	-0,07 0,16	-0,09 0,12	-0,12 0,12	-0,16 0,05	-0,1 0,11	-0,01 0,23
cor(w,y/n)	-0,19	0,01	0,01	0,05	0,05	0,03	-0,02	0,03	0,05
	-0,65 0,27	-0,21 0,23	-0,14 0,17	-0,07 0,18	-0,06 0,15	-0,09 0,14	-0,17 0,12	-0,08 0,14	-0,06 0,15
acor(w)	0,64**	0,69**	0,45	0,46	0,45	0,44	0,54*	0,45*	0,37
	0,45 0,9	0,51 0,86	0,31 0,58	0,25 0,66	0,3 0,58	0,3 0,58	0,36 0,72	0,3 0,58	0,22 0,51
acor(u)	0,97	0,97''	0,95	0,97*	0,96''	0,95	0,95	0,96	0,96
	0,94' 1	0,95 0,98	0,93 0,97	0,94 0,99	0,93 0,98	0,91 0,98	0,91 0,97	0,94 0,97	0,94 0,98
acor(y)	0,77*	0,64	0,61	0,52*	0,62*	0,66	0,6	0,62	0,64
	0,67 0,87	0,57 0,7	0,55 0,67	0,32 0,68	0,5 0,72	0,54 0,78	0,53 0,65	0,56 0,67	0,58 0,7
acor(y/n)	0,75*	0,56	0,57	0,51*	0,57*	0,6	0,53'	0,57''	0,61
	0,64 0,87	0,48 0,63	0,5 0,63	0,34 0,66	0,44 0,69	0,45 0,73	0,46 0,6	0,5 0,62	0,54 0,68

Note: The distributions of low and intermediate regimes are compared to that of high.′ refer to zero is not included to 80 % highest density region of distribution for the difference.″, * ,** refer to 90, 95 and 99 highest density regions.

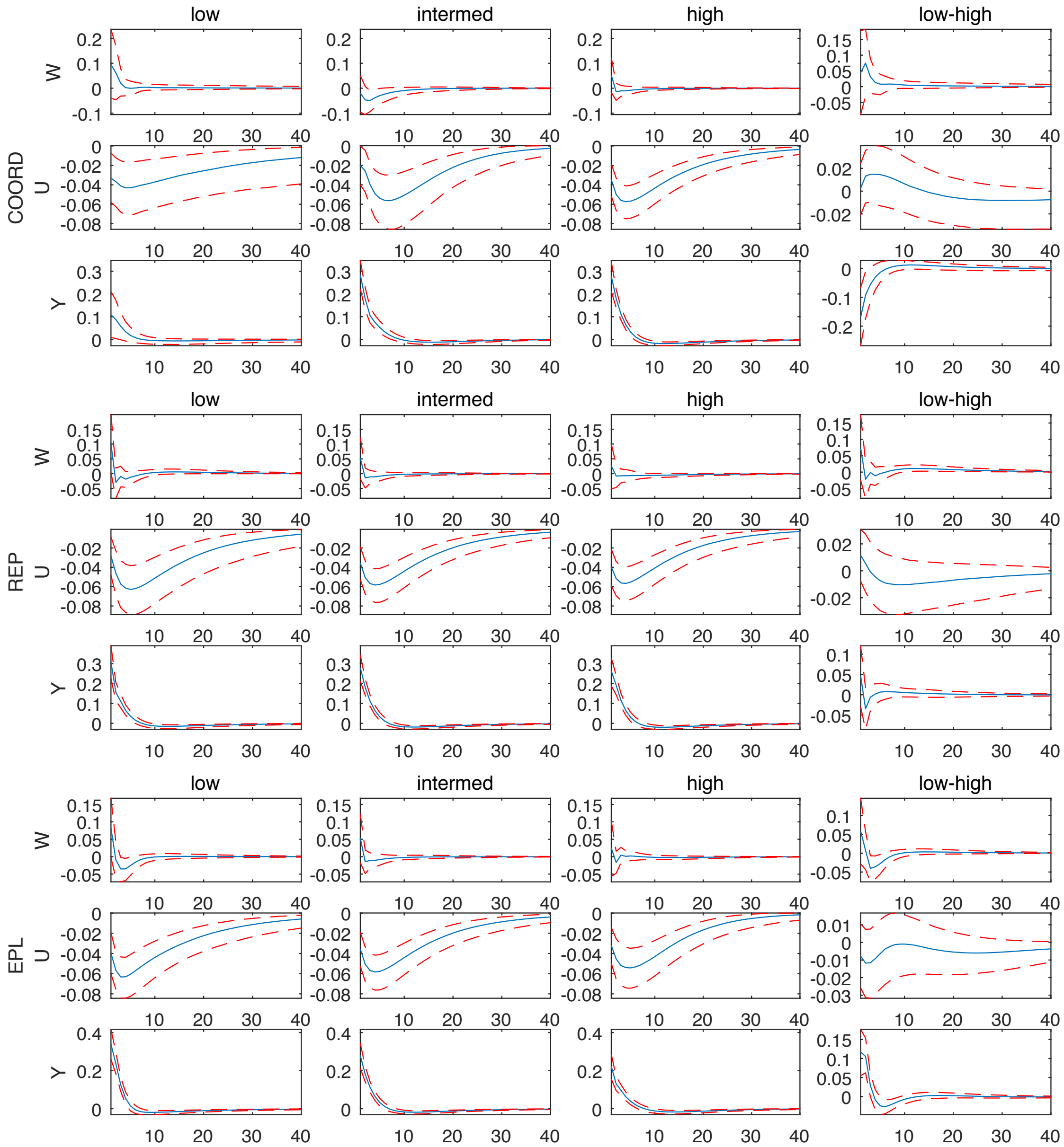

Figure 6. Impulse responses on temporary unit increase in US GDP growth conditional on three categories for wage setting coordination (COORD), replacement rate (REP) and employment protection (EPL), pre-2009 data, model without error terms for the VAR parameters. 80% confidence bands.

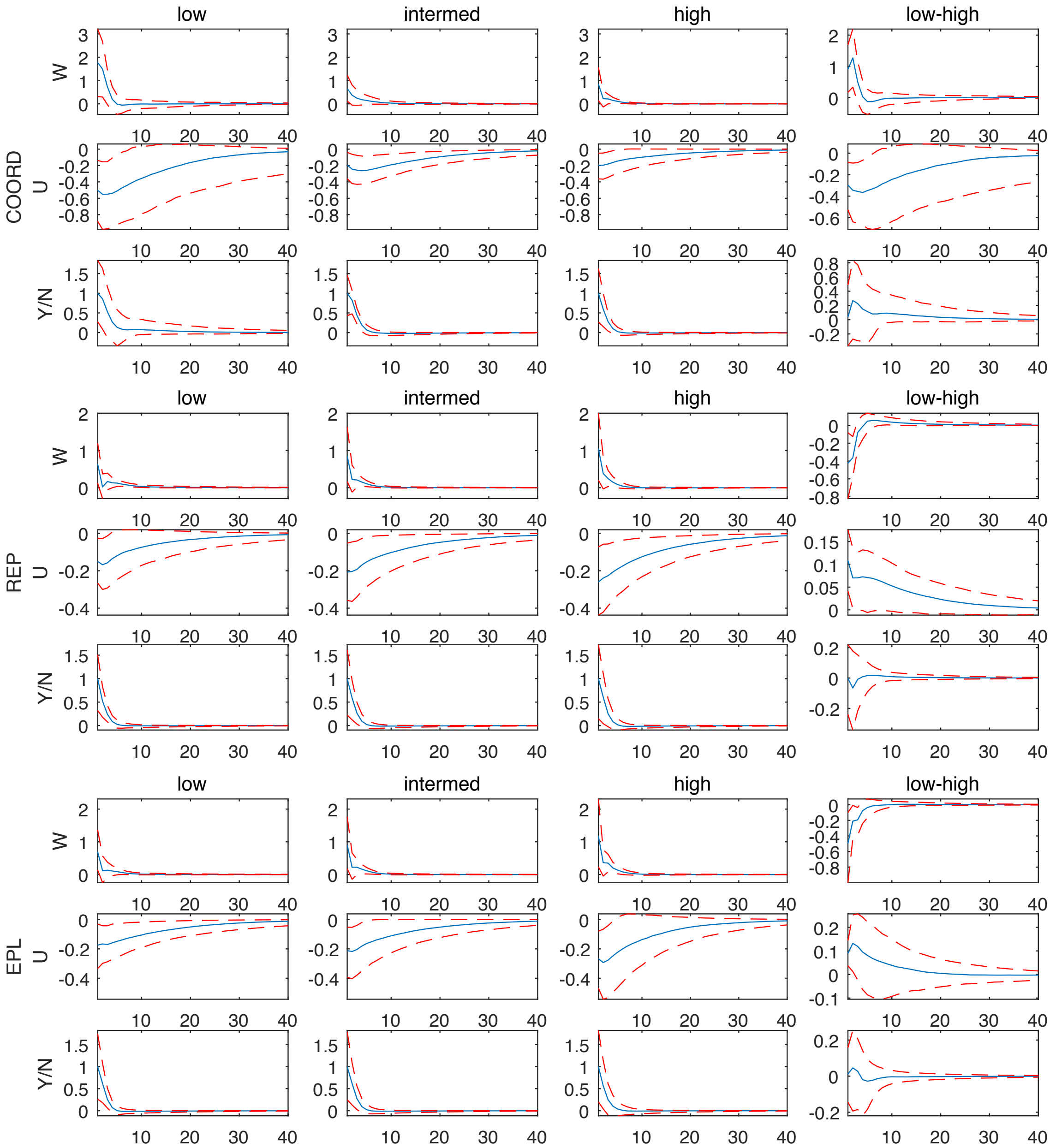

Figure 7. Impulse responses on productivity shock conditional on three categories for wage setting coordination (COORD), replacement rate (REP) and employment protection (EPL), pre-2009 data, model without error terms for the VAR parameters. 80% confidence bands that take into account both identification and parameter uncertainty. Impulse responses are normalized to give unitary response on impact for labour productivity Y/N.

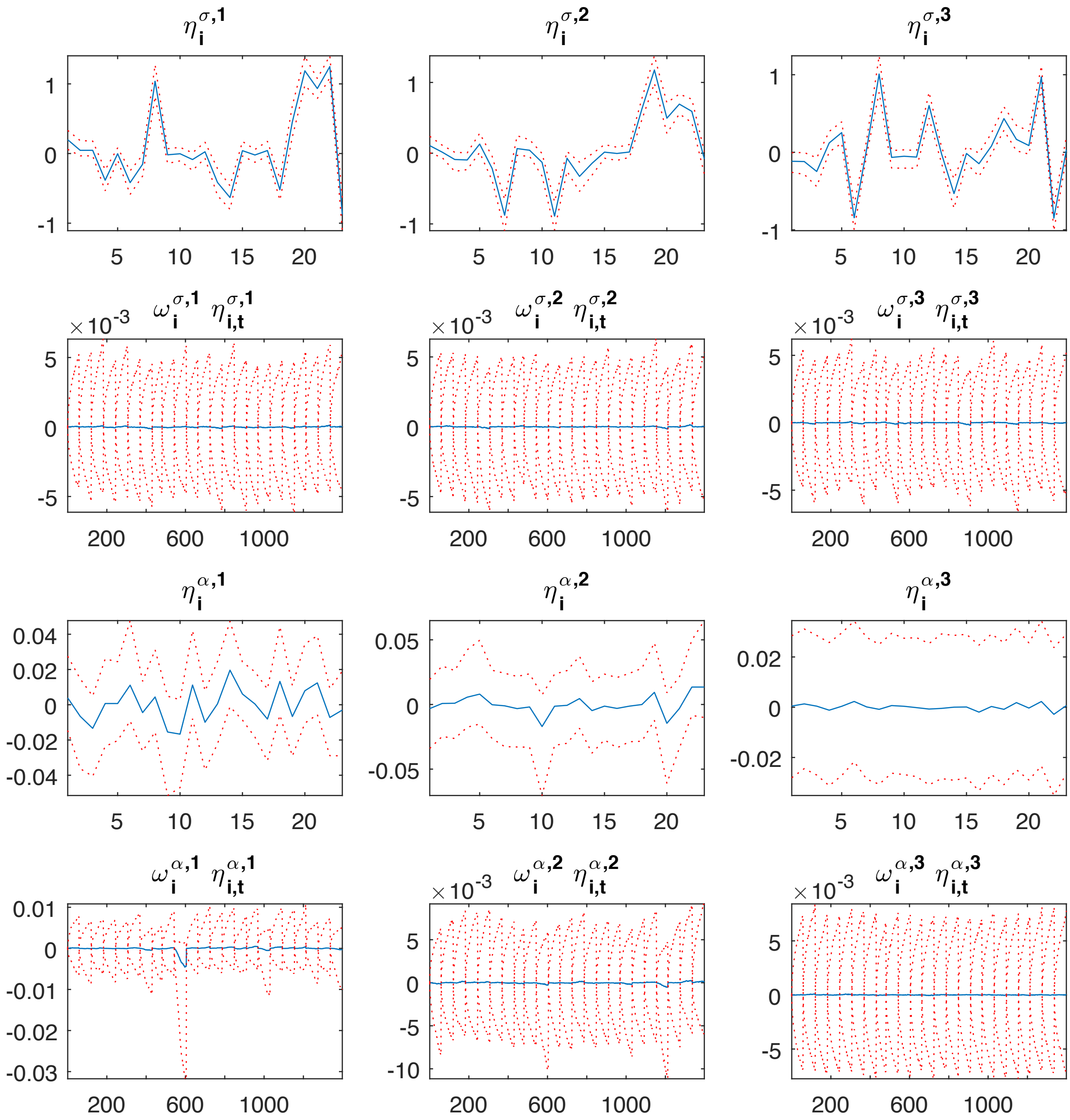

Figure 8. Error terms for the parameters of variance covariance matrix, $\Omega_{i,t}$. First two rows of plots show error terms for $log(\sigma)$'s. Ordering of the variables in the VAR is real wage growth, unemployment and GDP growth. Last two rows of plots show error terms for the elements in $A_{i,t}$. a_1 corresponds to (2,1) cell in A, a_2 to (3,1) cell and a_3 to (3,2) cell. The $\eta_i$terms are country specific initial conditions. The $\omega_{i,t}\eta_{i,t}$terms are the country specific time-varying error process and are stacked country by country.

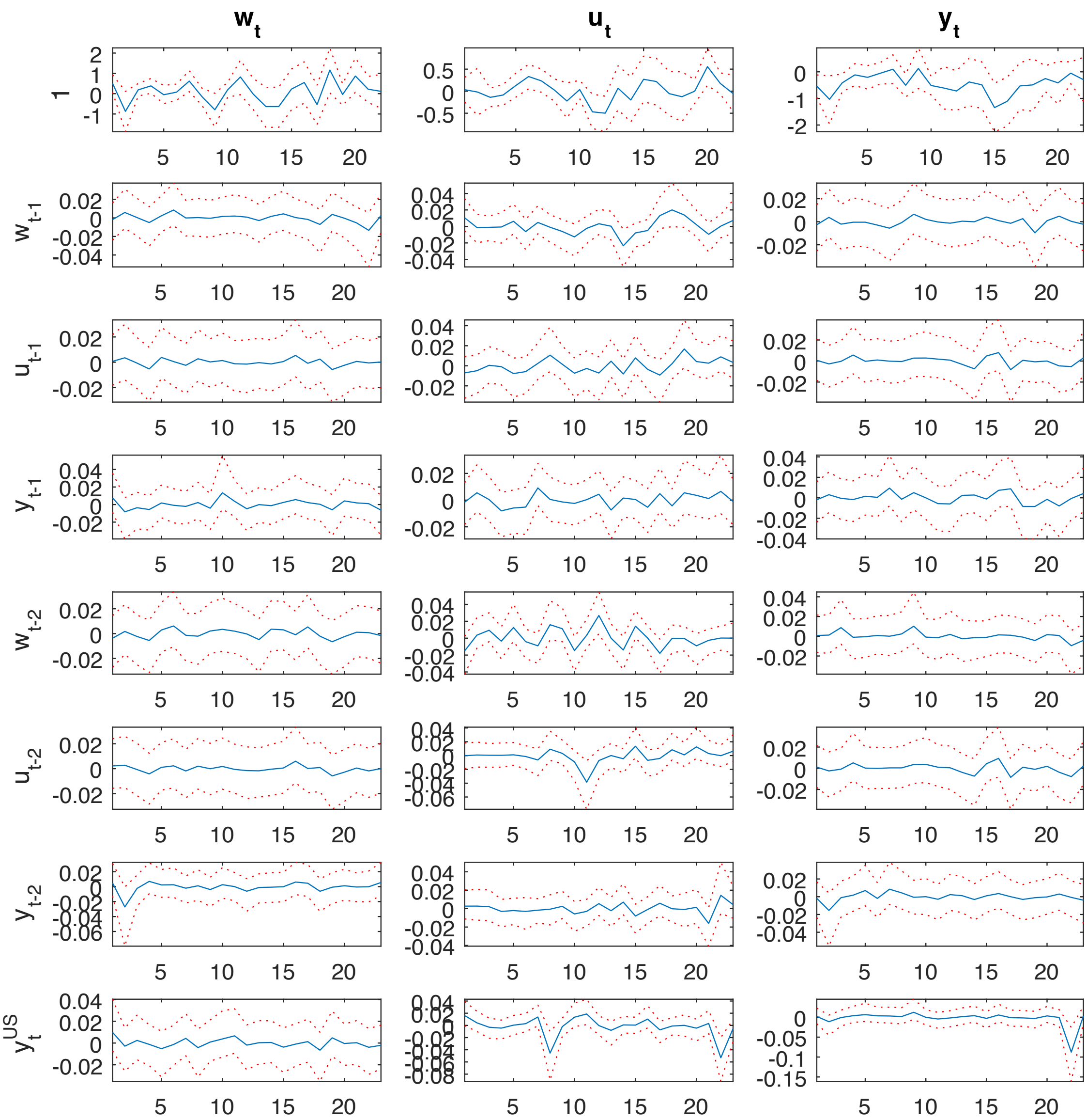

Figure 9. Error terms for the VAR coefficients, unit (country) specific initial conditions, η^{β}. Intercepts (first row of plots) are estimated without shrinkage.

