EUROPEAN CENTRAL BANK

EUROSYSTEM

Unemployment in an Estimated New Keynesian Model

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The opinions expressed are our own and not necessarily those of the ECB, the Eurosystem or the NBB.

Introduction and motivation

- An increasing number of central banks have developed and estimated medium-scale New Keynesian DSGE models for forecasting and policy analysis.
- See, for example, Smets et al (2010) for a brief description of the two aggregate euro area models used at the ECB (NAWM and CMR).
- Typically, the labour market is modelled using the Erceg, Henderson and Levin (2000) model of monopolistic competition and Calvo wage setting.
  - Plus: Fits the time series of hours worked and real wages quite well (e.g. Smets and Wouters, 2007)
  - Minus: no reference to unemployment

Introduction and motivation

- **Gali (2009):**
  - **proposes a reformulation of the EHL model, which implies a simple dynamic relation between wage inflation and unemployment;**
  - **Shows that this structural wage equation accounts reasonably well for the comovement of wage inflation and the unemployment rate in the US economy.**
  - **Variations in unemployment are associated with changes in wage mark-ups, either exogenous or resulting from nominal wage rigidities.**
- **This (forthcoming) paper embeds this reformulation in the Smets-Wouters (2007) model by adding the unemployment rate as an observable variable.**

Introduction and motivation

- This allows us to overcome the identification problem of wage mark-up and labour supply shocks mentioned in SW (2003, 2007) and emphasized by Chari et al (2009) as an illustration of the immaturity of the New Keynesian framework:
  - In SW (2007) wage mark-up shocks account for almost 50 percent of variations in real GDP beyond 10 years.
  - With only wages and employment/hours as observables those shocks can not be distinguished from labour supply/preference shocks.
  - The source of the shock is, however, important for welfare analysis.
  - Using unemployment (or labour participation) helps overcoming the identification problem

Introduction and motivation

- It also allows us to:
  - Better identify the wage Phillips curve;
  - Analyze the sources of unemployment variations;
  - Better identify the output gap in the model.

Introduction and motivation

- **This paper is part of a growing body of work that improves the modelling of the labour market in estimated DSGE models:**
  - **Christoffel et al (2007), Gertler, Sala and Trigari (2008), de Walque et al (2009);**
  - **Christiano, Trabandt and Walentin (2009)**

Outline

- Modifications to the Smets-Wouters (2007) model for the US economy
- Estimation results
- Conclusions

The modified Smets-Wouters model

- Benchmark model without unemployment differs slightly from Smets-Wouters (2007):
  - Somewhat different data and sample: Employment (rather than hours); Wage per worker
  - Jaimovich-Rebelo preferences;
  - Priors on standard deviation of shocks are uniform distributions instead of inverse-gamma;
  - Dixit-Stiglitz rather than Kimball aggregator.

The modified Smets-Wouters model

- **Large representative household with a continuum of members:**

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

where

$$\begin{aligned} U(C_t, \{N_t(i)\}, X_t) &\equiv \frac{1}{1-\sigma}\left((C_t - h\overline{C}_{t-1}) - \chi_t \, Z_t \int_0^1 \int_0^{N_t(i)} j^{\varphi} \, dj \, di \right)^{1-\sigma} \\ &= \frac{1}{1-\sigma}\left((C_t - h\overline{C}_{t-1}) - \chi_t \, Z_t \int_0^1 \frac{N_t(i)^{1+\varphi}}{1+\varphi} \, di \right)^{1-\sigma} \end{aligned}$$

and

$$Z_t = Z_{t-1}^{1-\upsilon} \, (\overline{C}_t - h\overline{C}_{t-1})^{\upsilon}$$

- **Extends Jaimovich-Rebelo (JR, 2009) preferences to allow for external habit formation and differentiated labour**

The modified Smets-Wouters model

- **The marginal rate of substitution between consumption and employment is:**

$$-\frac{U_{n(i),t}}{U_{c,t}} = \chi_t Z_t N_t(i)^{\varphi}$$

or in natural logs:

$$mrs_t(i) = z_t + \varphi\; n_t(i) + \xi_t$$

The modified Smets-Wouters model

- As in EHL, workers supplying a labor service of a given type get to reset their nominal wage with probability $1-\theta_w$ each period.
- The nominal wage in period t+k for workers who last re-optimised their wage in period t:

$$W_{t+k|t} = W_{t+k-1|t}\ \Pi^x (\Pi^p_{t-1})^{\gamma_w} (\Pi^p)^{1-\gamma_w}$$

- The first-order condition is:

$$\sum_{k=0}^{\infty} (\beta\theta_w)^k\ E_t \left\{ \frac{N_{t+k|t}}{C_{t+k}}\ \left(\frac{W^*_{t+k|t}}{P_{t+k}} - \mathcal{M}^n_{w,t}\ MRS_{t+k|t} \right) \right\} = 0$$

- The aggregate wage index can be written as:

$$W_t \equiv \left[\theta_w (W_{t-1} (\Pi^p_{t-1})^{\gamma_w})^{1-\epsilon_{w,t}} + (1-\theta_w)(W^*_t)^{1-\epsilon_{w,t}} \right]^{\frac{1}{1-\epsilon_{w,t}}}$$

The modified Smets-Wouters model

- **Log-linearisation leads to the following equation for nominal wage inflation:**

$$\pi_t^w = \gamma_w \pi_{t-1}^p + \beta E_t\{\pi_{t+1}^w - \gamma_w \pi_t^p\} - \lambda_w \left(\mu_{w,t} - \mu_{w,t}^n\right)$$

where $\lambda_w \equiv \frac{(1-\beta\theta_w)(1-\theta_w)}{\theta_w(1+\epsilon_w\varphi)}$, $\mu_{w,t}^n \equiv \log \mathcal{M}_{w,t}^n$

and $\mu_{w,t} \equiv (w_t - p_t) - mrs_t$

Introducing unemployment

- An individual will find it optimal to participate in the labour market in period t if:

$$\frac{W_t(i)}{P_t} \geq \chi_t Z_t \; j^{\varphi}$$

- The marginal supplier of type i labor is given by:

$$\frac{W_t(i)}{P_t} = \chi_t Z_t L_t(i)^{\varphi}$$

- Taking logs and integrating over i:

$$w_t - p_t = z_t + \varphi \; l_t + \xi_t$$

Introducing unemployment

- **Following Gali (2009), the unemployment rate is defined as:**

$$u_t \equiv l_t - n_t$$

- **Combining the definition of the average mark-up with the above and the labour supply equation:**

$$\mu_{w,t} = \varphi \; u_t$$

- **Putting this in the wage equation yields:**

$$\pi_t^w = \gamma_w \pi_{t-1}^p + \beta E_t\{\pi_{t+1}^w - \gamma_w \pi_t^p\} - \lambda_w \varphi \; u_t + \lambda_w \; \mu_{w,t}^n$$

Introducing unemployment

- **Wage equation:**

$$\pi_t^w = \gamma_w \pi_{t-1}^p + \beta E_t\{\pi_{t+1}^w - \gamma_w \pi_t^p\} - \lambda_w \varphi \; u_t + \lambda_w \; \mu_{w,t}^n$$

In contrast to SW, the error term only captures shocks to the wage mark-up, no preference shocks

- **Labor supply equation:**

$$w_t - p_t = z_t + \varphi \; l_t + \xi_t$$

$$u_t \equiv l_t - n_t$$

- **The Phillips curve will only include wage mark-up shocks, whereas the labour supply equation will only include preference shocks**

Modified Smets-Wouters model

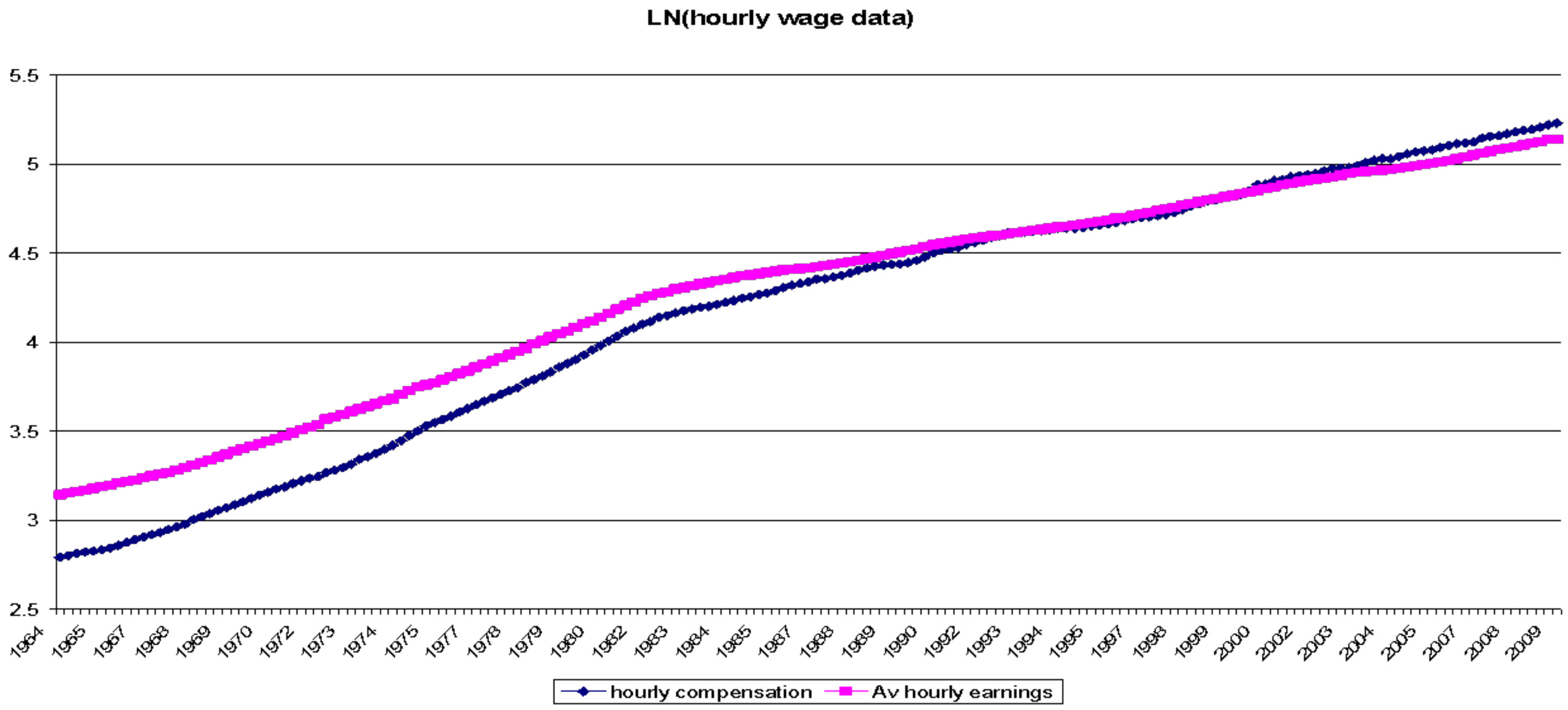
- **With the exception of the consumption Euler equation which reflects the change to JR preferences, all the other equations are as in SW (2007):**
  - **New Keynesian Phillips curve;**
  - **Capital accumulation equations;**
  - **Investment equation based on q-theory;**

Data

- US data (1965:1-2008:4);
- Use employment (extensive margin) rather than hours worked;
- Add unemployment.
- Use two wage concepts:
  - Compensation per employee, from the BLS Productivity and Costs Statistics
  - Average Weekly Earnings from the Current Employment Statistics
- Compare model without unemployment with the model with unemployment as observable.

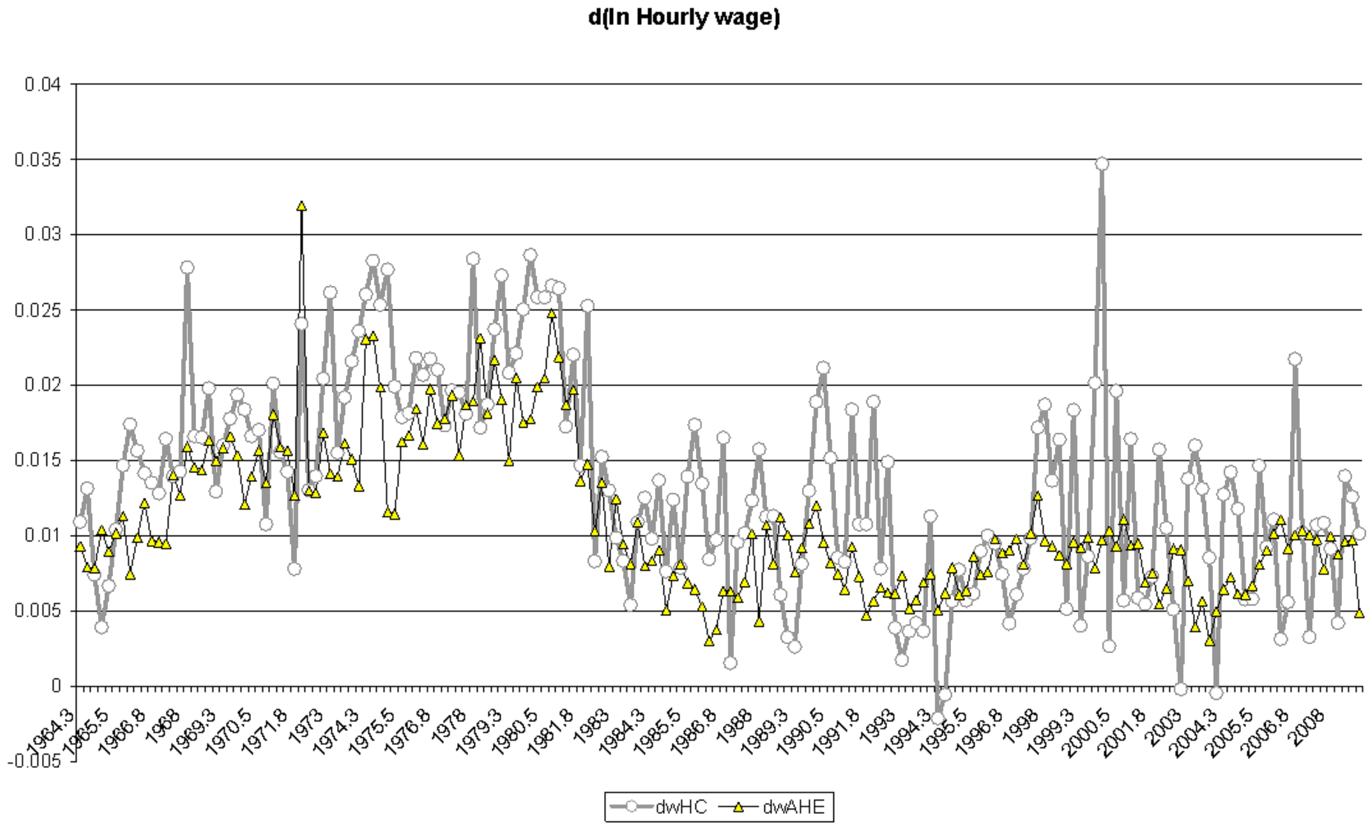
Data

- **Quite large discrepancies between the two wage data series:**



Data

- Quite large discrepancies between the two wage data series:



Data

- In the baseline model, we use both series and add measurement error to account for the differences;
- Results also available for each series used separately:
  - The higher volatility of the compensation series does affect estimates of the labour supply elasticity and some of the other parameters.

Estimation results

Most parameter estimates are very similar (see annex).

Focus on wage Phillips curve and labour supply equation:

Without UR:

$$w_t - p_t = z_t + 3.02 l_t$$

$$z_t = 0.19 z_t + 0.81\left(\overline{C}_t - 0.64\overline{C}_{t-1}\right)$$

$$\pi_t^w = 0.17\pi_{t-1}^p + 0.99 E_t\left\{\pi_{t+1}^w - 0.17\pi_t^p\right\} - 0.048 u_t + 0.016\mu_{w,t}^n$$

With UR:

$$w_t - p_t = z_t + 3.63 l_t + \xi_t$$

$$z_t = 0.91 z_t + 0.01\left(\overline{C}_t - 0.63\overline{C}_{t-1}\right)$$

$$\pi_t^w = 0.15\pi_{t-1}^p + 0.99 E_t\left\{\pi_{t+1}^w - 0.15\pi_t^p\right\} - 0.065 u_t + 0.018\mu_{w,t}^n$$

Estimation results

- The standard deviation of the wage mark-up shock drops from 17% to 8.2%:
- This implies that the standard deviation of the natural unemployment rate is of the order of 2.25%.
- The standard deviation of the change in the labour supply shock is 0.96.