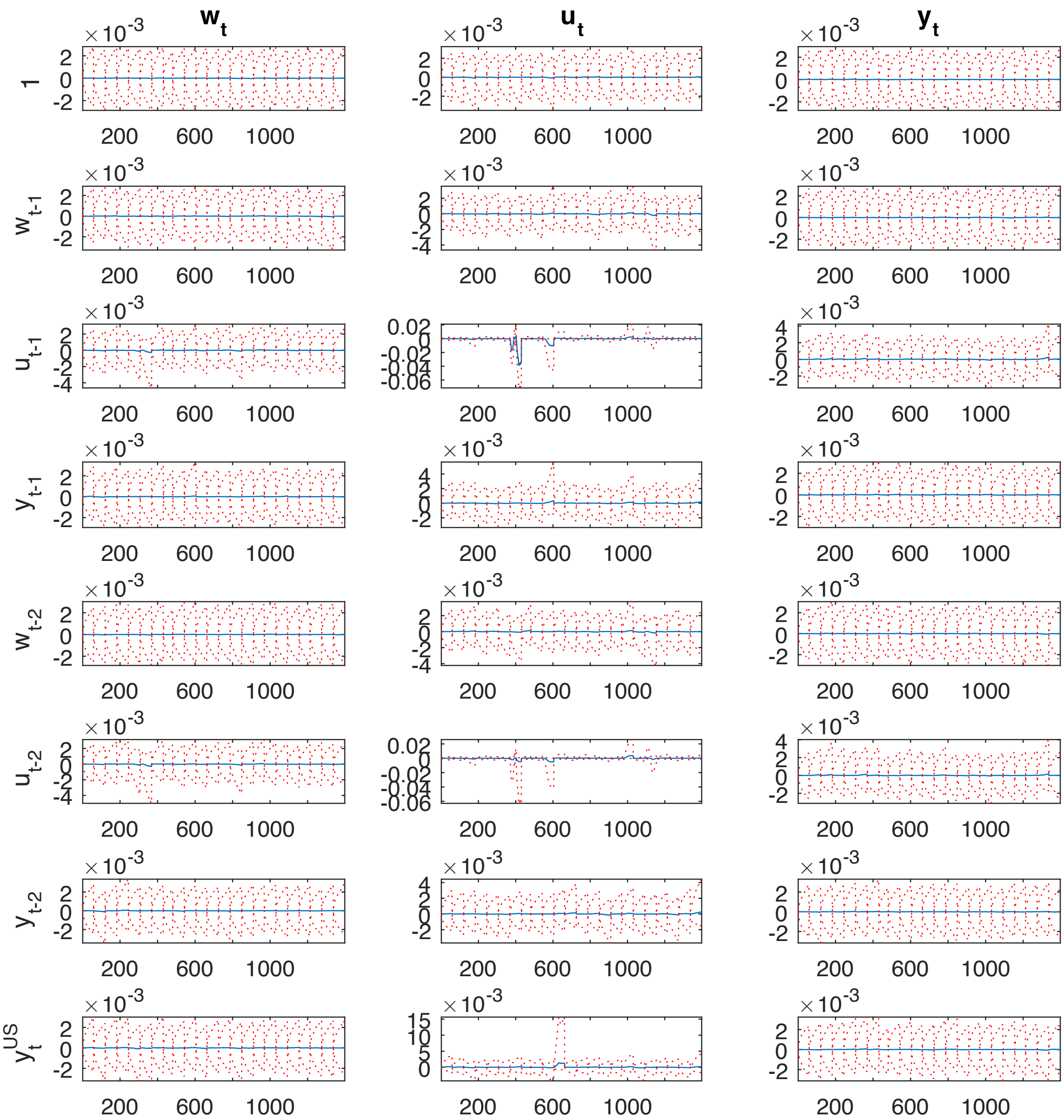

Figure 10. Error terms for the coefficients, country specific time varying part. Terms are stacked country by country.

3 CENTRALIZED WAGE SETTING IN A NEW KEYNESIAN MODEL

Abstract[*]
Centralized wage setting in a New Keynesian model is studied. Wage setting is fully centralized, and hence, a single all-encompassing union sets the wage for the whole economy. The wage setting of a large union is modelled with a novel approach. It is found that when the union maximizes the utility of the representative household, optimal wage-setting stabilizes price level and monetary policy should put more weight on output gap stabilization. Wage stickiness is modelled in a way that is relevant in the context of centralized wage-setting. Contrary to Calvo-type staggered wage setting, unions set the wages for a fixed period and the length of the period is known when wages are set. Given the same average length of wage agreements, welfare losses are smaller when wages are set by large unions than by households.

Keywords: Centralized wage setting, labour unions, monetary policy

3.1 Introduction

Wage bargaining in many European countries takes place at a sectoral or higher level. Wages are bargained by unions that are large enough to influence the overall economy. Still, the assumption in the New Keynesian business cycle models that take a closer modelling perspective on the labour market has been that unions are atomistic and take aggregate variables as given. Before the arrival of New Keynesian models, there was a notable literature on monetary policy and large wage setters (see e.g. Cuckierman and Lippi (1999), Holden (2005), Iversen

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& Soskice (2000), Lippi (2003)).

The only existing study on centralized wage setting in the New Keynesian (NK) framework is Gnocchi (2009). Gnocchi (2009) studies cases in which there are two or more unions in the economy, and the unions take the wage setting of other unions as given. In this paper, I consider a case with one union. This scenario is valid for countries where wage settlement takes place through nationwide collective agreements or for countries where wage bargaining is conducted by sectorial unions but those unions coordinate their wage demands and hence cannot take the wage-setting of others as given. Nationwide collective agreements were common in several European countries in the past and still occur in some countries (Belgium 1981-, Denmark 1960-1985, Finland 1968-, Ireland 1987-2008, Norway 1960-1990, Portugal 1988-1998, Sweden 1960-1992, Slovenia 1994-2009)[1]. Currently, in countries where wages are bargained collectively, the dominant level is sectorial. Still, in countries such as Germany, Norway, Sweden and Denmark, there is coordination between unions in the wage bargaining process, and hence, the unions need to take into account the macroeconomic effects from their wage-setting beyond their own sector.

Gnocchi (2009) models the anticipation effects of large unions through firms' labour demand elasticity. Large unions anticipate that their wage demands affect the aggregate wage, and through the aggregate wage rate, all other aggregate variables in the model are affected. Therefore, the wage decision of a single union affects not only the labour demand elasticity of the type of the workers it represents but also the total labour demand elasticity. In my paper, a different approach is chosen. Similar to optimal monetary and fiscal policy studies, I consider the union as a social planner that maximizes the utility of the representative household subject to the constraints of the model and using the nominal wage rate as an instrument. Otherwise, the model is the basic New Keynesian model with sticky prices and monetary policy that follows a Taylor-type rule. I first study a model with flexible wages and then an empirically more relevant model with sticky wages.

Contrary to Gnocchi (2009), I am able to show that the centralization of wage setting changes the dynamics of the model economy and has implications for monetary policy. Aside from Gnocchi (2009), the existing literature has worked with non-dynamic models. This is the first study to show that centralized wage-setting changes the behaviour of the economy in a dynamic model with New Keynesian features. The intuition behind this is straightforward. When the prices are sticky and the goods market is monopolistically competitive, the responses of an economy are suboptimal given that monetary policy follows the suboptimal monetary policy rule. As there is another large agent Ð a labour union that maximizes the utility of the representative agent Ð it can reduce welfare losses by bringing the economy closer to efficient allocations as much as possible with its instrument, the nominal wage rate. When wages are flexible, the union can perfectly control the marginal costs.

[1] In these countries, economy-wide bargaining was predominant in the given periods according to the classification used in the ICTWSS database.

A major characteristic of economies with centralized wage-setting is that wages are negotiated during a short period and then kept fixed for a longer period. This is different from Calvo- or Taylor-type wage setting, since there are periods when no fraction of the wages is renegotiated. Moreover, in economies with centralized wage-setting, the next round for wage negotiations is known well in advance. Typically, the timing of the next wage negotiations is decided as one part of the collective agreement. Hence, there is not the randomness that Calvo-type wage setting assumes. As a consequence of the union's infrequent wage- setting, there two kinds of agents in the model: first, the central bank, representative household and firm, which make decisions in each period, and the union, which can only change the wage rate during pre-specified periods (every other period in the model of this paper). It turns out that a model with this timing structure can be written so that it can be solved using standard algorithms for rational expectations models.

It is found that when wages are not adjusted in each period, this creates welfare losses, but the welfare loses are smaller than in a model with staggered wage setting of the same average contract length. This result illustrates that micro and macroeconomic frictions can imply very different dynamics when the economy adjusts to macroeconomic shocks.

The structure of the paper is as follows. Section 2 presents the model. Section 3 discusses the implications of the model. Section 4 introduces sticky wages to the model. Section 5 concludes.

3.2 Model

The model is the basic New Keynesian model by Clarida, Galí and Gertler (1999), except for the determination of the wages. It is assumed that the product market is monopolistically competitive and prices are set in a staggered fashion. Households maximize the expected lifetime utility subject to a sequence of budget constraints. Households choose the amount of consumption and bond holdings and supply the amount of labour that is required to meet firms' labour demand given the wages set by the labour union. The labour union sets the nominal wage in order to maximize the utility of the representative household given the model constraints.

Households

Households maximize expected lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t), \tag{1}$$

The utility function is given by

$$U(C_t, N_t) \equiv \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\phi}}{1+\phi} \tag{2}$$

Households receive utility from consumption, C and disutility from supplying labour, N. The maximization is subject to a sequence of period budget constraints

$$P_t C_t + B_{t+1}/R_t = B_t + W_t N_t + T_t + D_t \tag{3}$$

P is aggregate price level, B is households' bond holdings, R is return on bond holdings and is controlled by the central bank, W is nominal wage, T are taxes. It is assumed that firms are owned by the households and D is the profits that households receive from firms.

Households maximize utility by choosing the amount of consumption and asset holdings. This optimization leads to familiar Euler equation of form

$$\beta R_t E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \left(\frac{P_t}{P_{t+1}} \right) \right] = 1 \tag{4}$$

Firms

Monopolistically competitive firms set prices for differentiated goods. It is assumed that there is Calvo-type staggered price setting and only a fraction of $1-\theta$ of the firms are allowed to reset prices in a given period. As in Gnocchi (2009), it is assumed that there is an employment subsidy for the firms that exactly offsets the distortions arising from the monopoly power of the firms in the steady state. This assumption makes the steady state efficient.

Firms that produce intermediate goods operate with production functions of form

$$Y_t(j) = A_t N_t(j) \tag{5}$$

Sector specific total factor productivities A_t evolve according to

$$log(A_t) = \rho_a log(A_{t-1}) + \epsilon_t \tag{6}$$

The final goods are aggregated with

$$Y_t \equiv \left(\int_0^1 Y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}} \tag{7}$$

and hence the demand that a firm j faces for its output is given by

$$Y_{t+p}(j) \leq \left(\frac{\bar{P}_t(j)}{P_{t+p}} \right)^{-\epsilon} Y_{t+p}. \tag{8}$$

The firms set prices in order to maximize profits with respect to a sequence of demand constraints. To allow for imperfect private sector responses, prices are assumed to be sticky *a'la* Calvo and only a fraction $1-\theta$ of firms is allowed to reset prices in the current period. The maximization problem of a firm reads as

$$\max_{\bar{P}_t} \sum_{p=0}^{\infty} \theta^p E_t \left[Q_{t+p} [Y_{t+p}(j)(\bar{P}_t(j) - (1-\tau) MC^n_{t+p})] \right] \tag{9}$$

with subject to equation (8). The resulting FOC is given by

$$\sum_{p=0}^{\infty} \theta^p E_t \left\{ Q_{t,t+p} \left[(1-\epsilon) \left(\frac{\bar{P}_t(j)}{P_{t+p}} \right)^{-\epsilon} Y_t(j) + (1-\tau)\epsilon \frac{\bar{P}_t(j)^{-(\epsilon+1)}}{P^{-\epsilon}_{t+p}} Y_t MC^n_{t+p} \right] \right\} = 0 \tag{10}$$

Equation (10) contains a summation towards infinity, but following Schmitt-Grohé and Uribe (2007), it can be presented recursively as a two-period problem using auxiliary variables F_t and K_t.

$$\begin{aligned} \left(\frac{K_t}{F_t} \right)^{1-\epsilon} &= \frac{1-\theta \Pi_t^{\epsilon-1}}{1-\theta} \\ K_t &= \frac{W_t}{P_t A_t} + \theta \beta E_t \{ \Pi^{\epsilon}_{t+1} K_{t+1} \} \\ F_t &= \mu + \theta \beta E_t \{ \Pi^{\epsilon-1}_{t+1} F_{t+1} \}, \end{aligned} \tag{11}$$

where $\mu = (1-\tau)(\epsilon-1)/\epsilon$. When τ is set according to $\tau = 1/\epsilon$, the steady state is efficient.

Aggregate output is obtained as

$$\int_0^1 Y_t(i) di = \int_0^1 A_t N_t(i) di \tag{12}$$

The right-hand side reduces to $A_t N_t$ since the level of technology is assumed to be equal across firms and labour is assumed to be homogenous within the two sectors. Substituting (8) for the left hand side brings

$$Y_t \int_0^1 \left(\frac{P_t(i)}{P_t} \right)^{-\epsilon} = A_t N_t \tag{13}$$

$\Delta_t = \int_0^1 \left(\frac{P_t(i)}{P_t} \right)^{-\epsilon} di$ is the relative price dispersion among intermediate goods and its evolution is given by

$$\Delta_t = (1-\theta) \left(\frac{1-\theta \Pi_t^{\epsilon-1}}{1-\theta} \right)^{\frac{\epsilon}{\epsilon-1}} + \theta \Pi_t^{\epsilon} \Delta_{t-1} \tag{14}$$

Relative price dispersion results from staggered price-setting. It represents a real cost of deviations from the price stability. With relative price dispersion, the aggregate production level is lower than would be obtained from the used labour inputs without the relative price dispersion.

Monetary policy

Monetary policy follows a Taylor-type rule

$$R_t = \beta^{-1}\Pi_t^{\rho\pi}\tilde{Y}_t^{\rho pi} \tag{15}$$

where $\tilde{Y}_t$ is the output gap with respect to potential output, and potential output is the output that would prevail without price rigidities in an otherwise identical economy.

Wage setting

Wages are set by a large union, and the union is considered a constrained social planner that maximizes the welfare of the representative household. The union maximizes welfare by setting the wage rate. The constraints the union takes into account are the decision rules of households and firms, aggregate resource constraints and monetary policy rules of the central bank. The maximization problem of the union is given by the Lagrangian

$$\begin{aligned}
max_{\{d\}_{t=0}^{\infty}} E_0\Bigg\{ \sum_0^{\infty} \beta^t E_t \Bigg[u(C_t, N_t) \\
+\lambda_t^1 (C_t^{-\sigma} R_t^{-1} - \beta E_t C_{t+1}^{-\sigma} \Pi_{t+1}^{-1}) \\
+\lambda_t^2 \left[\frac{1-\theta\Pi_t^{\epsilon-1}}{1-\theta} - \left(\frac{K_t}{F_t}\right)^{1-\epsilon} \right] \\
+\lambda_t^3 (K_t - \frac{W_t}{P_t A_t} - \theta\beta E_t\{\Pi_{t+1}^{\epsilon} K_{t+1}\}) \\
+\lambda_t^4 (F_t - 1 - \theta\beta E_t\{\Pi_{t+1}^{(\epsilon-1)} F_{t+1}\}) \\
+\lambda_t^5 (C_t \Delta_t - A_t N_t) \\
+\lambda_t^6 (\Delta_t - (1-\theta)\left(\frac{1-\theta\Pi_t^{\epsilon-1}}{1-\theta}\right)^{\frac{\epsilon}{\epsilon-1}} - \theta\Pi_t^{\epsilon}\Delta_{t-1}) \\
+\lambda_t^7 (\Pi_t - \frac{P_t}{P_{t-1}}) \\
+\lambda_t^8 (R_t - \beta^{-1}\Pi_t^{\rho\pi}\tilde{Y}_t^{\rho y})\Bigg\},
\end{aligned} \tag{16}$$

where $d_t = [C_t \; N_t \; \Pi_t \; P_t \; W_t \; K_t \; F_t \; \Delta_t \; R_t]$. The problem is not stationary due to expectational terms. Following Marcet and Marimon (2011), the problem is stationarized adding λ_{-1}^i for $i = 1, 3, 4$. Lagged multipliers represent initial commitments. This results in the following augmented system

$$
\begin{aligned}
max_{\{d\}_{t=0}^{\infty}} E_0 \Bigg\{ \sum_{0}^{\infty} \beta^t E_t \Bigg[u(C_t, N_t) \\
+\lambda_t^1 C_t^{-\sigma} R_t^{-1} - \lambda_{t-1}^1 C_t^{-\sigma} \Pi_t^{-1} \\
+\lambda_t^2 \left[\frac{1-\theta\Pi_t^{\epsilon-1}}{1-\theta} - \left(\frac{K_t}{F_t}\right)^{1-\epsilon} \right] \\
+\lambda_t^3 (K_t - \frac{W_t}{P_t A_t}) - \lambda_{t-1}^3 \theta \Pi_t^{\epsilon} K_t \\
+\lambda_t^4 (F_t - 1) - \lambda_{t-1}^4 \theta \Pi_t^{(\epsilon-1)} F_t \\
+\lambda_t^5 (C_t \Delta_t - A_t N_t) \\
+\lambda_t^6 (\Delta_t - (1-\theta)\left(\frac{1-\theta\Pi_t^{\epsilon-1}}{1-\theta}\right)^{\frac{\epsilon}{\epsilon-1}} - \theta\Pi_t^{\epsilon}\Delta_{t-1}) \\
+\lambda_t^7 (\Pi_t - \frac{P_t}{P_{t-1}}) \\
+\lambda_t^8 (R_t - \beta^{-1} \Pi_t^{\rho_\pi} \tilde{Y}_t^{\rho_y}) \Bigg\}
\end{aligned}
\tag{17}
$$

The first order conditions to (17) give a system of nine equations that determine the evolution of Lagrangian multipliers and the nominal wage rate. Given the nominal wage rate and the process for productivity, paths of all other variables are determined.

The implications of the model are compared to an otherwise identical model with a competitive labour market where the labour supply decision takes place at the household level. Then, the equilibrium in the labour market results from the intratemporal optimization of the household, which leads to

$$
-\frac{U_{N_t}}{U_{C_t}} = \frac{W_t}{P_t} \tag{18}
$$

3.3 Dynamics

The steady state is solved as explained in Schmitt-Grohé and Uribe (2012). The system is linearized around the steady state and solved using Klein's (2000) algorithm. The model is parameterized using the following relatively conventional parameter values: $\beta = 0.99, \sigma = 1, \phi = 2, \theta = 3/4,\ \epsilon = 8,\ \rho_\pi = 1.5, \rho_y = 0.5,\ \rho_a = 0.7$

The steady-state values were found to be the same as with decentralized wage-setting such that consumption, gross inflation and the real wage equal unity. Moreover, they are independent of the monetary policy rule in place, and hence, there exists monetary policy neutrality in the steady state. This is in contrast to Gnocchi (2009), who finds that with two or more non-atomistic unions, the strictness of the inflation targeting affects the steady-state values of real variables. The difference results from the fact that as there is only a single union, it cannot set a mark-up and hence the situation is identical to that of a perfectly competitive labour market. If there was more than one but a still finite number of unions, they would be able to set mark-ups but would also understand that the size of their mark-up has an effect on the aggregate wage and therefore on price level and monetary policy reaction. This is in line with Lippi (2003), who finds that the conservatism of the central bank has real effects only when the number of unions is more than one but less than infinity.

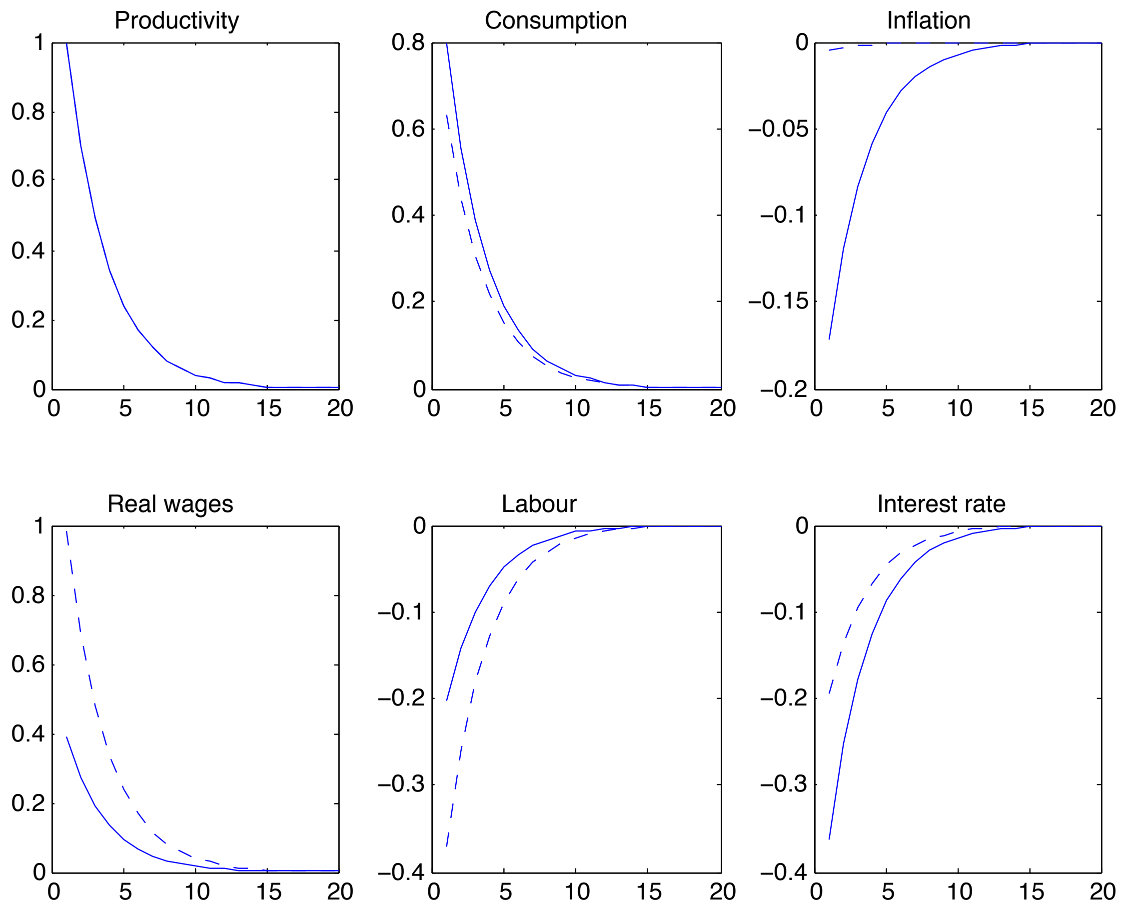

Figure 1. Impulse responses to a productivity shock. Solid line, competitive labour market. Dashed line, centralized wage setting.

Figure 1 plots the impulse responses to a unitary productivity shock under centralized wage setting and a competitive labour market. Given the parametrization of the model, in an otherwise identical flexible price economy, the consumption level should vary one-for-one with productivity, and employment should stay constant in response to productivity shock. Compared with competitive labour market, the real wage is more responsive under centralized wage setting. Unions set nominal wages such that real wages respond one-to-one with productivity. Hence, the marginal costs of firms do not change, and this results in price stability. Under the same monetary policy rule, aggregate production is lower in the model with centralized wage setting than with competitive labour market, and this results from the higher nominal interest rate.

When simulations of productivity shock were run with less or more aggressive monetary policy rules, it was found that the union always sets the wage rate such that price stability emerges regardless of the monetary policy. In addition, there was a determinate solution for the system even though monetary policy followed the constant nominal interest rate. These results stem from the fact that the union understands that deviations from price stability give rise to price dispersion. The union avoids this, since when relative price dispersion increases, more labour input is needed to obtain a given utility level from consumption. With baseline parameters for the monetary policy rule the welfare costs measured as a percentage of steady state consumption were -0,51 with competitive labour market and -0,17 with centralized wage setting.

The problem of the union is similar to that of optimal monetary policy design. In both cases, a large agent tries to set an allocation that maximizes the utility of the representative agent and satisfies the implementability constraints of the private sector (and that of the central bank when the maximizer is the union). When the steady state is efficient, targeting the natural interest rate (the interest rate that would take place in an identical flexible price economy) solves the optimal monetary policy problem. Then, both the output gap and inflation are stabilized, and an identical outcome results if the monetary policy strictly targets the inflation and output gap.

The union can stabilize price level with its wage policy, but it cannot stabilize the output gap. This is because under a Taylor-type rule with reasonable parameters, the nominal interest rate does not react strongly enough, and hence, the resulting real interest rate does not follow the path of the natural interest rate. In the case of positive productivity shock, the nominal interest rate is too high for a given productivity level to support the optimal allocation (the allocation prevailing in the flexible price economy).

When the monetary policy follows the optimal monetary policy rule, the outcomes in response to productivity shocks are the same as under competitive market wages and fully centralized wage-setting. Optimal monetary policy pushes the sticky price economy to efficient allocation. By lowering the nominal interest rate enough, the central bank stimulates aggregate demand to the point where the resulting competitive market real wages equal the marginal costs and stabilize the price level. There is no incentive for the union to deviate from this. Hence, the distinction between competitive market wages and centrally set wages arises only when the central bank follows the suboptimal rule.

An implication of these results for monetary policy is that under fully centralized wage setting, the central bank should control the output gap more than inflation, and hence the monetary policy rule should put more weight on targeting real variables than inflation. This is in stark contrast with Gnocchi (2009), who shows that in the case with two or more unions, strict inflation-targeting is the optimal policy. Because the union in my model stabilizes price level regardless of monetary policy, the other implication is that in situations where monetary policy cannot respond strongly, e.g., when the zero lower bound is binding or the economy belongs to a monetary union, fully centralized wage setting might produce very different outcomes compared with a competitive labour market.

Above, I have studied wage setting and monetary policy when the economy faces productivity shocks. In this case, inflation and the output gap move in the same directions; hence, stabilizing inflation stabilizes the output gap and vice versa. Much of the optimal monetary policy literature is interested in optimal policy in situations where there is a trade-off between stabilizing the output gap and stabilizing inflation. This happens, e.g., when the economy faces cost-push shocks. To introduce cost-push shocks, I allow for variation in τ.

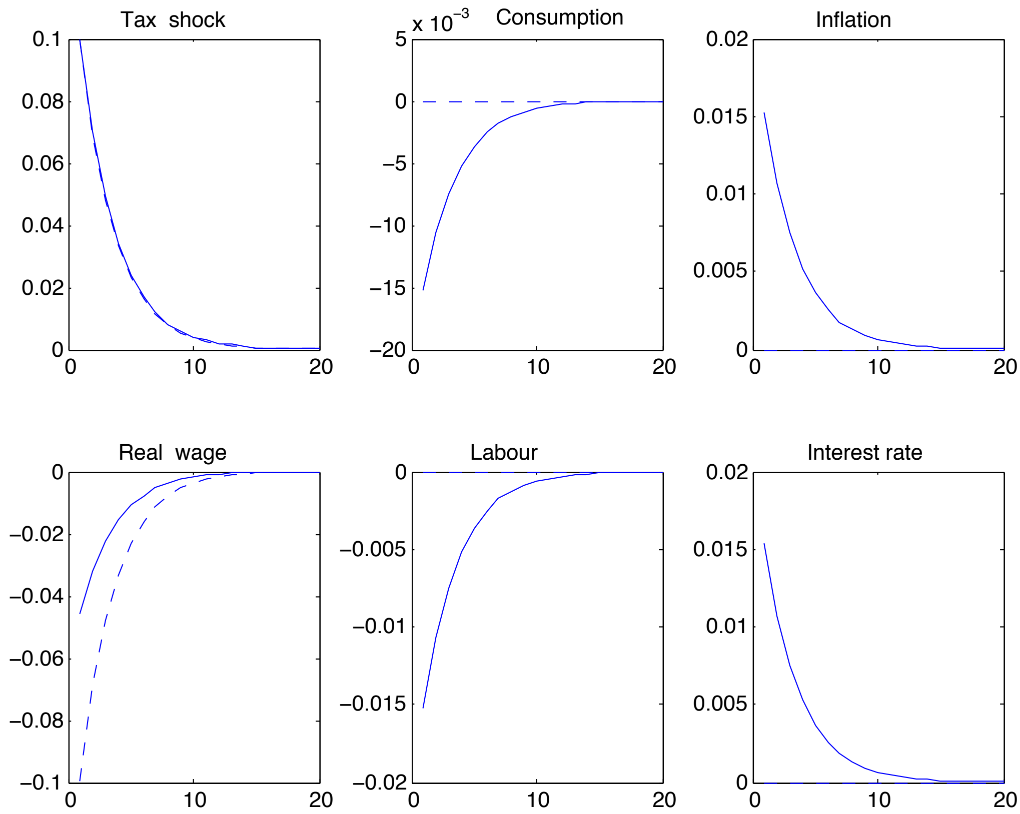

Figure 2. Impulse responses to a cost-push shock. Solid line, competitive labour market. Dashed line, centralized wage setting.

Figure 2 shows that in response to cost-push shock, the labour union sets a path for the real wage that exactly offsets the cost-push shock. The price level does not move since the costs that firms face are unchanged. As the price level is unchanged, the real interest rate is unchanged and aggregate demand is not affected. As a result, the economy stays at the efficient allocation. To this purely nominal shock that does not move the efficient allocation, fully centralized wage setting produces more optimal responses than does the competitive labour market. The union can fully stabilize the economy since the shock can be fully offset with appropriate changes in the nominal wage rate.

When a wages are an outcome of the competitive labour market, the economy instead moves away from the efficient allocation. Wages do not adjust enough to accommodate the cost-push shock and hence the price level increases. The central bank responds to inflation by raising the nominal interest rate, which depresses aggregate demand. The central bank cannot both close the output gap and stabilize price level in the case of cost-push shocks since in the efficient economy, there is no change in the real interest rate as a response to cost-push shock. Hence, monetary policy necessarily moves the economy away from efficient allocation since the central bank can influence the economy only by altering real interests by changing the nominal interest rate. This provides evidence that when wage setting is centralized, monetary policy trade offs might be less severe when the economy faces shocks that require solely nominal adjustment.