Variance decomposition

	y	π	w	n	u	l	R
	10 Quarter horizon						
Prod	41/56	4/5	25/35	4/7	-/4	-/6	9/12
Cpref	7/6	3/2	2/2	12/14	-/19	-/0	17/16
Govt	6/2	1/1	0/0	13/5	-/7	-/0	4/6
Fin	18/15	9/9	9/13	22/21	-/20	-/3	37/38
Monp	7/5	9/8	4/5	11/12	-/14	-/1	16/12
Pmup	6/2	33/34	47/32	6/4	-/0	-/7	4/2
Wmup	14/4	41/41	13/13	33/12	-/32	-/3	13/11
Lpref	-/9	-/0	-/1	-/24	-/4	-/80	-/3
	40 Quarter horizon						
Prod	42/64	4/5	53/70	2/7	-/2	-/8	8/11
Cpref	2/2	2/1	1/1	4/6	-/10	-/0	14/14
Govt	3/1	½	1/1	7/2	-/3	-/0	4/7
Fin	8/8	8/8	8/9	9/10	-/10	-/2	33/36
Monp	3/2	8/7	3/2	4/5	-/7	-/0	13/10
Pmup	3/1	27/28	28/12	3/2	-/0	-/2	4/2
Wmup	40/9	50/48	7/5	72/25	-/65	-/2	24/19
Lpref	-/15	-/0	-/0	-/44	-/2	-/86	-/2

Variance decomposition

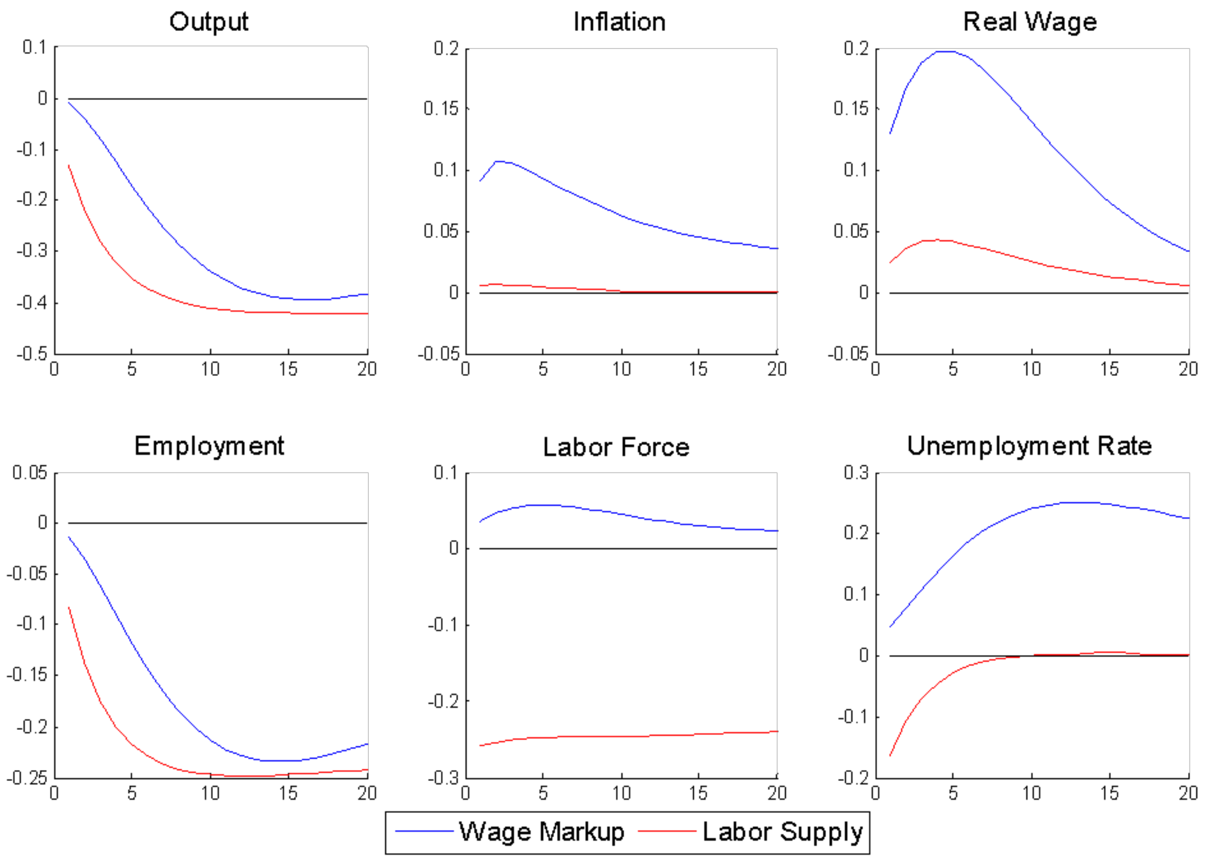
- The introduction of unemployment reduces substantially the role of wage mark-up shocks
- At business cycle frequencies, unemployment is largely driven by demand shocks and the wage mark-up shock
- Labour preference shocks have a significant role for employment and labour supply, but not for unemployment

Impulse responses

- **“Demand” shocks**

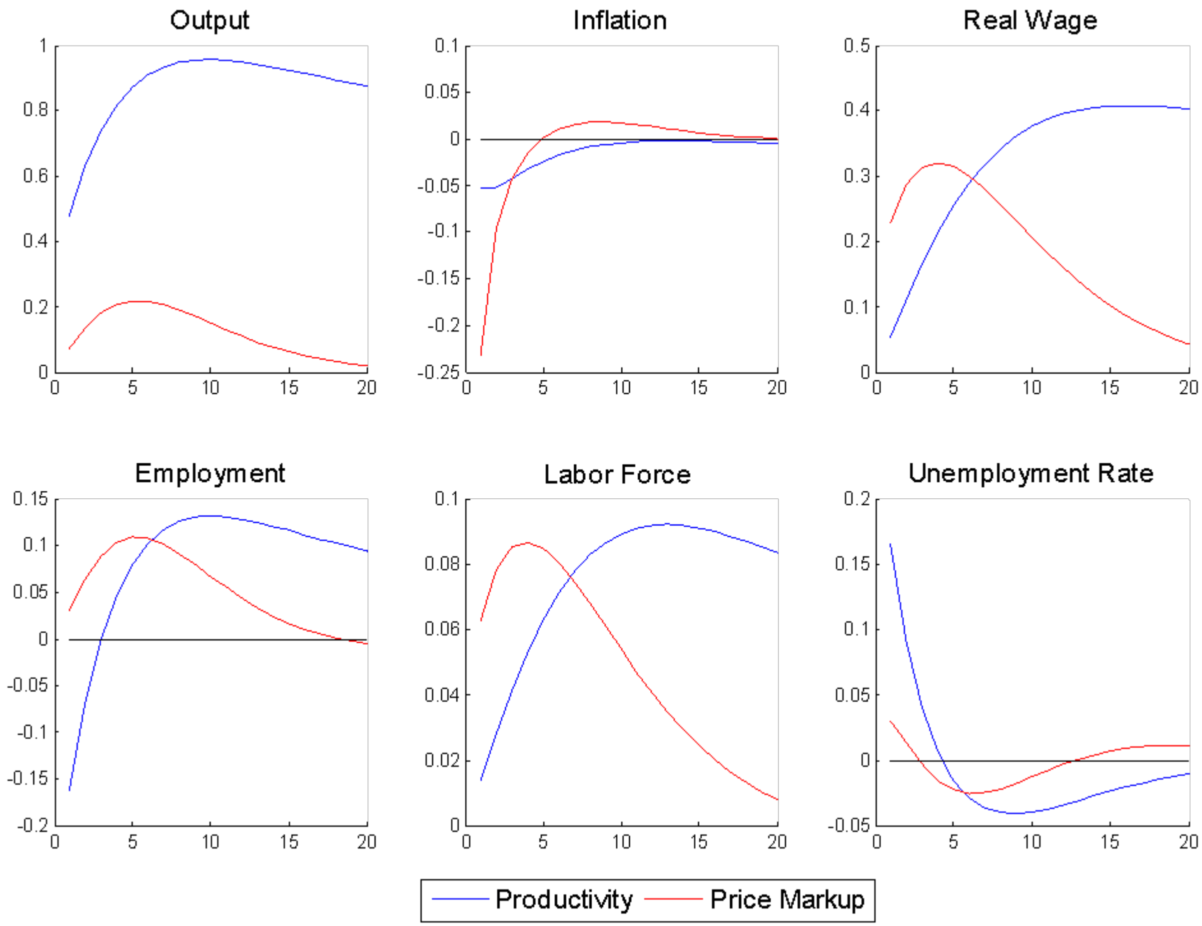
Impulse responses

- **Labour supply and mark-up shocks**

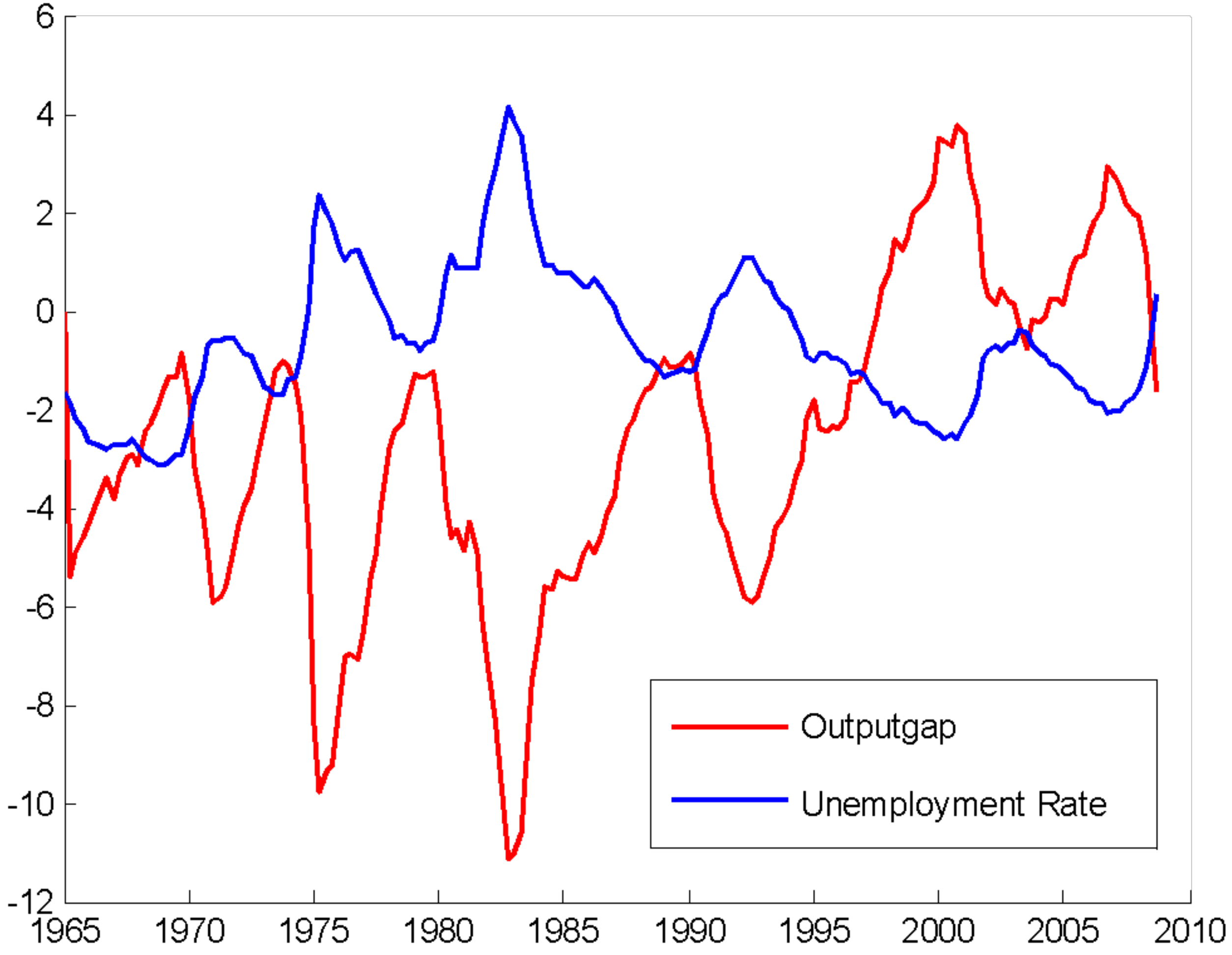


Impulse responses

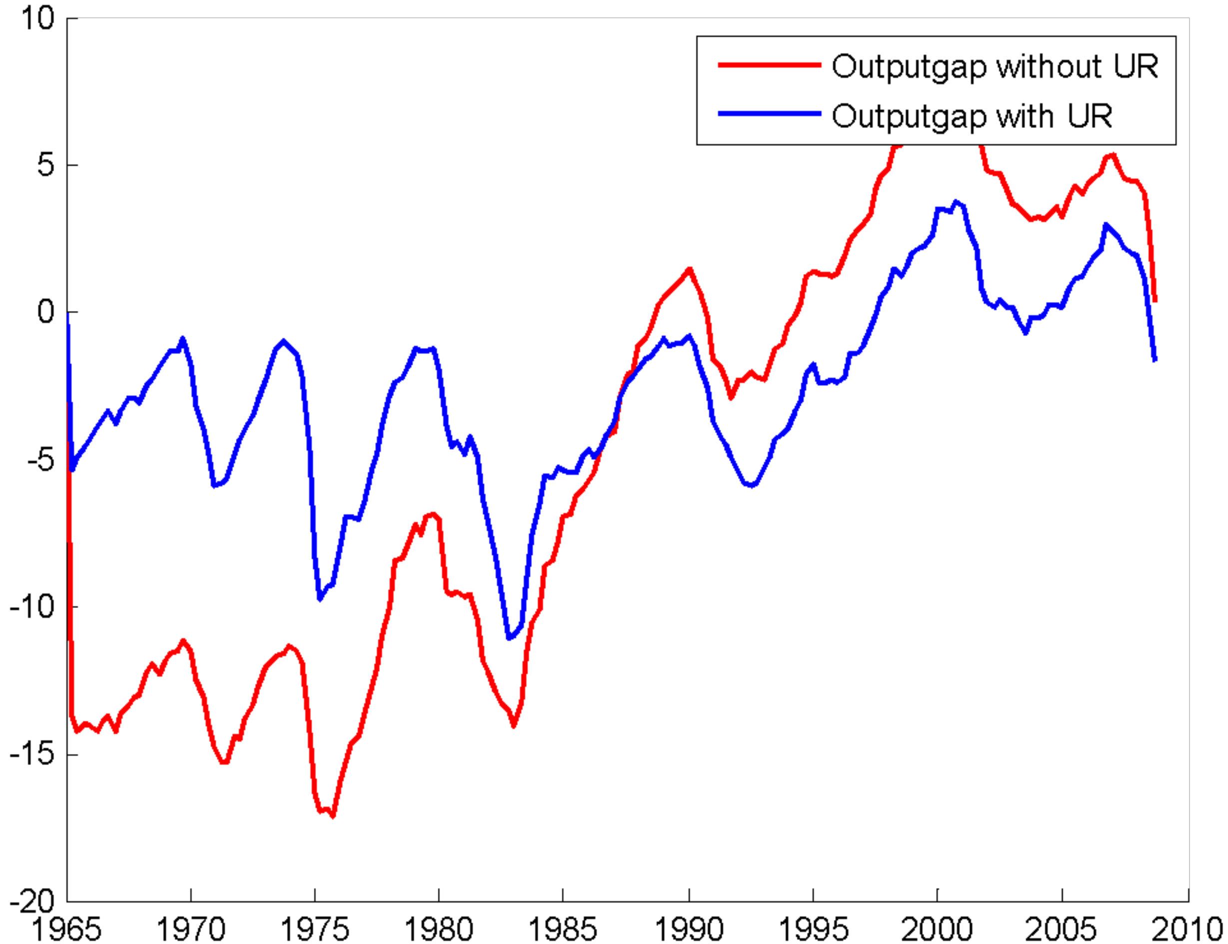
- **Productivity and price mark-up shocks**