3.4 Sticky wages

Since Erceg, Henderson and Levin (2000), the standard way of introducing wage stickiness in NK models has been to model the labour market analogously to product market price stickiness by assuming staggered Calvo-type wage setting. The approach is applicable for labour markets where wages are set by individual workers or firms specifically, but with centralized wage setting, Calvo-type staggered wage setting is hard to rationalize. Calvo-type rigidity assumes that wages are reset uniformly across periods. In addition, the wage setters face a constant probability of resetting the wage in the next period regardless of when the wage was reset the last time. Contrary to these features of Calvo-type rigidity, in countries with centralized bargaining, wages are set during a short period, within one or two quarters, and then the wages are kept fixed (or reset according to an agreed-upon schedule) for a longer period, typically at least for one year. Also, there is little randomness in the timing of the next round of wage negotiations. The length of wage agreements and the timing of the next negotiations are well known in advance.[2]

I model wage setting so that the wages are reset every second period and are thus kept fixed for one period after the period in which they are reset. In what follows, period t refers to the period that is relevant for the union, the period in which wages are kept fixed. Each period t is then divided into two sub periods, t_1, t_2; and consumption, production, pricing and monetary policy decisions are made periodically in these sub periods. In other words, households, firms and the central bank make decisions at quarterly frequencies and the union at annual frequencies. In period t_1, the union maximizes the utility of the representative household for the current period and periods onwards, expecting shocks to be equal zero in periods following the current period. The resulting Lagrangian for

[2] It should be acknowledged that in countries with centrally negotiated wage agreements, the aggregate wages also display variation between the periods when the official wage agreements are implemented. This variation results from, e.g., job switches, exits and new entrants to the labour market and from compensation related to firm or individual performance. As the current model is a stylized description of centralized wage setting, adding these elements is beyond the scope of this paper.

the union is illustrated below.

$$
\begin{aligned}
max_{\{d\}_{t=0}^{\infty}} E_0 \Bigg\{ \sum_0^{\infty} \beta^{2t} E_t \Big[u(C_{t_1}, L_{t_1}) + \beta u(C_{t_2}, L_{t_2}) \\
+\lambda_{t,1}^1 (C_{t,1}^{-\sigma} R_{t,1}^{-1} - \beta E_{t,1} C_{t,2}^{-\sigma} \Pi_{t,2}^{-1}) + \lambda_{t,2}^1 \beta C_{t,2}^{-\sigma} R_{t,2}^{-1} - \lambda_{t-1,2}^1 C_{t,1}^{-\sigma} \Pi_{t,1}^{-1} \\
+\lambda_{t,1}^2 \left[\frac{1-\theta \Pi_{t,1}^{\epsilon-1}}{1-\theta} - \left(\frac{K_{t,1}}{F_{t,1}} \right)^{1-\epsilon} \right] + \lambda_{t,2}^2 \beta \left[\frac{1-\theta \Pi_{t,2}^{\epsilon-1}}{1-\theta} - \left(\frac{K_{t,2}}{F_{t,2}} \right)^{1-\epsilon} \right] \\
+\lambda_{t,1}^3 (K_{t,1} - \frac{W_t}{P_{t,1} A_{t,1}} - \theta \beta E_{t,1} \{ \Pi_{t,2}^{\epsilon} K_{t,2}) \\
+\lambda_{t,2}^3 \beta K_{t,2-} - \frac{W_t}{P_{t,2} A_{t,2}}) - \lambda_{t-1,2}^3 \theta \Pi_{t,1}^{\epsilon} K_{t,1} \\
+\lambda_{t,1}^4 (F_{t,1} - 1 - \theta \beta E_{t,1} \{ \Pi_{t,2}^{(\epsilon-1)} F_{t,2}) \\
+\lambda_{t,2}^4 \beta (F_{t,2} - 1) - \lambda_{t-1,2}^4 \theta \Pi_{t,1}^{(\epsilon-1)} F_{t,1} \\
+\lambda_{t,1}^5 (C_{t,1} \Delta_{t,1} - A_{t,1} L_{t,1}) + \lambda_{t,2}^5 \beta (C_{t,2} \Delta_{t,2} - A_{t,2} L_{t,2}) \\
+\lambda_{t,1}^6 (\Delta_{t,1} - (1-\theta) \left(\frac{1-\theta \Pi_{t,1}^{\epsilon-1}}{1-\theta} \right)^{\frac{\epsilon}{\epsilon-1}} - \theta \Pi_{t,1}^{\epsilon} \Delta_{t-1,2}) \\
+\lambda_{t,2}^6 \beta (\Delta_{t,2} - (1-\theta) \left(\frac{1-\theta \Pi_{t,2}^{\epsilon-1}}{1-\theta} \right)^{\frac{\epsilon}{\epsilon-1}} - \theta \Pi_{t,2}^{\epsilon} \Delta_{t,1}) \\
+\lambda_{t,1}^7 (\Pi_{t,1} - \frac{P_{t,1}}{P_{t-1,2}}) + \lambda_{t,2}^7 \beta (\Pi_{t,2} - \frac{P_{t,2}}{P_{t,1}}) \\
+\lambda_{t,1}^8 (R_{t,1} - \beta^{-1} \Pi_{t,1}^{\rho_\pi} \tilde{Y}_{t,1}^{\rho_y}) + \lambda_{t,1}^8 \beta (R_{t,2} - \beta^{-1} \Pi_{t,2}^{\rho_\pi} \tilde{Y}_{t,2}^{\rho_y}) \Bigg\}
\end{aligned}
$$

The model can be solved similarly to the flexible wage model. The solution to the Lagrangian determines the wage rate, and structural equations determine the evolution of endogenous variables given the wage rate and shocks in period t_2. Conditional on shocks equalling zero on expectation in periods following the wage-setting period, the model can be solved as a standard rational expectations model.

Figure 3 plots the impulse responses to unitary productivity shock under the same parametrization as with flexible wages. The qualitative features are similar to the flexible wage case. There are only slight deviations from the price stability. The dynamics are compared with Calvo-type staggered wage setting of household unions that face a 0.5 probability of resetting wages each period, corresponding to two quarter average length of wage contracts. In this economy, the response of nominal wages is actually slightly negative and the real wages rise only less than 0.15 % in response to a 1% productivity shock. This implies that adding wage stickiness results in even more divergent responses between economies with centralized and decentralized wage setting.

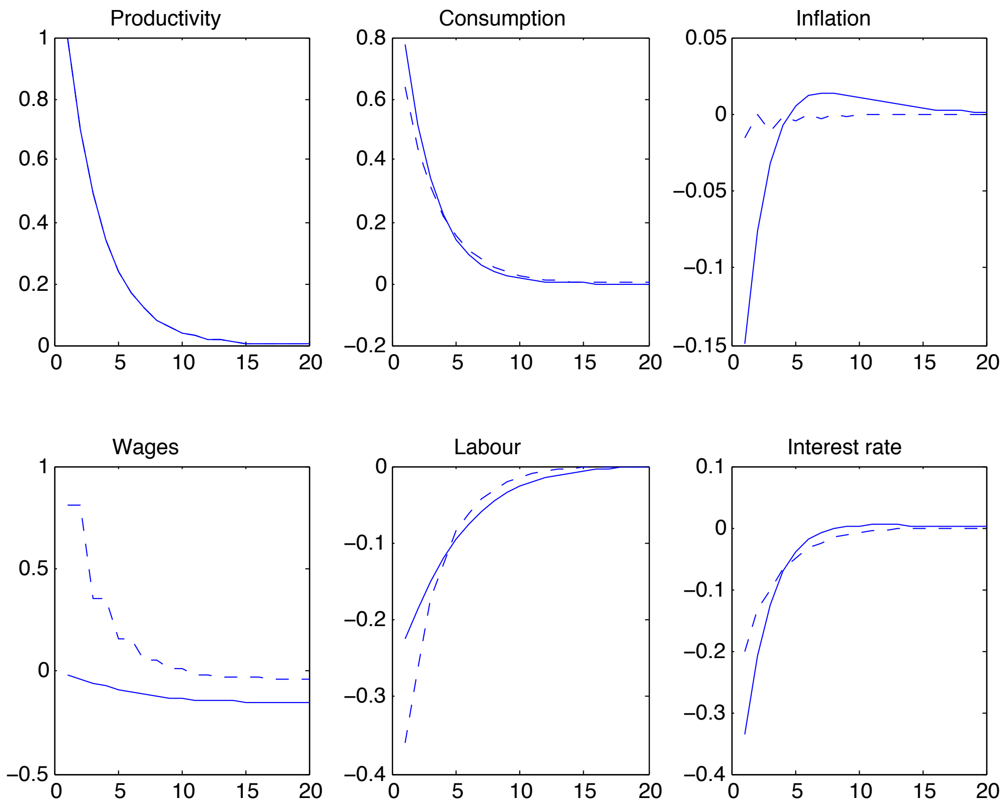

Figure 3. Responses with two-period fixed wages. Solid line, perfect labour market. Dashed line, centralized wage setting.

Welfare analysis showed that keeping wages fixed for two periods increases welfare losses from -0.17% of the flexible wage economy to -0.41% of the two-period fixed wage economy. Welfare losses are measured as a fraction of steady state consumption equal to utility losses subject to a flexible price economy. The welfare losses in the economy with staggered and decentralized wage setting are -1.60%. The result illustrates that when the economy is subject to macroeconomic shocks, macroeconomic rigidity can be less severe for the adjustment than microeconomic rigidity of similar scale.

3.5 Conclusions

In this paper, I have shown that the wage setting of a single all-encompassing union results in price stability in an otherwise basic New Keynesian model. I have derived a way to model infrequently adjusted wages in a way that is relevant for centralized wage setting. Even when the wages are adjusted infrequently, the wage setting of a large union results in price stability. Even though the wage setting of the union results in price stability, it cannot close the output gap since the nominal interest rate does not react enough with respect to changes in the natural interest rate. Hence, in an economy with centralized wage setting, monetary policy should give more weight to the output gap than in an economy with decentralized wage setting.

As the model is very stylized, its implications should be viewed with caution. In the model of this study, the union aims at stabilizing the price level in order to avoid costs from relative price distortions. In a more general model with search and matching frictions in the labour market and capital and capital adjustment costs, the aim of the union might be different. Still, this analysis shows that the appropriate wage setting policy of a large union could bring in a stabilization tool. When modelling economies where wages are bargained collectively, the assumption of small household unions and staggered wage setting might lead to misleading dynamics and policy suggestions.

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4 WAGE-SETTING COORDINATION IN A SMALL OPEN ECONOMY

Abstract*

In many European countries where wage bargaining takes place at the sectorial level, there is coordination between unions. In several countries, coordination is implemented as a form of pattern bargaining, and wages are negotiated first in the manufacturing sector. This paper studies wage setting coordination in a two-sector open economy. Wages are set by sector-specific non-atomistic unions that anticipate the effects of their wage demands on aggregate variables. A method to model strategic interaction of large agents in a dynamic stochastic general equilibrium model is developed. It is found that in terms of steady state, large wage setters can increase the aggregate welfare over competitive market allocation through the exploitation of terms of trade externality. However, this happens only when the strategic interaction is minimal, if unions play a Nash game, or one of the unions sets the wage for both sectors. In pattern bargaining, a Stackelberg game, strategic behaviour eats the aggregate surplus and only the leader gains at the expense of the follower. Hence, the steady state results of this paper do not support the importance of wage leadership of the tradable sector or pattern bargaining in general. In terms of dynamics, it is found that if non-tradable sector wages are pegged to wage developments at the tradable sector, it produces large welfare losses for the non-tradable sector, which speaks against the importance of wage norm set by the tradable sector. .

Keywords: Wage-setting coordination, labour unions, open economy

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4.1 Introduction

Wage bargaining in many European countries takes place at a sectorial or higher level (Table 5). Wages are set by unions that are large enough to influence the overall economy. In the open economy context, "conventional wisdom" has been that export sector unions should have a leading role in wage setting (Calmfors and Seim 2013). In practice, this form of coordination has been most notably in place in Sweden and Germany. The argument is that export sector unions have a better understanding of sound cost levels compared to the rest of the world, and it is therefore beneficial for the aggregate welfare if wage setting in the rest of the economy is conditioned on the export sector's wages. In this setting, the labour market equilibriums in the non-exporting sectors are not fully determined by the sectorial supply and demand conditions. It is interesting that this conventional wisdom has gained acceptance among economists, since economists typically tend to favour market structures where the actual market participants produce the equilibrium.

This paper studies wage setting coordination in a small open economy DSGE model. The economy consists of non-tradable and tradable sectors, and both sectors have labour unions that set the wages. The setting is similar to that in Calfmors and Seim (2013), who study pattern bargaining in a static framework. The model economy is a member of a monetary union and, as in Galí and Monacelli (2008), it is assumed that the monetary union consists of a continuum of small economies for which the union-wide aggregate variables are exogenous.

The unions in both sectors are non-atomistic, and when setting wages, they anticipate the effects of their wage demands on aggregate variables. The consumption of domestic households consists of imported traded goods and non-traded goods. Hence, the wage level in the non-tradable sector has a direct effect on the real wage of tradable sector workers, which in turn affects the nominal wage set in the tradable sector. Since in the monetary union, there is no stabilizing effect of the nominal exchange rate, nominal wages in the tradable sector translate directly to export prices. I study how coordination in wage-setting changes steady-state allocations and responses to shocks. Similarly to Calmfors and Seim (2013), I study pattern bargaining as a Stackelberg game and uncoordinated bargaining as a Nash game. In addition, I study coordination forms where the wage follower sets exactly the same wage as the wage leader. In many economies where export sector unions are wage leaders, this seems to be the outcome of pattern bargaining.

The steady-state analysis in paper corresponds to the analysis in Calmfors and Seim (2013), but I allow for a richer model. Naturally, the drawback is that there is no possibility for analytical results, but the richer modelling environment with many relevant features makes the results more robust and creates the possibility for some quantitative judgements. The results of Calmfors and Seim (2013)question the conventional wisdom that export-sector wage leadership leads to the best economic performance, but they still find Stackelberg-type pattern wage setting better than uncoordinated wage setting. By contrast, I find that Stackelberg-type wage setting is welfare-detrimental for the aggregate economy and that only the wage leader gains compared with the Nash game.

The analysis in this paper is welfare-based. The union's objective is to maximize the expected utility of the representative household subject to model constraints. The ranking of different wage setting schemes is based on the ranking of aggregate utility, which corresponds to modern monetary policy analysis. The wage setting of a union is Ramsey-optimal. In Calmfors and Seim (2013), the rankings of wage-setting regimes are evaluated in terms of employment and wage rates. That approach can be useful for policy discussion since results based on employment and wage levels are easier to communicate. However, the problem is that such an approach is model-specific.

Instead, the analysis in this paper does not tell which wage setting regime is optimal in terms of employment or competitiveness but in terms of aggregate utility. Hence, the policy guidance is not clear, but I argue that this approach is more robust Ð robust in the sense that in a stylized model, welfare losses can be very different from those in the real world. For example, in a representative agent model, it is hard to generate similar welfare losses for unemployment as in the real world. Hence, optimization problems that wage setters face can be very different in the real world compared with a model economy.

The results suggest that strategic behaviour of unions is welfare-detrimental. The best institutional frameworks in terms of steady-state allocations are wage-setting regimes where the leader's wage is imposed on the follower. However, this holds only in cases where there are no heterogeneities, when productivity is the same in both sectors. Furthermore, when the welfare costs of export demand shocks are taken into account, pegging the non-tradable sector wage to tradable sector wage is highly welfare-detrimental.

Besides Calmfors and Seim (2013), I am not aware of studies that analyse coordination between non-tradable and tradable sector unions using general equilibrium model. Vartiainen (2003) and Holden (2003) study wage setting in a static open economy model. Gnocchi (2009) studies the wage setting of non-atomistic unions in a closed economy New Keynesian model. In his model, unions are similar to each other and they take the wages of other unions as given. Gnocchi finds that the steady-state allocation is different from the model with atomistic unions, but the dynamics are the same.

4.2 Model

The model is based on the New Keynesian (NK) small open economy models by Galí and Monacelli (2005, 2008) but with several extensions. The models in Galí and Monacelli (2005, 2008) are the prototype open economy models in the New Keynesian literature and were hence chosen as a starting point. Similarly to Galí and Monacelli (2008), the economy belongs to the monetary union and takes the union wide aggregate variables as given. Intermediate goods are sold through a monopolistically competitive market, and price rigidities are assumed. Labour is the only input in the production. Households derive utility from leisure and consumption and can trade nominal bonds with the rest of the monetary union. For simplicity, the trade in goods is also restricted to take place within the monetary union, and the model abstracts from modelling the world economy.