Output gap and unemployment

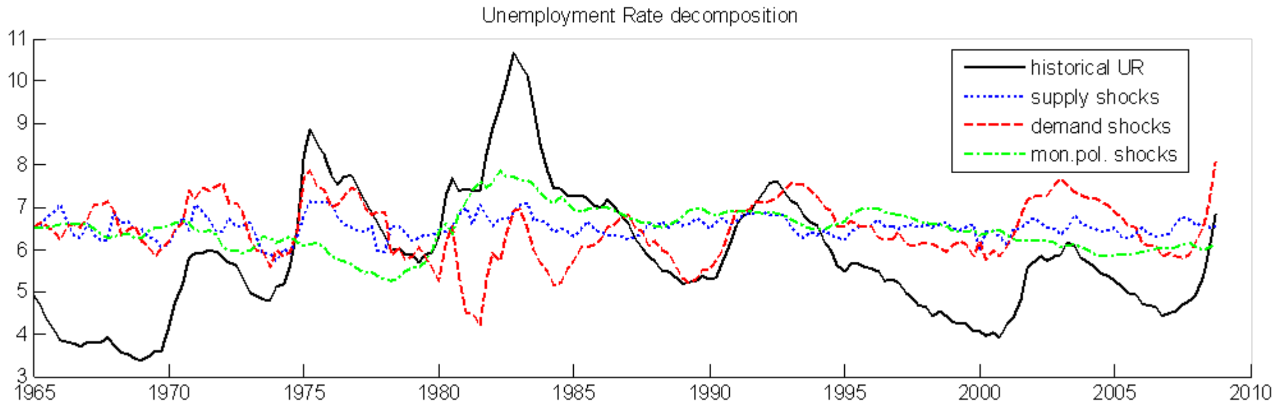


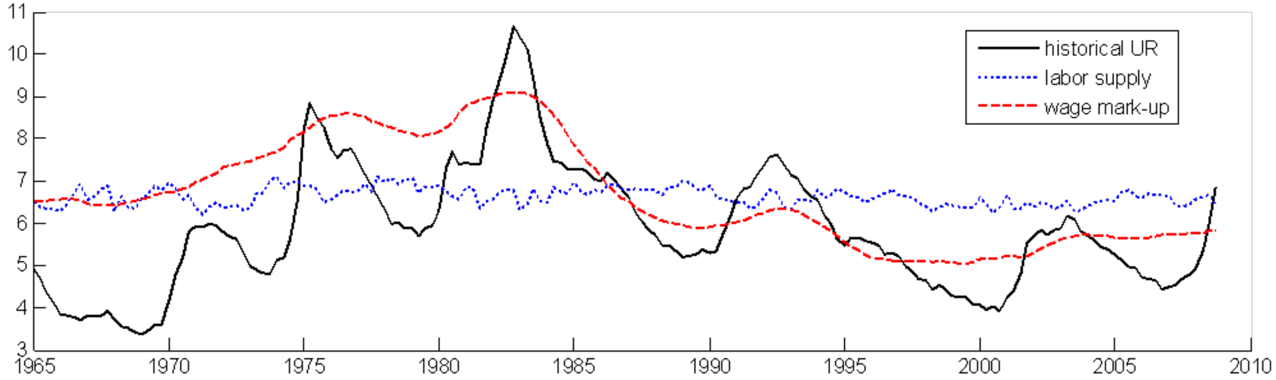
Output gap and unemployment



Historical decomposition

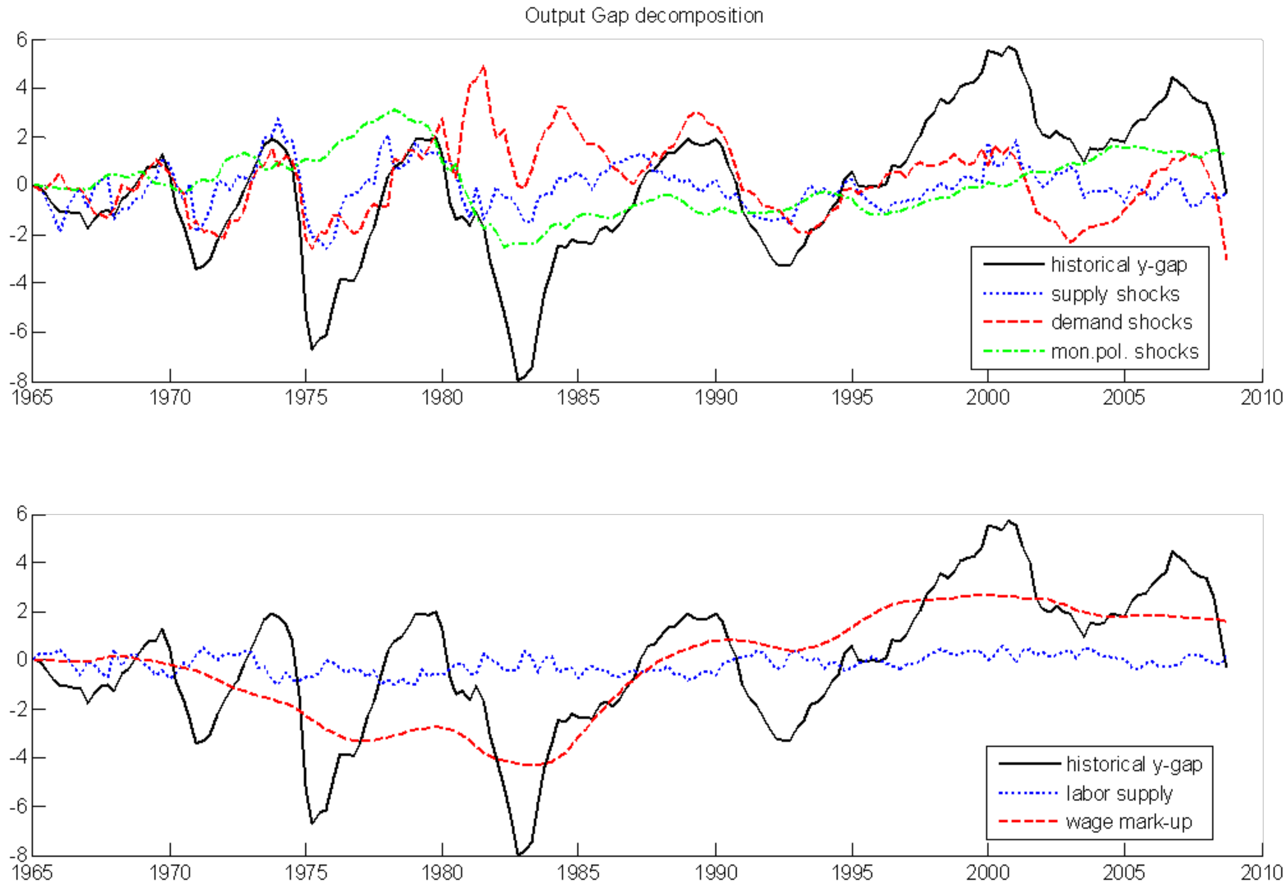
Unemployment rate





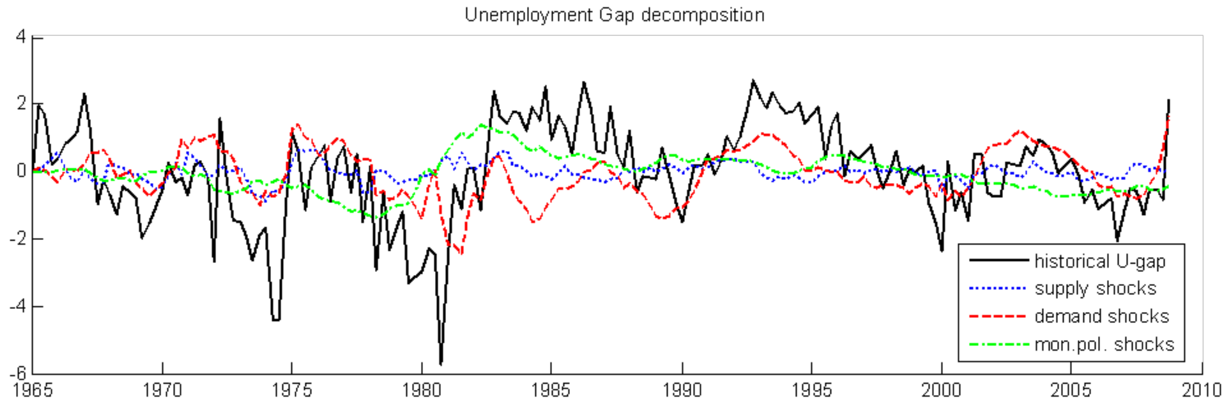
Historical decomposition

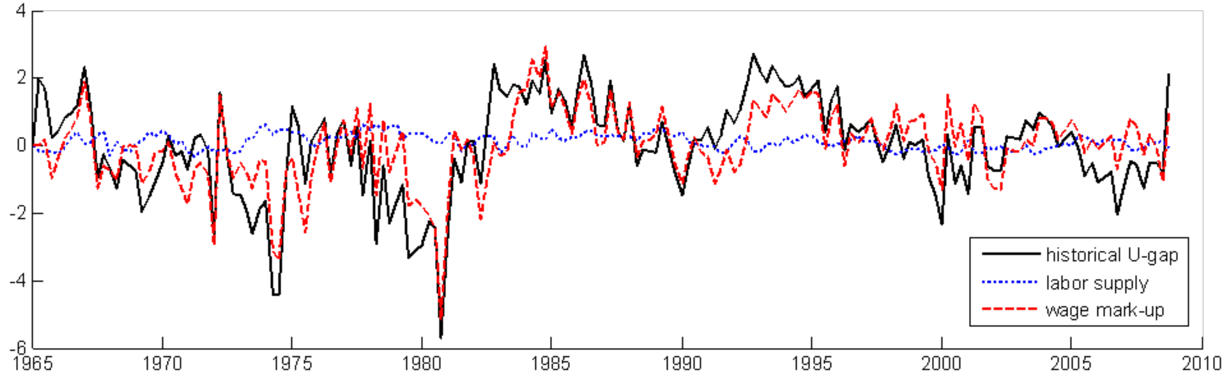
Output gap



Historical decomposition

Unemployment gap





Conclusions

- **Adding unemployment (labour supply) in the standard CEE/SW model helps identifying labour supply from labour mark-up shocks; mark-up shocks do not explain a lot of output and the variance of the mark-up shocks is reasonable.**