Typically, in the DSGE models that include labour market imperfections, wages are set by atomistic household-unions that take aggregate variables as given. In this model, wages are instead set by large unions that take into account the effects of their wage setting on aggregate variables. In order to model coordination in wage setting, two sectors are assumed. One sector produces non-tradable goods and the other produces tradable goods that are all exported. Some of the non-tradable goods are consumed by the domestic households and some are used as intermediate inputs in the production of exports. To make the wage-setting problem of sectorial unions meaningful, I deviate from the standard single representative agent framework and assume that in both sectors there are representative households that supply labour only for that sector. Without the assumption of two representative households, both unions would be maximizing the utility of the same household and there would be no room for a game between unions. To really make use of modelling two representative households, incomplete financial markets are assumed. Without that assumption, the households would be able to insure themselves perfectly and would consume the same amounts from both sectors in all states of the world. Debt elasticity in the interest rate is assumed to break the complete financial market assumption.

Households

The economy consists of two types of household workers. A share of s_T supplies labour for the tradable goods sector and a share of s_N for non-tradable goods sector. Jobs in both sectors require sector-specific skills, and it is assumed that acquiring new skills is so costly that there is no sectorial re-allocation.

Both types of households maximize expected lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^k, N_t^k), \quad k = T, N \tag{1}$$

where T refers to tradable sector household and N to non-tradable sector household. The periodic utility function is given by

$$U(C_t^k, N_t^k) \equiv \frac{C_t^{k\,1-\sigma}}{1-\sigma} - \frac{N_t^{k\,1+\phi}}{1+\phi} \tag{2}$$

Households obtain utility from consumption, C, and disutility from supplying labour, N. Maximization is subject to a sequence of periodic budget constraints given by

$$P_t C_t^k + B_{t+1}^k / R_t^k \leq D_t^k + W_t^k N_t^k + B_t^k \tag{3}$$

where P is the aggregate price level, W is the nominal wage rate and N is employment. As is typical in the NK literature, it is assumed that firms are owned by the households and D denotes the profits that the household receives. This assumption is for simplicity. It would be more empirically relevant to have worker households and capital owner households in the model, since capital holdings are very unevenly distributed. A version with capital owners was also simulated, but the results are very similar to the results with the current setup. Since adding a new household type to the model increases the model dimension without changing the results, I chose the more parsimonious version.[1]However, I introduce the constraint that a household can only own shares of firms of the sector to which the household supplies labour. This is assumed to make the role of profits minimal in wage setting. If households owned shares of firms from both sectors, this would increase the role of profits in wage setting since a union would take into account how the wage it sets affects the profits in the other sector. It is arguable that empirically the trade unions do not put much weight on profit income in the wage setting since the share of profit income of total income is small for most of the wage earners.[2]

B is the holdings of bonds that are traded within the monetary union. The return on bonds, R, is assumed to be debt elastic as in Schmitt-Grohé and Uribe (2003)[3]

$$R_t^k = R_t^* exp(-\rho_a B_{t+1} - \rho_o B_{t+1}^k) \tag{4}$$

The return on a household's bond holding consists of R_t^*, the union wide interest rate and the risk premium. The risk premium includes both country-specific and household-specific parts. The country-specific risk premium depends on the aggregate level of bond holdings, B, and the household-specific premium depends on the household's own bond holdings, B^k. ρ_a measures the debt elasticity with respect to aggregate bond holdings and ρ_o debt elasticity with respect to the household's own bond holdings. It is assumed that a household internalizes the effect from its bond holdings to risk premium only through the household-specific risk premium part.

Debt elasticity with respect to aggregate bond holdings is needed to ensure the usual stability condition for the solution of the rational expectations model, the Blanchard-Kahn condition. The size of the domestic economy is assumed to be infinitesimal, and hence monetary policy does not respond to fluctuations in the domestic economy. Galí and Monacelli (2008) assume perfect financial mar-

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1 In a model with Stackelberg wage setting, one extra equation in the model constraints brings four equations in total to the model after the wage setting problem is solved. See Section 4 for details.

2 In Finland, in 2015, the average share of profits to total income was 1,3 % when excluding the top income decile. Source: Statistics Finland and own calculations.

3 Schmitt-Grohé and Uribe (2003) have only aggregate bond holdings in the function for the risk premium, and the functional form is slightly different. The reason for the chosen functional form was to ease the derivations.

kets, but instead, domestic fiscal policy is sufficiently responsive to ensure stability.

Debt elasticity of the interest rate subject to the household's own bond holdings is needed because there are two representative households in the model, and complete financial markets within the domestic economy would lead to full risk-sharing between the households. In that case, the ratio of sectorial consumption levels would always equal the steady state ratio of sectorial consumption levels in all states of the world. This would be unappealing for the analysis of the wage setting in terms of dynamics, since full risk-sharing would mitigate the effect of wage setting on consumption, which is a major determinant of household utility in this model.

In each period, a household allocates its income to consumption and bond holdings. This leads to a first-order optimality condition for the inter temporal optimization, which is given by

$$\beta E_t \left[\left(\frac{C_{t+1}^k}{C_t^k} \right)^{-\sigma} \left(\frac{P_t}{P_{t+1}} \right) \right] = \frac{1 - \rho_o B_{t+1}^k}{R_t^k} \tag{5}$$

Equation (3) differs from the standard Euler equation by the numerator on the right hand side, which comes from the fact that households internalize the impact of their bond holdings on the interest rate they face.

It should be noted that households do not decide on labour supply. Sectorial unions set the wages, and households supply the amount of labour that satisfies firms' labour demand.

Intermediate goods producing firms

The production site of the model consists of non-tradable and tradable sector firms that produce intermediate goods for the wholesale firms. Intermediate goods producing firms use sector-specific labour as their input, and the productivity of labour depends on an exogenous productivity process. Intermediate goods producing firms produce differentiated goods and hence have monopoly power in the price setting.

Firms that produce intermediate goods operate in the two sectors with production functions of form

$$Y_{k,t}(j) = A_{k,t} N_{k,t}(j) \qquad k = N, T \tag{6}$$

Sector specific total factor productivities $A_{k,t}$ evolve according to

$$log(A_{k,t}) = \rho_a log(A_{k,t-1}) + \epsilon_{k,t} \tag{7}$$

The non-tradable and tradable final goods are aggregated from intermediate goods using the following aggregation technology

$$Y_{k,t} \equiv \left(\int_0^1 Y_{k,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}} \tag{8}$$

The firms in both sectors set prices in order to maximize profits with respect to a sequence of demand constraints. To allow for imperfect private sector responses, prices are assumed to be sticky *a'la* Calvo and only a fraction $1-\theta$ of firms is allowed to reset prices on the current period. The maximization problem of a firm reads as

$$\max_{\bar{P}_{k,t}} \sum_{p=0}^{\infty} \theta^p E_t \left[Q^k_{t,t+p} [Y_{k,t+p}(j)(\bar{P}_{k,t}(j) - MC^n_{k,t+p})] \right] \tag{9}$$

subject to

$$Y_{k,t+p}(j) \leq \left(\frac{\bar{P}_{k,t}(j)}{P_{k,t+p}} \right)^{-\epsilon} Y_{k,t+p}. \tag{10}$$

The price that a firm j in sector k sets is, $\bar{P}_k, t, (j)$. $Q^k_{t,t+1}$ is a stochastic discount factor and $MC^n_{k,t}$ is the nominal marginal cost. The resulting FOC is given by

$$\sum_{p=0}^{\infty} \theta^p E_t \left\{ Q^k_{t,t+p} \left[(1-\epsilon) \left(\frac{\bar{P}_{k,t}(j)}{P_{k,t+p}} \right)^{-\epsilon} Y_{k,t}(j) + \epsilon \frac{\bar{P}_{k,t}(j)^{-(\epsilon+1)}}{P^{-\epsilon}_{k,t+p}} Y_t MC^n_{k,t+p} \right] \right\} = 0 \tag{11}$$

Equation (11) contains a summation towards infinity, but following Schmitt-Grohé and Uribe (2007), it can be presented recursively as a two-period problem using auxiliary variables $F_{k,t}$ and $K_{k,t}$.

$$K_{k,t} = F_{k,t} \frac{\epsilon - 1}{\epsilon} \left(\frac{1 - \theta \pi^{\epsilon-1}_{t,k}}{1-\theta} \right)^{\frac{1}{1-\epsilon}} \tag{12}$$

$$F_{k,t} = \left(\frac{\bar{P}_{k,t}}{P_{k,t}} \right)^{1-\epsilon} Y_{k,t} + \theta \beta E_t \left\{ \left(\frac{C^k_{t+1}}{C^k_t} \right)^{-\sigma} \frac{1}{\pi_{k,t+1}} \left(\frac{\bar{P}_{k,t}}{P_{k,t}} \frac{P_{k,t+1}}{\bar{P}_{k,t+1}} \right)^{1-\epsilon} \pi^{\epsilon}_{k,t+1} F_{k,t+1} \right\} \tag{13}$$

$$K_{k,t} = \left(\frac{\bar{P}_{k,t}}{P_{k,t}} \right)^{-\epsilon} MC_{k,t} + \theta \beta E_t \left\{ \left(\frac{C^k_{t+1}}{C^k_t} \right)^{-\sigma} \frac{1}{\pi_{k,t+1}} \left(\frac{\bar{P}_{k,t}}{P_{k,t}} \frac{P_{k,t+1}}{\bar{P}_{k,t+1}} \right)^{-\epsilon} \pi^{1+\epsilon}_{k,t+1} K_{k,t+1} \right\} \tag{14}$$

The evolution of prices over time is given by the relation

$$1 = (1-\theta) \left(\frac{\bar{P}_{k,t}}{P_{k,t}} \right)^{1-\epsilon} + \theta \pi^{\epsilon-1}_{k,t} \tag{15}$$

The relation for sectorial aggregate output and production is obtained after substituting equation (6) to equation (8) and integrating the resulting equation over j.

$$\int_0^1 Y_{k,t}(j)dj = \int_0^1 A_{k,t}N_{k,t}(j)dj \tag{16}$$

The right-hand side reduces to $A_{k,t}N_{k,t}$ since the level of technology is assumed to be equal across firms and labour is assumed to be homogenous within the two sectors. Substituting (10) for the left hand side brings

$$Y_{k,t}\int_0^1 \left(\frac{P_{k,t}(j)}{P_{k,t}}\right)^{-\epsilon} dj = A_{k,t}N_{k,t}. \tag{17}$$

$\Delta_{k,t} = \int_0^1 \left(\frac{P_{k,t}(j)}{P_{k,t}}\right)^{-\epsilon} dj$ measures price dispersion and its evolution is given by

$$\Delta_{k,t} = (1-\theta)\left(\frac{\bar{P}_{k,t}}{P_{k,t}}\right)^{-\epsilon} + \theta\pi_{k,t}^{\epsilon}\Delta_{k,t-1}. \tag{18}$$

The price dispersion draws a wedge between the aggregate production and the aggregate final output and is the real cost of price level variability in the NK models with Calvo type price rigidity.

Final goods

Households consume final consumption goods that consists of imports and domestic non-tradable goods:

$$C_t \equiv \left[(1-\alpha)^{\frac{1}{\eta}} C_{N,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{19}$$

Demands for non-tradable and imported goods by domestic households are given by

$$C_{N,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \quad ; \quad C_{F,t} = \alpha\left(\frac{P_{F,t}^{*}}{P_t}\right)^{-\eta} C_t \tag{20}$$

Imported goods are aggregated from exports of all monetary union member countries according to

$$C_{F,t} \equiv \left(\int_0^1 C_{E,t}(i)^{\frac{\gamma-1}{\gamma}} di\right)^{\frac{\gamma}{\gamma-1}} \tag{21}$$

where the countries are distributed on the unit interval. The elasticity of substitution parameter γ gives the price elasticity that a country faces for its aggregate exports.

The bundle of exported goods that the domestic economy produces consist of non-tradable and tradable goods by

$$C_{E,t} \equiv \left[(1-\kappa)^{\frac{1}{\eta^*}} C_{N,t}^{E}{}^{\frac{\eta^*-1}{\eta^*}} + \kappa^{\frac{1}{\eta^*}} C_{T,t}^{\frac{\eta^*-1}{\eta^*}} \right]^{\frac{\eta^*}{\eta^*-1}} \tag{22}$$

Equation (22) is to take into account that the production chain of exports requires inputs that are usually thought of as part of the non-tradable sector. These could include, for example, transportation and construction. Equation (22) increases the strategic interaction between the sectorial unions. Since part of the exports consists of non-tradables, the non-tradable sector wages directly affect the cost competitiveness of the domestic exports.

Cost-minimizing demands of exporters for non-tradable and tradable goods are given by

$$C_{N,t}^{E} = (1-\kappa)\left(\frac{P_{N,t}}{P_{E,t}}\right)^{-\eta^*} C_{E,t} \quad ; \quad C_{T,t} = \kappa\left(\frac{P_{T,t}}{P_{E,t}}\right)^{-\eta^*} C_{E,t} \tag{23}$$

It is assumed that the rest of the monetary union's member economies are equal to the home economy except in those economies where the labour market is competitive. Hence, the total demand for exports of the domestic economy can be derived from the demand functions for the final goods above, and the total demand for exports is given by:

$$C_{E,t} = \alpha\left(\frac{P_{E,t}}{\mu_t^{ed} P_{F,t}^*}\right)^{-\gamma}\left(\frac{P_{F,t}^*}{P_t^*}\right)^{-\eta} C_t^* \tag{24}$$

Variables with asterisk denote monetary union wide aggregates. μ^{ed} is an exogenous demand shifter for the exports of domestic economy and captures the role of export demand shock. It is set to follow

$$log(\mu_t^{ed}) = \rho_e log(\mu_{t-1}^{ed}) + \epsilon_t^{ed} \tag{25}$$

Some identities

Total demand for tradable goods is $Y_{T,t} = C_{T,t}$ and for the non-tradable goods $Y_{N,t} = C_{N,t}^{E} + C_{N,t}$. Aggregate consumption is the sum of sectorial consumptions, $C_t = s_N C_t^N + s_T C_t^T$.

Wage setting

In both sectors, there is a labour union that sets the wage rate for its sector. The labour union maximizes the utility of the representative household of its sector subject to model constraints. Given the wage level, households supply the amount of labour that is required to meet firms' labour demands, and this clears the labour market. The wage formation structure that I chose corresponds to right-to-manage bargaining where the labour unions have all the bargaining power. This structure was chosen for its simplicity and because it is comparable to how the labour market is typically modelled in DSGE models, when the labour supply and wage settings take place at the household level. At the household level, the labour supply decision rule is an outcome of the intratemporal utility maximization of households. The essential difference between the wage setting of a large union and household-level wage setting is that in household-level wage setting, the maximization is subject to the household's budget constraint and the firm's wage demand, whereas in union-level wage setting, the maximization is subject to all constraints of the model.

In both settings, household level and union level, the labour supply is determined by maximization of utility of the representative household. Another approach, instead of wage *setting*, would have been to formulate wage *bargaining* between firms and unions, which is what Calmfors and Seim (2013) do. In their setup, there is Nash bargaining between the employers' federation and the labour union, and the objective is the weighted sum of household utility and firm profits. If the approach in Calmfors and Seim (2013) was chosen, already the differences in the maximization objectives between union and household level wage setting would produce differences in the results, and there would be less transparency when analysing how the level of wage setting alters the results. Since in my setup, the objectives of union- and household-level wage setting are the same, maximization of the utility of the representative household, it is possible to analyse the effect of changing the wage-setting level from the household level to the union level.

The sectorial union maximizes the utility of the representative household of its sector subject to the constraints of the model, equations (3)-(24). This approach to union's wage setting is similar to planner's problem in Ramsey optimal policy formulation, which is usually used in the context of optimal fiscal and monetary policy, see e.g. Schmitt-Grohé & Uribe (2007). In the optimal fiscal and monetary policy studies the instruments that planner has are tax rates, fiscal spending or interest rates. Here the instrument is the sectorial nominal wage. In addition, there are not only one planner but instead two planners, the sectorial unions and in the planning problem the action of the other planner needs to be taken into account. Several wage setting regimes are considered. Unions can set wages with or without coordination. Similarly to Calmfors and Seim (2013) uncoordinated wage setting is modelled as Nash game and wage leadership as a Stackelberg game. Nash bargaining has no direct empirical counterpart but serves as useful benchmark for other types of wage setting regimes. Stackelberg type wage leadership is modelled to proxy pattern bargaining, which is common in many countries where the predominant wage bargaining level is sectorial. In addition, wage norm-type wage setting is considered. In this type of wage setting, either of the unions sets the wage and the wage of the other union is pegged to that.