- **Unemployment helps estimating the wage Phillips curve and generally improves the marginal likelihood of the original system by about 20; unemployment has relevant information.**

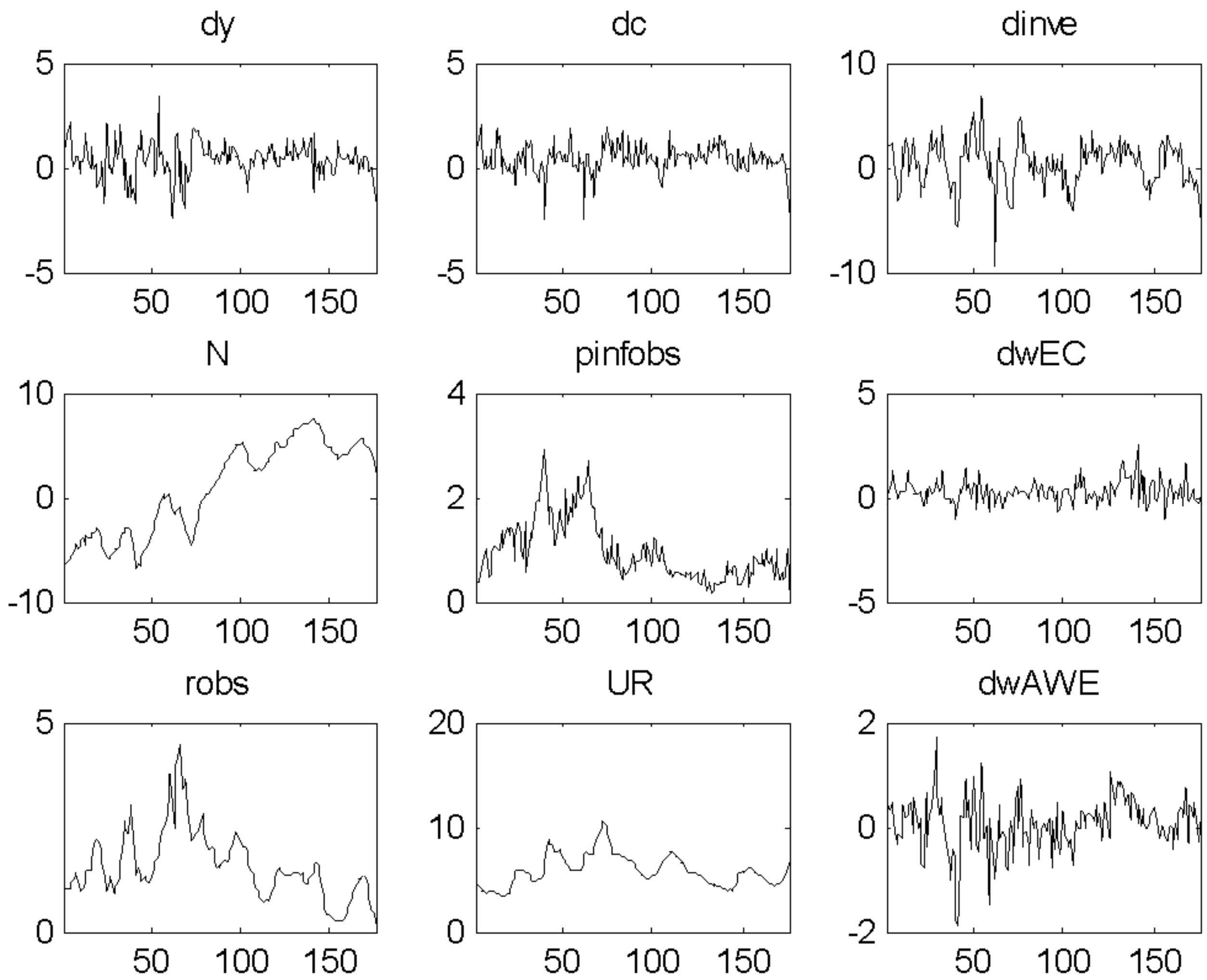
Conclusions

- **Labour supply comoves positively with employment; low wealth effects on labour supply**
- **Unemployment most driven by demand and labour mark-up shocks.**

Extensions

- Estimate a model for the euro area
- May improve the forecast for wages.