Uncoordinated bargaining

Let y_t denote all the other variables in the model except wage rates. Equations (3)-(24) can be written in the form

$$G(y_t, y_{t-1}, w_{N,t}, w_{T,t}) - E_t F(y_{t+1}) = 0 \tag{26}$$

where $G(:)$ consists of terms including only variables that are known on period t and $F(:)$ includes terms that include only expectational variables.

In uncoordinated wage setting, a Nash game, the union's problem in sector k is defined as

$$\max_{y_t, w_t^k} \sum_{j=0}^{\infty} E_t \beta^j \Big\{ U(C_{t+j}^k, N_{t+j}^k) \\ -\lambda_{t+j}^k \big[G(y_{t+j}, w_{t+j}^N, w_{t+j}^T) - F(y_{t+1+j}) \big] \Big\} \tag{27}$$

where λ_t is a vector of Lagrange multipliers. Maximization of the system in (27) leads to time-inconsistent policy. Variables of period t enter the system only in $G(:)$ part, whereas variables of all later periods enter both $G(:)$ and $F(:)$. Eg on period t, y_2 enters $F(:)$ in expectations and on period $t+1$ it enters $G(:)$ as known. Following Marcet and Marimon (2011) the system is augmented with lagged multipliers to give

$$\max_{y_t, w_t^k} \sum_{j=0}^{\infty} E_t \beta^j \Big\{ U(C_{t+j}^k, N_{t+j}^k) \\ -\lambda_{t+j}^k G(y_{t+j}, y_{t-1+j}, w_{t+j}^N, w_{t+j}^T) - 1/\beta \lambda_{t-1+j}^k F(y_{t+j}) \Big\} \tag{28}$$

In the Nash game, the wage of other sector is taken as given. Let $x_t^k = [y_t \; w_t^k]$. The first order conditions for the unions' wage setting are given as:

$$\frac{\partial U(C_t^k, N_t^k)}{\partial x_t^k} + \lambda_t^k \frac{\partial G(y_t, y_{t-1}, w_t^N, w_t^T)}{\partial x_t^N} + \beta E_t \lambda_{t+1}^k \frac{\partial G(y_{t+1}, y_t, w_{t+1}^N, w_{t+1}^T)}{\partial x_t^k} \\ -1/\beta \lambda_{t-1}^k \frac{\partial F(y_t)}{\partial x_t^k} = 0 \tag{29}$$

Equations (28) and (29) give the evolution of the wages and Lagrangian multipliers. Given wages, the system of equations in (26) determines the evolution of rest of the model variables.

Wage leadership

The wage leadership is modelled similarly to Calmfors and Seim (2013) as a Stackelberg game. The follower's problem corresponds to that in a Nash game since the follower takes the wage of the leader as given. The leader takes into account the reactions of the follower, and the first order conditions of the follower are included as constraints in the leader's maximization.

Let variables with F in the upper index correspond to the follower and L to the leader. The maximization problem of the leader is given as

$$\begin{aligned}
\max_{y_t, w_t^F, w_t^L} \sum_{j=0}^{\infty} E_t \beta^j \Big\{ & U(C_{t+j}^L, N_{t+j}^L) \\
& -\lambda_{t+j}^L G(y_{t+j}, y_{t-1+j}, w_{t+j}^N, w_{t+j}^T) - 1/\beta \lambda_{t-1+j}^L F(y_{t+j}) \\
-\lambda_{t+j}^L \Big(\frac{\partial U(C_t^F, N_t^F)}{\partial x_t^F} & + \lambda_t^F \frac{\partial G(y_t, y_{t-1}, w_t^N, w_t^T)}{\partial x_t^F} - 1/\beta \lambda_{t-1}^F \frac{\partial F(y_t)}{\partial x_t^F} \Big) \\
& + \lambda_{t-1}^L \lambda_t^F \frac{\partial G(y_t, y_{t-1}, w_t^N, w_t^T)}{\partial x_{t-1}^F} \Big\}. \qquad (30)
\end{aligned}$$

The first-order conditions for (30) define the evolution the wage rate and the Lagrangian multipliers of the leader. Conditionally on the wage rate of the leader, equations in (29) determine the evolution of the wage rate and the Lagrangian multipliers of the follower. Given wages, the system of equations in (26) determines the evolution of rest of the model variables.

Wage norm

One feature of pattern bargaining is that the wage set by the leader might become a normative reference point for the followers (Calmfors and Seim (2013)). To model this, I assume a wage setting regime where either of the unions sets the wage, and the wage rate on the other sector is pegged to that. In this wage-setting regime, the maximization problem for the leader is similar to that in Nash bargaining, but an additional equation is added as a constraint

$$W_{F,t} = W_{L,t}. \qquad (31)$$

The follower has no maximization problem, since its wage is given according to (31). First-order conditions in the leader's problem determine the evolution of wages and Lagrangian multipliers. Given wages, the evolutions of the rest of the model variables are determined by equations in (26).

Firm level

The wage setting regimes described above are compared to wage setting by the households. There, the wages are outcomes of standard intratemporal utility maximization of households. Real wages are equal to the marginal rate of substitution between leisure and consumption.

$$-\frac{U_{N_t^k}}{U_{C_t^k}} = \frac{W_t^k}{P_t} \qquad (32)$$

In the next sections this regime is referred as firm-level wage setting.

Table 1. Parameter values

Discount factor	β	.99
Risk aversion	σ	1
Frisch elasticity	ϕ	2
Price stickiness	θ	.4
Demand elasticity of intermediate goods	ϵ	6
Share of imports in consumption	α	.25
Share of non-tradable goods in exports	1-κ	.37
Elasticity of substitution between imports and non-tradables in consumption	η	0.85
Elasticity of substitution between tradables and non-tradables in exports	η^*	1
Price elasticity of exports	γ	5
Debt elasticity with respect to aggregate bonds	ρ_a	.02
Debt elasticity with respect to household bonds	ρ_i	.02
Autocorrelation of TFP shock	ρ_a	.9
Autocorrelation of external demand shock	ρ_e	.9
Autocorrelation of discount rate shock	ρ_d	.7

4.3 Parameterization

The parameter values are shown in Table 1. $\beta, \sigma, \phi, \theta$ and autocorrelation coefficients are parameterized using conventional values in the literature. The share of non-tradables in exports, $1 - \kappa$, is set to 0.37 to obtain the average input share of non-tradables for manufacturing sectors in the countries Austria, Denmark, Finland, Germany and Sweden in 2011.[4] α is set to 0.25 to obtain the average of the value-added share of manufacturing sectors for the same data. The average value-added share of manufacturing sectors in the data is 0.16, and in the model, it is given by $s_T = \alpha\kappa = 0.16$. The value-added share of the non-tradable sector is given by $s_N = (1-\alpha) + \alpha(1-\kappa) = 0.84$. Unitary steady state labour productivity is assumed for both sectors, and hence the value added shares equal population shares. In the production of exports, the elasticity of substitution between non-tradables and tradables, η^* is assumed to be unitary following Cacciatore *et al.* 2016. The price elasticity of exports, γ, is set to 5 as in Cacciatore *et al.* 2016 following the estimates by Imbs and Mejean (2015). The debt elasticity parameters ρ_a and ρ_i are assumed to be equal and are set to the lowest possible value to obtain a rational expectations solution for the dynamic model.

4.4 Steady state allocations

Figure 1 shows the first best responses of both unions and equilibria under the wage leadership of both unions. The Nash equilibrium lies in the intersection of

4 Source: OECD input-output tables and own calculations.

the best response curves. The wage setting of the wage follower is functionally identical to that in the Nash equilibrium since the wage follower takes the wage of the leader as given. Hence, the equilibria of Stackelberg games lie on the first best response curves of the follower. Both first-best response lines are non-increasing, and hence wage-setting actions are strategic substitutes. As is well known, the follower in a Stackelberg game is worse off compared to the Nash equilibrium if the actions of players are strategic substitutes.[5] Table 1 confirms this. In addition, compared to the Nash equilibrium, the aggregate utility is also lower in Stackelberg games. The weighted utility loss of the follower sector households is always greater than is the weighted utility gain of the wage leader sector households.

There are two channels in which the unions can operate strategically. First, there is a standard terms of trade externality, which is well known in the literature of optimal monetary policy in an open economy (see e.g. Benigno & Benigno (2003)). By increasing the price level of exports, a social planner (be it a labour union or central bank), can make households better off since households will earn more consumption for a given labour input. The consumption level itself will be lower compared to market allocation, but the consumption-employment ratio gives a higher utility level. The strength of this channel is determined by the price elasticity of exports, which is parameterized by γ.

The other channel is the substitutability of non-tradable and tradable intermediate goods in the production of exports, which gives a clear first-mover advantage. The leader has an incentive to set a high wage that the follower needs to compensate with a lower wage to get an optimal demand for exports. The share of non-tradables in the production of exports, δ, and substitutability between non-tradables and tradable in the production of exports are key parameters to determine the strength of this channel.

The negative slope of the non-tradable sector's first best response derives from the high elasticity of employment in the non-tradable sector to the tradable sector wage. Consider first a case where δ is set to unity and non-tradable goods are not used in the production of exports. All else being equal, an increase in the tradable sector wage results in a higher decrease in tradable sector employment as long as the price-elasticity of exports is greater than one. This means that the wage sum of the tradable sector decreases, which in turn implies a lower consumption level, which lowers the demand of tradable sector households for non-tradable sector production. To compensate this, the non-tradable sector needs to decrease the nominal wage level so that a larger fraction of domestic consumption goes to non-tradable goods instead of imports.

By manipulating the terms of trade, unions are able to increase the aggregate welfare compared to firm level wage setting, but this happens only in wage setting regimes where the strategic interaction of the unions is minimal. The strategic interaction is minimal under Nash bargaining and wage norms. In Stackelberg games, only the leader sector gains over market or Nash allocation. Against conventional wisdom, it is actually the tradable sector that has a higher incentive to drive the economy to a low competitiveness equilibrium.

5 See e.g. Rasmusen (2007, p. 94).

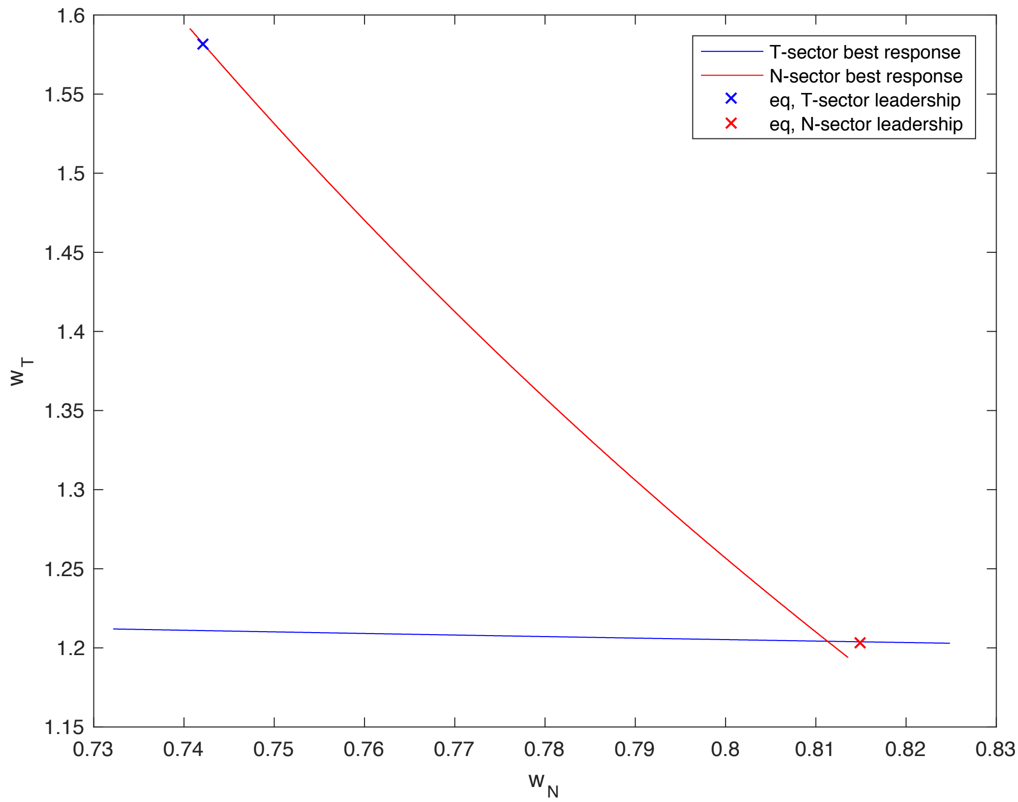

Figure 1. Best response functions. Nash equilibrium lies in the intersection of lines. The equilibria under Stackelberg games are denoted with x's.

This paper's main insight in terms of steady-state analysis can be summarized as follows. In an open economy, there are externalities that large wage setters can take advantage of and thus increase the aggregate welfare over market allocation. Still, adverse consequences arising from strategic interaction can consume this surplus and bring the economy to a worse equilibrium. Tradable sector leadership or norms do not seem to be beneficial in terms of aggregate household welfare. However, tradable sector leadership does lead to a lower wage rate in the non-tradable sector, in line with conventional wisdom, but this comes with a high welfare cost. However, against conventional wisdom, the low wage in the non-tradable sector does not follow from the tradable sector's commitment to a lower wage. Instead, when the tradable sector is the wage leader, it sets the wage considerably higher than the market wage and pushes the economy to an equilibrium where the non-tradable sector needs to compensate with lower wages.

One might argue that the wage leadership model in this paper does not hold up in reality because, in practice, the wage agreement on the tradable sector is taken as a normative ceiling by other unions. To model this, an inequality constraint should be added to the model to take into account that the non-tradable sector wage cannot exceed the tradable sector wage. This constraint has not been added because it would complicate the computation. However, this does not create problems for the analysis because the follower does not set higher wages than the leader, as can be seen from Table 1. Even if this inequality constraint were added to the model, it would not be binding.

Next, the robustness of the steady-state results of the model are studied by altering some parameter values.

4.4.1 Demand elasticity of exports, γ

The price elasticity parameter of exports, γ, was set to 5 in the baseline parametrization, which is line with recent estimates provided by Imbs and Mejean (2015) and used in the parametrization of an open economy DSGE model in Cacciatore *et al.* (2016). However, usually it is thought that it is the high international competition faced by export sector firms that makes the export sector's wage leadership beneficial for the aggregate economy. In line with this, in Calmfors and Seim (2013), demand elasticity is assumed to be infinite. To study the robustness of results with respect to demand elasticity, the model was simulated with $\gamma = 15$.

The main insight holds, but interestingly under wage norms, a wage lower than the competitive labour market wage is chosen. This results from the imperfect competition in the intermediate goods markets. Firms generate profits that are distributed to households, and this distorts the labour supply optimality condition, since part of the income does not consist of wage income. Even in the absence of labour market imperfections, employment is lower than would be socially optimal. Labour unions understand this and thus have incentives to set a slightly lower than competitive market wage. This channel dominates when γ is sufficiently high and gains from the terms of trade manipulation are limited. It is noticeable that this happens only under wage norms. Under wage leadership, the strategic incentives are such that only the leader gains and does so at the expense of the follower. The welfare cost for the follower is so large that for the overall economy, the wage leaderships are welfare detrimental compared to firm-level wage-setting when the demand elasticity of exports is high.

4.4.2 Share of non-tradables in the production of exports, δ

When δ is increased to one, non-tradable sector intermediate goods are not used in the production of exports. As shown in Figure 4 in the Appendix, the best response curve of the export sector is now horizontal. This is because the substitutability channel is now shut down. Hence, the only way that the non-tradable sector wage affects the tradable sector wage setting is through the real wage. The domestic price level is determined by the non-tradable union since import prices are assumed to be constant. With logarithmic utility in terms of consumption ($\sigma = 1$), income and substitution effects cancel each other out for optimal labour supply. For this reason the real wage level is irrelevant for the tradable sector union. What matters is only the relation of tradable sector wages and export prices to the monetary union price level, which is exogenous. For this reason, the tradable sector wage level is solely unresponsive to the non-tradable wage level.

Table 1. Steady state allocations and welfare costs

Regime	w_{NT}	w_T	w_{NT}/p	w_T/p	n_{NT}	n_T	c_{NT}	c_T	Welfare costs NT	T	total
					Baseline parameterization						
firm level	0,833	0,833	0,83	0,83	0,62	0,29	0,91	0,91			
Nash	0,811	1,204	0,82	1,22	0,56	0,17	0,81	0,80	-3,95	12,50	1,31
NT lead	0,815	1,204	0,83	1,22	0,55	0,17	0,81	0,79	-3,95	12,25	1,23
T lead	0,742	1,582	0,80	1,70	0,56	0,12	0,78	0,76	-7,64	14,73	-0,48
NT norm	0,862	0,862	0,84	0,84	0,59	0,28	0,88	0,88	0,23	0,30	0,25
T norm	0,870	0,870	0,85	0,85	0,58	0,27	0,87	0,87	0,21	0,31	0,25
					$\gamma = 15$						
firm level	0,833	0,833	0,83	0,83	0,62	0,29	0,91	0,91			
Nash	0,836	0,831	0,83	0,83	0,67	0,32	0,98	0,98	0,86	0,32	0,69
NT lead	0,937	0,808	0,87	0,75	0,57	0,32	0,88	0,89	2,73	-9,74	-1,26
T lead	0,589	0,918	0,73	1,13	0,67	0,19	0,86	0,82	-13,83	11,92	-5,59
NT norm	0,832	0,832	0,83	0,83	0,68	0,32	1,00	1,00	0,71	0,71	0,71
T norm	0,832	0,832	0,83	0,83	0,68	0,32	1,00	1,00	0,71	0,71	0,71
					$\sigma = 0.1$						
firm level	0,833	0,833	0,83	0,83	0,51	0,34	0,85	0,85			
Nash	0,870	1,205	0,85	1,17	0,40	0,19	0,68	0,69	-4,04	8,74	1,07
NT lead	0,845	1,197	0,84	1,19	0,42	0,20	0,70	0,70	-3,99	10,24	1,70
T lead	0,809	1,479	0,82	1,51	0,39	0,14	0,65	0,65	-7,03	10,38	-0,07
NT norm	0,876	0,876	0,85	0,85	0,47	0,31	0,80	0,80	0,32	0,44	0,37
T norm	0,889	0,889	0,86	0,86	0,46	0,31	0,78	0,79	0,30	0,46	0,36
					$A_{NT} = 0.9$						
firm level	0,771	0,787	0,77	0,79	0,62	0,29	0,84	0,86			
Nash	0,750	1,124	0,76	1,14	0,55	0,17	0,75	0,74	-4,03	11,45	0,92
NT lead	0,754	1,124	0,76	1,14	0,55	0,17	0,74	0,74	-4,03	11,19	0,84
T lead	0,686	1,475	0,74	1,58	0,56	0,12	0,72	0,71	-7,74	13,69	-0,88
NT norm	0,799	0,799	0,78	0,78	0,59	0,28	0,81	0,82	0,28	-1,53	-0,30
T norm	0,813	0,813	0,79	0,79	0,57	0,27	0,79	0,81	0,23	-1,48	-0,32

Note: Welfare cost defined as percentages points of steady-state consumption decrease to provide the equivalent level of welfare as that in the firm-level wage setting. Thus, a positive figure means that welfare is higher in the alternative wage-setting regime than in the firm-level wage setting. Total welfare costs are weighted averages of sectorial welfare costs and weights are the sectorial population shares.

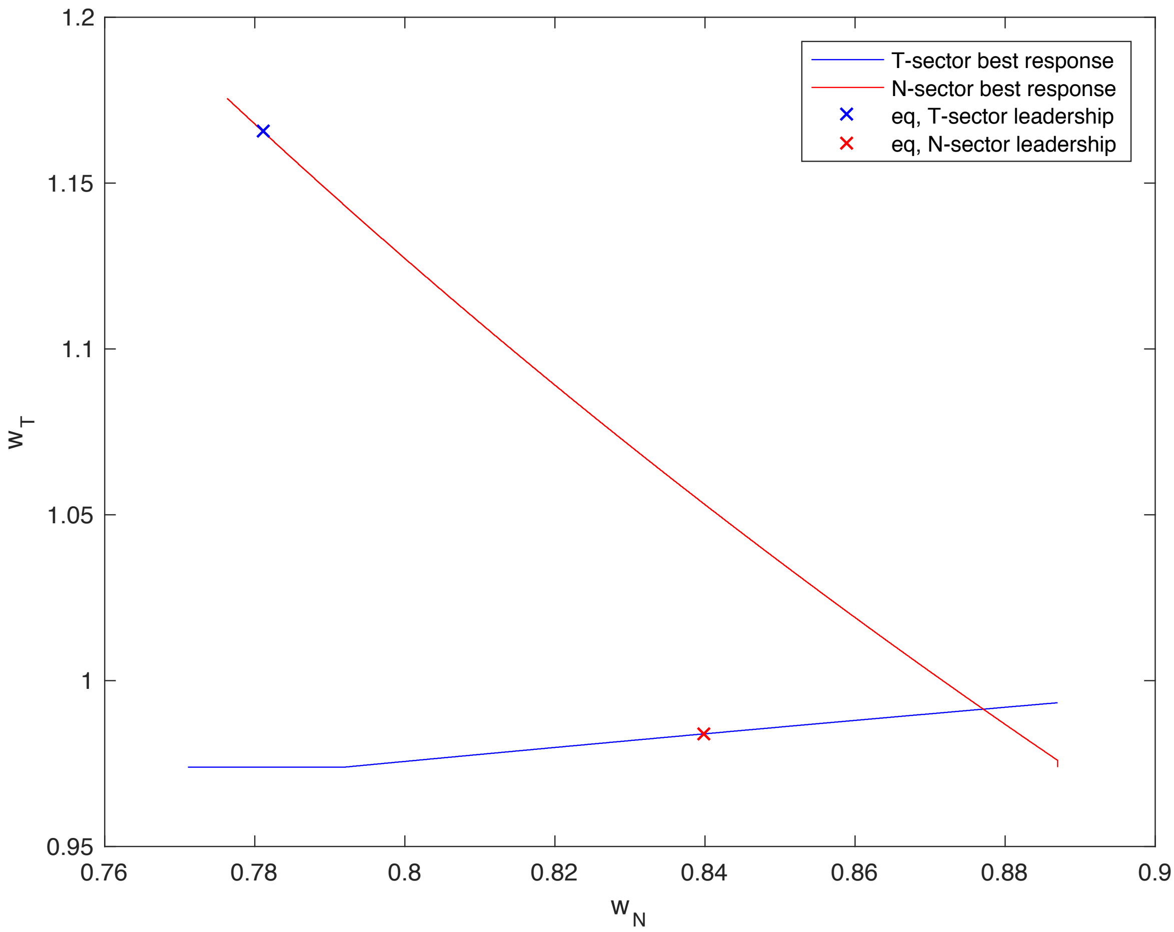

Figure 2. Best response functions, $\sigma = 0.1$. Nash equilibrium lies in the intersection of lines. The equilibria under Stackelberg games are denoted with x's.

4.4.3 Slopes of best response curves

Downward-sloping best response curves imply that there is no wage comparison competition between sectors. Higher wages in one sector do not lead to higher wage demands in the other sector. Contrary to the model of this study, e.g Vartiainen (2010) suggests upward-sloping best response curves are more realistic. Also, Calmfors and Seim (2013) study wage setting where the relative wages between sectors are important for the unions. Calmfors and Seim (2013) implement this by modifying the objective function of a union so that it depends on household utility but it is penalized if the wage level is lower than in the other sector.

Within the model of this study, upward-sloping best response curves were not found for the non-tradable sector when tried over a wide range of parameterizations. When σ was changed to a value below unity, the tradable sector union has a slightly upward-sloping best response curve, Figure 2. This results from the fact that when σ is below unity, the substitution effect in the labour supply dominates. The results with $\sigma = .1$ are shown in Table 1. Qualitatively, the results are the same as in the baseline parameterization. Neither under this parameterization the wage leadership of the export sector brings a more optimal allocation than the firm level or Nash wage setting for the overall economy.

4.4.4 Heterogenous productivities

Compared to other wage setting regimes, wage setting norms have seemed to bring the highest aggregate utility. However, this has hinged on equal sectorial productivities. The lowest panel in Table 1 shows the results when the assumption of equal sectorial productivities is relaxed and A_{NT} is set to 0.9 while keeping $A_T = 1$. Now, the wage norm regimes are no longer optimal for the aggregate welfare. Empirically, even larger productivity differences between sectors are plausible, which speaks against the usefulness of wage norms in practice.

4.5 Dynamics

This section studies the welfare consequences of different wage setting regimes when the economy is subject to shocks. As the previous section focused on the steady state comparisons in a static framework, this section studies how wage setting regimes influence the ability of the model economy to adjust to shocks. The shocks considered are export demand, domestic demand and productivity shocks, and each shock is studied in turn.

Dynamics are obtained by linearizing the equations and solving the linearized system using Klein's (2000) algorithm. Welfare comparisons are obtained by taking the second-order approximation using the algorithm in Gomme and Klein (2011). Second-order approximation is needed since lifetime welfare costs of deviations from the deterministic steady state are zero up to the first-order approximation, and in addition, all the effects, most notably the welfare cost of relative price distortions, are not taken into account in first-order approximations. Analysis here is similar to Schmitt-Grohé and Uribe (2007), who study optimal fiscal and monetary policy in a medium scale DSGE model.

The welfare comparisons are made with respect to firm-level wage setting. To make the welfare comparisons meaningful, the deterministic steady states across comparison regimes must be equal. This is implemented by assuming that in the firm-level wage-setting, there are sectorial mark-ups. Mark-ups are calibrated to bring the same sectorial steady state wages as in the comparison regime. Since the steady state values for all other variables are determined by the sectorial wages and exogenous variables, the steady states are the same for the comparison regimes.

4.5.1 Export demand shock

To derive intuition for the analysis, consider first the impulse responses of firm-level wage-setting to negative export demand shock in Figure 3. No frictions are assumed for the firm-level wage-setting, and hence it corresponds to a perfect labour market. A perfect labour market outcome is that both sectors adjust to export demand shock, but the adjustment through wages is considerably higher in the tradable sector. Conventional wisdom has been that in an export-oriented economy, non-tradable sector wages should closely follow tradable sector wages. Table 2 shows that if the non-tradable sector wage is pegged to the tradable sector wage, this produces high welfare costs for the non-tradable sector. Impulse responses in Figure 3 illustrate that if the wage norm holds strictly, then the non-tradable sector is forced to over-adjust. Under the firm level wage setting, the consumption level of the non-tradable sector households drops in response to negative shock. But under the wage norm, the consumption level actually increases. This results from the increased labour demand for the non-tradable sector as the non-tradable sector's wage level falls.

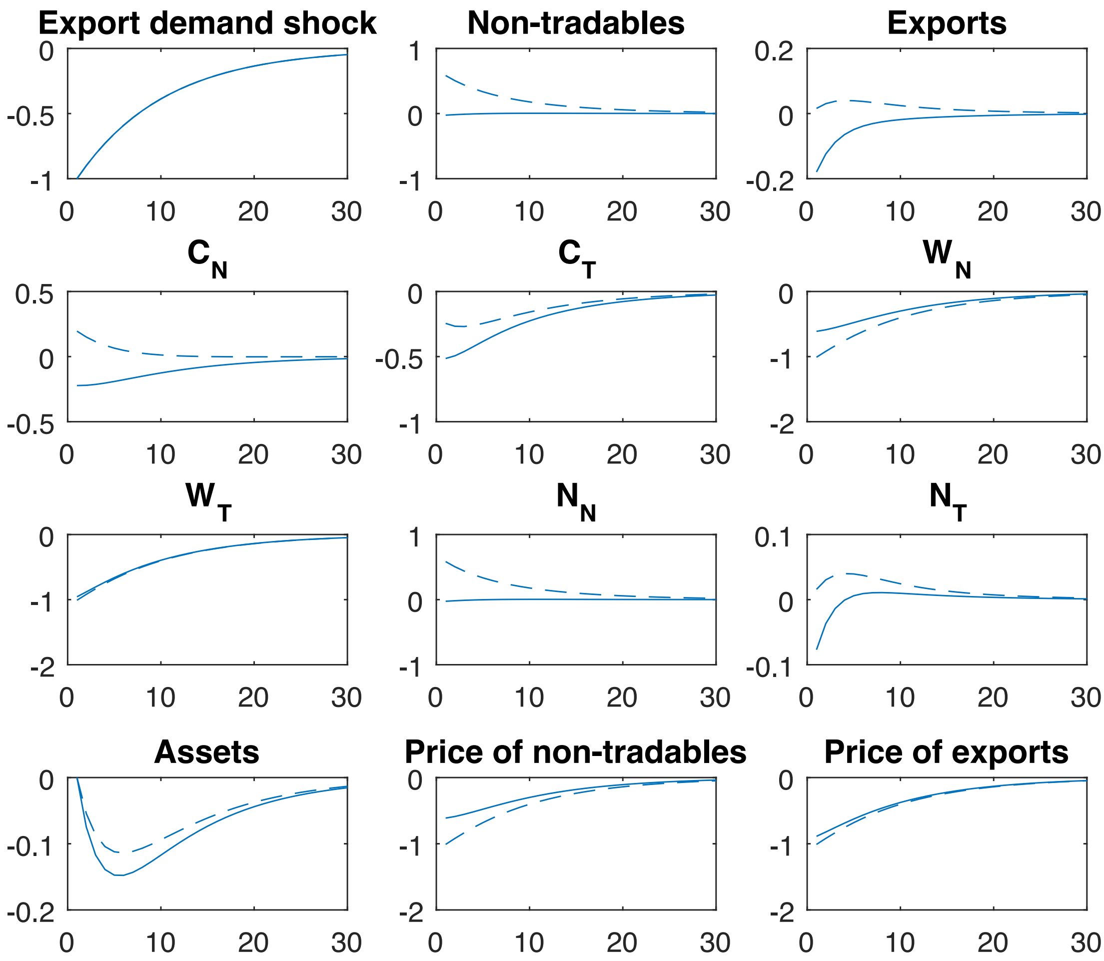

Figure 3. Impulse responses to export demand shock. Solid line, firm level.Dashed line tradable sector wage norm.

Table 2 shows welfare costs for both the baseline parameterization and with flexible prices, $\theta = 0$. When prices are sticky, the wage setting of unions brings in a generally higher level of welfare compared to firm level wage setting. This is because price stickiness creates a market friction and market allocations are no longer optimal, creating the possibility for large wage setters to increase welfare over market allocation.

When the price elasticity of exports increases, welfare costs of both the non-tradable and tradable sector wage norms increase. This is because higher price elasticity of exports requires that the prices of exports need to be more closely in line with external demand, which increases the divergence of the economic environments of the non-tradable and tradable sectors. This indicates that even if the exports sector is subject to tight international competition, it is not optimal for the whole economy to closely follow the tradable sector; instead, sector-specific adjustment is needed.

Contrary to steady state allocations, the differences between Nash and Stack-

Table 2. Standard deviations and welfare costs, export demand shock

	Standard deviations							Welfare costs		
Regime	w_{NT}	w_T	p	n_{NT}	n_T	c_{NT}	c_T	NT	T	total
				Baseline parameterization						
firm level	0,291	0,433	0,17	0,05	0,14	0,07	0,10			
Nash	0,253	0,393	0,16	0,09	0,19	0,09	0,13	0,19	0,05	0,17
NT lead	0,240	0,400	0,16	0,09	0,19	0,10	0,14	0,18	0,21	0,18
T lead	0,148	0,550	0,09	0,05	0,22	0,05	0,07	0,19	0,63	0,26
NT norm	0,265	0,265	0,16	0,10	0,38	0,08	0,15	0,29	-6,96	-0,85
T norm	0,388	0,388	0,16	0,05	0,14	0,08	0,08	-1,23	-1,25	-1,23
					$\theta = 0$					
firm level	0,220	0,234	0,16	0,01	0,02	0,05	0,06			
Nash	0,220	0,233	0,16	0,01	0,02	0,05	0,06	0,00	-0,01	0,00
NT lead	0,220	0,233	0,16	0,00	0,03	0,05	0,06	0,00	-0,01	0,00
T lead	0,196	0,259	0,14	0,01	0,05	0,05	0,06	0,00	0,02	0,00
NT norm	0,222	0,222	0,17	0,01	0,14	0,05	0,07	0,04	-1,01	-0,12
T norm	0,228	0,228	0,17	0,05	0,02	0,07	0,05	-0,16	-0,10	-0,15
					$\gamma = 15$					
firm level	0,313	0,549	0,17	0,06	0,20	0,07	0,11			
Nash	0,311	0,590	0,16	0,06	0,13	0,07	0,11	0,19	0,20	0,19
NT lead	0,250	0,629	0,15	0,08	0,14	0,09	0,13	0,35	0,63	0,40
T lead	0,211	0,647	0,08	0,03	0,23	0,04	0,05	0,36	0,77	0,43
NT norm	0,322	0,322	0,17	0,13	0,74	0,07	0,15	-0,40	-27,49	-4,67
T norm	0,481	0,481	0,17	0,04	0,14	0,08	0,06	-2,08	-1,49	-1,99

Notes: Conditional on 0.1 standard deviation for export demand shock. Welfare cost defined as percentage points of steady state consumption decrease to provide the equivalent level of welfare as in the firm-level wage setting. Thus, a positive figure means that welfare is higher in an alternative wage-setting regime than in a firm-level wage setting. Total welfare costs are weighted averages of sectorial welfare costs, and weights are the sectorial population shares.

elberg wage setting are not so large in terms of dynamics. This indicates that the strategic incentives of the unions are smaller in terms of dynamics than terms of steady state allocations.

4.5.2 Domestic demand shock

Domestic demand shock is modelled as a shock to the discount rate. Positive shock decreases the willingness of domestic households to save, which increases the demand for consumption goods. Since the shock is purely domestic shock, the demand conditions of exports are not affected. Interestingly, Table 3 shows

Table 3. Standard deviations and welfare costs, domestic demand shock

	Standard deviations							Welfare costs		
Regime	w_{NT}	w_T	p	n_{NT}	n_T	c_{NT}	c_T	NT	T	total
				Baseline parameterization						
firm level	0,143	0,022	0,04	0,03	0,04	0,06	0,04			
Nash	0,060	0,016	0,02	0,05	0,03	0,07	0,05	0,27	-0,23	0,19
NT lead	0,054	0,016	0,02	0,05	0,03	0,08	0,05	0,23	-0,21	0,17
T lead	0,070	0,109	0,04	0,04	0,11	0,07	0,05	0,11	-0,13	0,07
NT norm	0,068	0,068	0,02	0,04	0,13	0,06	0,04	0,32	-0,64	0,17
T norm	0,008	0,008	0,00	0,07	0,02	0,09	0,06	0,08	0,34	0,12
					$\theta = 0$					
firm level	0,076	0,022	0,06	0,01	0,04	0,03	0,02			
Nash	0,075	0,020	0,06	0,01	0,04	0,03	0,02	0,01	-0,04	0,00
NT lead	0,073	0,021	0,06	0,00	0,04	0,03	0,02	0,02	-0,08	0,00
T lead	0,087	0,035	0,06	0,01	0,04	0,04	0,02	-0,04	0,01	-0,03
NT norm	0,050	0,050	0,04	0,01	0,25	0,04	0,04	0,04	-2,79	-0,41
T norm	0,005	0,005	0,00	0,07	0,03	0,09	0,06	-0,39	0,22	-0,30

Notes: Conditional on 0.1 standard deviation for domestic demand shock. Welfare cost defined as percentage points of steady state consumption decrease to bring the equivalent level of welfare as in the firm-level wage setting. Thus, a positive figure means that welfare is higher in the alternative wage setting regime than in the firm level wage setting. Total welfare costs are weighted averages of sectorial welfare costs, and weights are the sectorial population shares.

that in the context of domestic shock, the non-tradable sector has more possibility than the tradable sector to increase welfare over market allocation. When the prices are flexible, ($\theta = 0$), market frictions vanish and wage setting by the unions cannot increase the welfare over market allocations. Flexible price allocation again illustrates that wage setting regimes that have the same wages for both sectors are welfare-detrimental, and in the case of domestic shock, sector-specific adjustment is needed.

4.5.3 Productivity shocks

Table 4 shows the results when the economy is subject to productivity shocks. The upper panel in Table 4 shows the results when the same productivity is common to both sectors. The overall picture is similar as that for demand shocks. Wage-setting by the unions is welfare-improving when prices are sticky, but when prices are flexible and markets are frictionless, unions are not able to bring better allocations than firm-level bargaining.

In the lower panel in Table 4, it is assumed that the productivity shock takes place only at the tradable sector and the non-tradable sector productivity stays

Table 4. Standard deviations and welfare costs, productivity shock

	Standard deviations							Welfare costs		
Regime	w_{NT}	w_T	p	n_{NT}	n_T	c_{NT}	c_T	NT	T	total
				Baseline parameterization						
firm level	0,223	0,251	0,06	0,02	0,02	0,29	0,31			
Nash	0,231	0,249	0,06	0,04	0,03	0,28	0,31	0,08	0,12	0,09
NT lead	0,223	0,261	0,06	0,04	0,04	0,27	0,30	0,00	0,23	0,04
T lead	0,264	0,214	0,04	0,03	0,07	0,29	0,32	0,17	0,18	0,18
NT norm	0,238	0,238	0,05	0,03	0,07	0,29	0,32	0,11	0,00	0,09
T norm	0,243	0,243	0,05	0,05	0,02	0,27	0,29	0,02	0,25	0,06
				$\theta = 0$						
firm level	0,238	0,264	0,07	0,00	0,01	0,30	0,32			
Nash	0,238	0,264	0,07	0,00	0,01	0,30	0,32	0,00	0,00	0,00
NT lead	0,223	0,279	0,08	0,00	0,03	0,29	0,32	-0,05	0,16	-0,02
T lead	0,231	0,273	0,08	0,00	0,03	0,29	0,32	-0,01	0,01	0,00
NT norm	0,250	0,250	0,05	0,00	0,08	0,30	0,33	0,00	-0,22	-0,04
T norm	0,256	0,256	0,05	0,04	0,01	0,28	0,30	-0,11	0,09	-0,07
				A_{NT} constant						
firm level	0,184	0,143	0,12	0,02	0,03	0,05	0,04			
Nash	0,167	0,146	0,12	0,03	0,03	0,05	0,05	0,11	0,10	0,11
NT lead	0,158	0,149	0,11	0,04	0,03	0,06	0,06	0,11	0,15	0,12
T lead	0,116	0,208	0,08	0,02	0,13	0,04	0,03	0,12	0,22	0,14
NT norm	0,161	0,161	0,11	0,02	0,07	0,04	0,04	0,14	-0,10	0,10
T norm	0,151	0,151	0,10	0,06	0,01	0,08	0,08	-0,06	0,29	-0,01

Notes: Conditional on 0.1 standard deviation for productivity shock. Welfare cost defined as percentage points of steady state consumption decrease to provide the equivalent level of welfare as in the firm-level wage setting. Thus, a positive figure means that welfare is higher in the alternative wage-setting regime than in the firm-level wage setting. Total welfare costs are weighted averages of sectorial welfare costs, and weights are the sectorial population shares.

constant. This increases the welfare detrimentally of both non-tradable and tradable sector norms. Similarly to the steady state results of previous sections, the heterogeneity in sectorial productivities makes strict wage norms undesirable.

4.6 Conclusions

This paper developes a novel way to model wage setting coordination between non-tradable and tradable sector unions in an open economy. The analysis is based on studying the steady state allocations and on dynamic simulations. The comparisons of different wage-setting regimes are made in reference to household welfare, as is common in studies on optimal monetary and fiscal policy.

The model features monopolistic competition and price-setting frictions in the goods market. The product market frictions in the model and terms of trade externality make the steady-state market allocations and shock adjustment suboptimal. The suboptimality of market allocations creates the possibility for a large agent, be it the government, central bank or labour union, to increase the aggregate welfare with appropriate policies. In this model, it is found that in general, some form of unionized wage setting is able to produce allocations that are welfare-enhancing with respect to firm-level wage setting. This happens typically when the strategic interaction between the unions is minimal. Wage leaderships that are modelled as Stackelberg games are mostly welfare detrimental for the aggregate economy both in terms of steady state and dynamics. Strategic incentives of unions produce allocations that increase only the utility of other sector households at the expense of the other sector.

Essentially, the results suggest than in an open economy with product market frictions, there are externalities that the large wage setters could take advantage of to increase the aggregate welfare. However, strategic incentives of the unions can bring the economy to an equilibrium where the aggregate welfare is lower than in a firm-level wage setting and only one of the sectors gains.

According to the results, it does not seem probable that the large role of the export sector in the wage setting leads to optimal outcomes for the overall economy. Hence, for purely economic reasons, it does not seem reasonable, for example, for governments to support some wage-setting regimes over others. When studying which wage setting regime is optimal when the economy is subject to shocks, the results illustrate that sector-specific adjustment is preferable.

	Level of bargaining					
	Firm		Sectorial	National	Coordination	Pattern bargaining
Austria			x		4	x
Belgium				x	5	o
Germany			x		4	x
Finland				x	5	o
France		x			2	o
Ireland	x				3	o
Italy			x		3	o
Netherlands			x		3	o
Portugal			x		3	o
Slovakia		x			2	o
Australia	x				2	o
Canada	x				1	o
Czech	x				2	o
Denmark			x		4	x
Japan	x				4	x
New Zealand	x				1	o
Norway			x		4	o
Sweden			x		4	x
Hungary	x				2	o
Korea	x				3	
New Zealand	x				1	o
Poland	x				1	o
Switzerland			x		3	o
UK	x				1	o
USA	x				1	o

Table 5. Wage setting in OECD countries in 2011. Coordination is measured on scale 1 to 5 and higher value indicates higher coordination.

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YHTEENVETO (SUMMARY IN FINNISH)

Esseitä työmarkkinainstituutioista ja makrotalouden dynamiikasta

Väitöskirja tarkastelee, kuinka työmarkkinoiden institutionaaliset rakenteet vaikuttavat talouden sopeutumiskykyyn. Väitöskirja sisältää sekä teoreettista että ekonometrista tutkimusta. Väitöskirja koostuu johdantoluvusta sekä kolmesta tutkimuksesta.

Luvussa kaksi estimoidaan OECD-maiden paneeliaineistolle vektoriautoregressiivinen (VAR) malli. Mallilla tutkitaan, voidaanko maidenvälisiä eroja kokonaistaloudellisessa dynamiikassa selittää tilastollisesti merkitsevästi eroilla työmarkkinainstituutioissa. VAR-mallin muuttujat ovat työttömyys, reaalipalkka, kokonaistuotanto ja työvoiman tuottavuus. Tutkittavat työmarkkinainstituutiomuuttujat ovat irtisanomissuoja, työttömyyskorvausten taso ja palkkaneuvotteluiden koordinaatio/keskittyneisyys. Kyseiset muuttujat on valittu siksi, että niiden vaikutuksia on tutkittu teoreettisessa tutkimuskirjallisuudessa ja näihin työmarkkinainstituutioihin liittyvät reformit ovat aika ajoin julkisessa keskustelussa esillä. Tulosten perusteella työmarkkinainstituutiomuuttujien ja suhdannevaihteluiden dynamiikan välillä on yhteys. Maissa, joissa on vahvat instituutiot, makrotaloudellisten muuttujien volatiliteetti on pienempää. Mikäli työvoiman irtisanomissuoja on voimakas ja työttömyysturvan taso on korkea, työttömyys palautuu hitaasti tasapainotasoon kysyntäsokin jälkeen. Mikäli palkat neuvotellaan koordinoidusti, palkat reagoivat voimakkaammin kysyntäsokkeihin ja työttömyys heikommin. Havaitut erot ovat kuitenkin pieniä, minkä perusteella voidaan olettaa, että ainoastaan hyvin suurilla työmarkkinainstituutioreformeilla voidaan muuttaa talouden sopeutumiskykyä merkittävästi.

Luvussa kolme mallinnetaan suuren ammattiliiton palkanmuodostusta dynaamisessa yleisen tasapainon (DSGE) mallissa. Tutkimuksessa tarkastellaan, kuinka talouden dynamiikkaa muuttuu, kun suuri ammattiliitto asettaa palkan koko talouteen. Edustavan kotitalouden hyvinvointia verrataan tilanteeseen, jossa palkat määräytyvät kilpailullisilla markkinoilla tai usean pienen ammattiliiton toimesta, kun mukana on Calvo-tyyppinen palkkajäykkyys. Lisäksi tutkitaan, kuinka optimaalisen rahapolitiikan sääntö muuttuu, kun palkat asettaa suuri ammattiliitto. Tulosten perusteella useaksi periodiksi eteenpäin kiinnitettävät palkat eivät tuota hyvinvointitappioita Calvo-tyyppiseen palkkajäykkyyteen verrattuna. Kun palkat asetetaan täysin keskitetysti suuren ammattiliiton toimesta, ammattiliitto kykenee kontrolloimaan tuotantokustannuksia ja siten hintatasoa. Tällöin hintavakauden sijaan keskuspankin on optimaalista tähdätä tuotantokuilun vaihtelun minimoimiseen. Mallissa oletettujen hyödykemarkkinoiden epätäydellisyyden vuoksi talouden vasteet sokkeihin eivät ole optimaalisia. Tällöin ammattiliitto, joka sisäistävä palkanmuodostuksen kokonaistaloudelliset vaikutukset, kykenee parantamaan talouden sopeutumiskykyä ja pienentämään edustavan kotitalouden hyvinvointitappiota. Tämä korostuu sokkien kohdalla, joiden vaikutuksia keskuspankki ei pysty vakauttamaan korkopolitiikalla.

Luvussa neljä rakennetaan kahden sektorin avoimen talouden uuskeynesiläinen DSGE-malli ja tutkitaan, kuinka palkanmuodostuksen koordinaatio vaikuttaa talouden sopeutumiseen. Sektorit ovat ulkomaiselle kilpailulle avoin vientisektori ja kotimainen, suljettu sektori. Ammattiliitot kummallakin sektorilla ovat suuria ja ymmärtävät palkkavaateidensa kokonaistaloudelliset seuraukset. Mallissa vientisektori kohtaa tuottavuus- ja vientikysyntäsokkeja ja suljettu sektori kotimaisia kysyntäsokkeja. Tulosten mukaan palkkajohtajuusmalli, jota mallinnetaan Stackelberg-pelinä ei ole optimaalinen koko talouden kannalta. Verrattuna koordinoimattomaan Nash-peliin ainoastaan palkan ensimmäisenä asettava sektori hyötyy. Nash-peli tuottaa työpaikkakohtaista palkanmuodostusta suuremman kokonaishyödyn, mutta Stackelberg-pellissä liittojen strateginen käyttäytyminen syö kokonaishyödyn. Mikäli suljetun sektorin palkat sidotaan vientisektorin palkkoihin ei tämäkään tuota optimaalista palkan asetantaa koko talouden kannalta vaan ainoastaan vientisektori hyötyy tästä suhteessa työpaikkatason palkanmuodostukseen. Tässä asetelmassa talouden kohdatessa vientikysynnän shokin on vientisektorin sopeutuminen helpompaa, mutta samalla suljetun sektorin palkkataso pakotetaan tasolle, joka poikkeaa siitä, mikä olisi täydellisten markkinoiden tuottama tasapaino. Kun koko talous pakotetaan sopeutumaan vientisektorin kokemiin kysynnän vaihteluihin, ulkomaisten sokkien läpimeno talouteen kasvaa ja talouden volatiliteetti suurenee, mikä tuottaa hyvinvointitappioita. Tulokset eivät tue väitettä, että vientisektorin merkittävä rooli palkkaneuvotteluissa olisi välttämättä optimaalinen koko talouden kannalta

Huolimatta työmarkkinainstituutioiden ja työmarkkinoiden rakenteellisten uudistusten keskeisestä roolista julkisessa keskustelussa ja kansainvälisten instituutioiden toimenpidesuosituksissa, niitä koskeva laadukas tutkimus on suhteellisen vähäistä. Työmarkkinoiden rakenteellisia uudistuksia perustellaan yleensä makrotaloudellisilla ja työmarkkinoiden kokonaisvaikutuksilla, minkä vuoksi olisi tärkeää, että työmarkkinainstituutioita kyettäisiin tarkastelemaan modernin makrotaloustieteen menetelmin ja käytännöin. Väitöskirjan tutkimuksissa kehitetään menetelmiä tätä varten.