Appendix: Data series used



Appendix: Estimation results

					GJRWs based on dwEC		GJRWsc_UR based on dwEC		GJRWs based on dwAWE free cwtrend		GJRWsc_UR based on dwAWE free cwtrend		GJRWs_dwAWE dwEC + dwAWE free cwtrend measurement error		GJRWsc_UR_dwAWE dwEC + dwAWE free cwtrend measurement error	
Parameters		Prior Assumptions														
		prior	mean	stdev	mode	s.d.	mode	s.d.	mode	s.d.	mode	s.d.	mode	s.d.	mode	s.d.
AR and MA coefficients																
crhoa	prodty	beta	0.5	0.2	0.972	0.005	0.988	0.004	0.982	0.003	0.994	0.003	0.976	0.004	0.988	0.005
crhob	risk prem.	beta	0.5	0.2	0.288	0.101	0.570	0.122	0.245	0.102	0.385	0.116	0.261	0.110	0.362	0.149
crhog	gov spending	beta	0.5	0.2	0.977	0.010	0.990	0.005	0.973	0.009	0.986	0.006	0.974	0.009	0.986	0.007
crhoqs	inv.spec.tech	beta	0.5	0.2	0.760	0.051	0.946	0.033	0.755	0.048	0.828	0.064	0.767	0.049	0.817	0.070
crhoms	monetary pol	beta	0.5	0.2	0.129	0.060	0.069	0.045	0.128	0.064	0.112	0.059	0.127	0.061	0.081	0.050
crhopinf	p markup	beta	0.5	0.2	0.870	0.047	0.852	0.052	0.993	0.006	0.888	0.045	0.855	0.062	0.780	0.093
crhow	w markup	beta	0.5	0.2	0.983	0.005	0.848	0.095	0.989	0.004	0.958	0.034	0.989	0.004	0.974	0.024
cmap	p parkup	beta	0.5	0.2	0.731	0.083	0.706	0.091	0.813	0.065	0.687	0.092	0.674	0.101	0.608	0.137
cmaw	w markup	beta	0.5	0.2	0.897	0.062	0.792	0.119	0.752	0.083	0.787	0.085	0.634	0.191	0.698	0.190
crhols	labor supply	beta	0.5	0.2			0.999	-	0.999	-	0.999	-			0.999	-
crhotax	Ar(2) tax	beta	0.5	0.2												
Structural parameters																
csadjcost	inv adj cost	norm	4	1.5	4.779	1.005	2.141	0.802	4.465	0.967	4.039	1.188	4.293	0.986	4.109	1.326
csigma	IES	norm	1.5	0.38	1.666	0.182	1.832	0.267	1.949	0.191	1.659	0.215	1.748	0.177	1.556	0.227
chabb	habit	beta	0.7	0.1	0.644	0.050	0.467	0.104	0.641	0.048	0.628	0.073	0.640	0.053	0.633	0.083
cprobw	calvo w	beta	0.5	0.1	0.673	0.079	0.688	0.060	0.600	0.047	0.520	0.065	0.670	0.044	0.574	0.057
csigl	labor elast.	norm	2	0.75	2.973	0.608	5.029	0.448	2.962	0.541	4.455	0.449	3.020	0.565	3.632	0.448
cprobp	calvo p	beta	0.5	0.1	0.642	0.049	0.616	0.041	0.609	0.052	0.650	0.050	0.572	0.052	0.588	0.048
cindw	index w	beta	0.5	0.15	0.408	0.128	0.419	0.133	0.252	0.094	0.213	0.080	0.175	0.073	0.153	0.065
cindp	index p	beta	0.5	0.15	0.280	0.110	0.282	0.106	0.212	0.087	0.217	0.084	0.215	0.087	0.215	0.089
czcap	capacity utiliz	beta	0.5	0.15	0.479	0.109	0.670	0.114	0.388	0.091	0.547	0.115	0.483	0.108	0.632	0.116
cfc	fixed cost	norm	1.25	0.13	1.854	0.076	1.706	0.071	1.863	0.076	1.763	0.076	1.837	0.077	1.802	0.080
crpi	monpol inflation	norm	1.5	0.25	2.012	0.176	1.955	0.175	2.044	0.167	2.009	0.176	1.970	0.171	2.017	0.170
crr	monpol inertia	beta	0.75	0.1	0.826	0.022	0.859	0.018	0.826	0.022	0.862	0.018	0.821	0.022	0.863	0.018
cry	monpol y-gap	norm	0.125	0.05	0.060	0.014	0.152	0.034	0.078	0.016	0.120	0.032	0.070	0.014	0.133	0.031
crdy	monpol d(y-gap)	norm	0.125	0.05	0.240	0.027	0.269	0.032	0.218	0.025	0.215	0.027	0.238	0.027	0.228	0.029
constepinf		gamm	0.625	0.1	0.900	0.114	0.696	0.104	0.673	0.107	0.755	0.103	0.792	0.116	0.705	0.118
constebeta		gamm	0.25	0.1	0.147	0.057	0.151	0.062	0.133	0.054	0.139	0.057	0.125	0.050	0.192	0.076
constelab		norm	0	2	3.002	1.181	-3.981	1.030	3.677	1.136	-3.929	1.261	3.986	1.080	-2.242	1.457
ctrend		norm	0.4	0.1	0.350	0.016	0.283	0.017	0.391	0.021	0.364	0.036	0.376	0.018	0.318	0.030
cgy	(gov - prodty)	norm	0.5	0.25	0.709	0.086	0.695	0.080	0.693	0.087	0.695	0.082	0.709	0.086	0.699	0.084
calfa	prod function	norm	0.3	0.05	0.170	0.016	0.146	0.016	0.162	0.042	0.166	0.016	0.180	0.016	0.162	0.017
cwterm		norm	0.25	0.1					0.192	0.016	0.100	0.025	0.099	0.027	0.062	0.030
clandaw		norm	1.500	0.25			1.379	0.045			1.320	0.050			1.278	0.052
cchi	JR-stock	beta	0.5	0.2	0.852	0.117	0.009	0.004	0.747	0.152	0.015	0.007	0.807	0.148	0.008	0.005
cal	els/Δlabstar=>a	norm	0.5	0.25												
ctax		norm	0.000	1												
st errors shocks																
ea	prodty	unif	2.5	1.44	0.401	0.024	0.425	0.026	0.398	0.024	0.4159	0.0256	0.401	0.024	0.409	0.025
eb	risk prem.	unif	2.5	1.44	1.796	0.468	0.882	0.349	2.176	0.589	1.7465	0.5784	1.896	0.552	1.774	0.745
eg	gov spending	unif	2.5	1.44	0.475	0.026	0.468	0.026	0.476	0.026	0.4696	0.0258	0.474	0.026	0.471	0.026
eqs	inv.spec.tech	unif	2.5	1.44	0.413	0.040	0.583	0.172	0.427	0.039	0.4116	0.0406	0.422	0.039	0.423	0.041
em	monetary pol	unif	2.5	1.44	0.227	0.013	0.220	0.013	0.225	0.013	0.2169	0.0125	0.228	0.013	0.212	0.012
epinf	p markup	unif	2.5	1.44	0.094	0.034	0.068	0.020	0.059	0.022	0.0769	0.0295	0.055	0.019	0.060	0.021
ew	w markup	unif	2.5	1.44	0.280	0.198	0.619	0.304	0.104	0.039	0.1162	0.052	0.066	0.036	0.052	0.035
eAWE	Measurement	unif	2.5	1.44									0.319	0.028	0.336	0.027
eEC	Measurement	unif	2.5	1.44									0.445	0.029	0.449	0.029
els	labor supply	unif	2.5	1.44			1.397	0.132			1.2473	0.1293			0.964	0.125
etax	tax	unif	2.5	1.44												
log density (laplace approx)						-962.5		-978.8		-921.5		-941.8		-1043.0		-1045.0
mode log posterior						-879.9		-889.1		-832.2		-849.9		-952.4		-949.7

Appendix:

Parameters		Prior Assumptions			GJRWsc_UR_dwAWE		GJRWsc_UR_dwAWE with correlation (ea,els)		GJRWsc_UR_dwAWE with ea = cal*els		GJRWsc_UR_dwAWE with wc = w+tax	
		prior	mean	stdev	mode	s.d.	mode	s.d.	mode	s.d.		
AR and MA coefficients												
crhoa	prodty	beta	0.5	0.2	0.988	0.005	0.9855	0.0044	0.9856	0.0044	0.9864	0.0054
crhob	risk prem.	beta	0.5	0.2	0.362	0.149	0.3937	0.1419	0.4333	0.1683	0.6169	0.2174
crhog	gov spending	beta	0.5	0.2	0.986	0.007	0.983	0.0071	0.9831	0.0084	0.989	0.0065
crhoqs	inv.spec.tech	beta	0.5	0.2	0.817	0.070	0.8077	0.070	0.8297	0.068	0.8943	0.0838
crhoms	monetary pol	beta	0.5	0.2	0.081	0.050	0.0791	0.049	0.078	0.0489	0.0597	0.043
crhopinf	p markup	beta	0.5	0.2	0.780	0.093	0.7656	0.0975	0.7756	0.0923	0.7015	0.2605
crhow	w markup	beta	0.5	0.2	0.974	0.024	0.9783	0.0254	0.9691	0.0228	0.9569	0.0259
cmap	p parkup	beta	0.5	0.2	0.608	0.137	0.5921	0.1408	0.6064	0.1348	0.5728	0.2425
cmaw	w markup	beta	0.5	0.2	0.698	0.190	0.719	0.1747	0.6898	0.1931	0.7371	0.1316
crhols	labor supply	beta	0.5	0.2	0.999	-	0.999	-	0.999	-	0.999	-
crhotax	Ar(2) tax	beta	0.5	0.2							0.91	0.0451
Structural parameters												
csadjcost	inv adj cost	norm	4	1.5	4.109	1.326	3.9968	1.2018	3.7605	1.3262	2.469	1.7721
csigma	IES	norm	1.5	0.38	1.556	0.227	1.5183	0.207	1.4629	0.2045	1.581	0.2471
chabb	habit	beta	0.7	0.1	0.633	0.083	0.6153	0.0799	0.6043	0.0985	0.4758	0.1827
cprobw	calvo w	beta	0.5	0.1	0.574	0.057	0.5552	0.0599	0.5747	0.0563	0.5725	0.0592
csigl	labor elast.	norm	2	0.75	3.632	0.448	3.6449	0.4442	3.6224	0.4191	3.6029	0.4489
cprobp	calvo p	beta	0.5	0.1	0.588	0.048	0.5686	0.0486	0.5709	0.0493	0.554	0.0534
cindw	index w	beta	0.5	0.15	0.153	0.065	0.1651	0.0691	0.1562	0.0661	0.1604	0.0661
cindp	index p	beta	0.5	0.15	0.215	0.089	0.2174	0.0904	0.2235	0.0915	0.2577	0.1214
czcap	capacity utiliz	beta	0.5	0.15	0.632	0.116	0.5885	0.1152	0.6232	0.1179	0.583	0.1235
cfc	fixed cost	norm	1.25	0.13	1.802	0.080	1.9084	0.0842	1.8903	0.0802	1.8878	0.0923
crpi	monpol inflation	norm	1.5	0.25	2.017	0.170	2.0038	0.1674	1.9833	0.1697	2.0288	0.1778
crr	monpol inertia	beta	0.75	0.1	0.863	0.018	0.8614	0.0176	0.8617	0.0178	0.8666	0.0169
cry	monpol y-gap	norm	0.125	0.05	0.133	0.031	0.1384	0.0317	0.1363	0.0324	0.1561	0.0412
crdy	monpol d(y-gap)	norm	0.125	0.05	0.228	0.029	0.2156	0.026	0.2226	0.0271	0.238	0.0385
constepinf		gamm	0.625	0.1	0.705	0.118	0.7198	0.1063	0.6933	0.1017	0.6796	0.1009
constebeta		gamm	0.25	0.1	0.192	0.076	0.1556	0.0622	0.1428	0.0582	0.1462	0.0619
constelab		norm	0	2	-2.242	1.457	-1.6511	1.3285	-2.08	1.3513	-1.784	1.5471
ctrend		norm	0.4	0.1	0.318	0.030	0.347	0.0225	0.343	0.0234	0.3323	0.0244
cgy	(gov - prodty)	norm	0.5	0.25	0.699	0.084	0.7123	0.0871	0.9403	0.1033	0.9594	0.1071
calfa	prod function	norm	0.3	0.05	0.162	0.017	0.1663	0.017	0.1596	0.0165	0.1496	0.0175
cwterm		norm	0.25	0.1	0.062	0.030	0.0797	0.0284	0.0768	0.0288		
clandaw		norm	1.500	0.25	1.278	0.052	1.2575	0.0497	1.2717	0.0447	1.2521	0.0429
cchi	JR-stock	beta	0.5	0.2	0.008	0.005	0.0135	0.0071	0.0112	0.0052	0.012	0.0059
cal	els=>a	norm	0.5	0.25					0.2319	0.0344	0.2475	0.0399
ctax		norm	0.000	1							-1.3428	0.1866
st errors shocks												
ea	prodty	unif	2.5	1.44	0.409	0.025	0.3918	0.0235	0.3158	0.0206	0.3103	0.022
eb	risk prem.	unif	2.5	1.44	1.774	0.745	1.6192	0.6275	1.4392	0.6761	0.8162	0.6289
eg	gov spending	unif	2.5	1.44	0.471	0.026	0.4766	0.0261	0.454	0.0254	0.4526	0.0257
eqs	inv.spec.tech	unif	2.5	1.44	0.423	0.041	0.4237	0.0411	0.4212	0.0453	0.4762	0.1535
em	monetary pol	unif	2.5	1.44	0.212	0.012	0.2113	0.0121	0.2121	0.0122	0.2115	0.0129
epinf	p markup	unif	2.5	1.44	0.060	0.021	0.0592	0.0202	0.0597	0.0205	0.0583	0.0195
ew	w markup	unif	2.5	1.44	0.052	0.035	0.0537	0.0336	0.0529	0.0346	0.0735	0.041
eAWE	Measurement	unif	2.5	1.44	0.336	0.027	0.3347	0.0262	0.3382	0.0259	0.2739	0.0295
eEC	Measurement	unif	2.5	1.44	0.449	0.029	0.4467	0.0282	0.4451	0.0282	0.4317	0.029
els	labor supply	unif	2.5	1.44	0.964	0.125	0.9534	0.1241	0.9589	0.119	0.9277	0.1268
etax	tax	unif	2.5	1.44							0.1742	0.0357
(ea,els)	correlation	norm	0	0.25			0.5931	0.0529				
log density (laplace approx)						-1045.0		-1012.7		-1006.8		-1017.8
mode log posterior						-949.7		-914.84		-907.96		-915.69

Appendix

usmodel_jan2010_SW_N_dwEC_GJRWs_dwAWE

0q	dy	y	c	inve	w	winfEC	winfAWE	pinfobs	robs	N
ea	23.23	23.23	3.72	3.07	4.00	0.02	0.04	3.92	10.89	20.27
eb	31.88	31.88	81.80	8.16	3.60	2.63	3.99	1.08	28.01	33.16
eg	28.47	28.47	0.89	0.88	0.37	0.48	0.72	0.44	3.78	30.48
eqs	9.18	9.18	0.29	82.32	2.12	3.14	4.76	3.40	3.52	9.37
em	5.48	5.48	9.95	3.80	2.47	3.35	5.07	3.31	47.03	5.46
epinf	1.49	1.49	0.94	1.67	65.65	0.09	0.14	74.98	5.80	0.54
ew	0.27	0.27	2.41	0.10	21.78	20.36	30.80	12.87	0.98	0.72
eEC	0.00	0.00	0.00	0.00	0.00	69.92	0.00	0.00	0.00	0.00
eAWE	0.00	0.00	0.00	0.00	0.00	0.00	54.49	0.00	0.00	0.00

4q	dy	y	c	inve	w	winfEC	winfAWE	pinfobs	robs	N
ea	22.29	33.73	16.28	6.30	13.48	0.13	0.17	5.35	11.33	7.29
eb	29.45	14.31	37.52	1.81	3.16	3.24	4.22	2.19	23.04	21.14
eg	25.15	11.54	3.99	1.81	0.32	0.78	1.02	1.02	4.45	18.44
eqs	11.58	20.83	0.20	83.39	5.99	9.25	12.07	8.72	25.46	25.68
em	6.27	9.72	17.89	3.47	4.76	8.04	10.49	8.43	22.46	13.52
epinf	2.80	5.70	5.70	3.16	55.24	0.22	0.28	41.13	6.08	4.83
ew	2.47	4.15	18.42	0.06	17.04	30.18	39.37	33.16	7.17	9.10
eEC	0.00	0.00	0.00	0.00	0.00	48.17	0.00	0.00	0.00	0.00
eAWE	0.00	0.00	0.00	0.00	0.00	0.00	32.37	0.00	0.00	0.00

10q	dy	y	c	inve	w	winfEC	winfAWE	pinfobs	robs	N
ea	21.39	41.62	21.70	11.94	25.47	0.24	0.31	4.39	8.83	3.88
eb	28.87	6.50	14.16	0.94	1.87	3.01	3.83	2.03	16.77	11.59
eg	24.31	6.23	5.85	3.62	0.15	0.77	0.98	1.14	4.02	12.70
eqs	11.96	18.24	1.55	75.44	8.50	10.18	12.98	9.45	36.65	22.14
em	6.75	6.64	10.08	2.86	4.46	8.32	10.60	9.15	16.01	10.59
epinf	2.90	6.37	5.79	4.11	46.99	0.23	0.29	32.60	4.39	6.46
ew	3.82	14.40	40.87	1.09	12.55	32.84	41.86	41.23	13.32	32.63
eEC	0.00	0.00	0.00	0.00	0.00	44.41	0.00	0.00	0.00	0.00
eAWE	0.00	0.00	0.00	0.00	0.00	0.00	29.15	0.00	0.00	0.00

40q	dy	y	c	inve	w	winfEC	winfAWE	pinfobs	robs	N
ea	21.44	41.51	18.71	23.76	52.81	0.76	0.95	3.85	8.03	1.63
eb	28.30	2.39	3.27	0.60	0.94	2.77	3.45	1.67	13.77	4.20
eg	23.86	2.57	6.21	8.17	0.54	0.84	1.05	1.30	4.41	6.54
eqs	12.41	7.96	3.19	52.49	7.93	9.87	12.30	8.23	32.99	8.67
em	6.82	2.54	2.48	1.92	2.56	7.65	9.53	7.67	13.28	3.91
epinf	3.24	2.80	1.76	3.18	28.32	0.63	0.78	27.05	3.86	2.61
ew	3.93	40.22	64.38	9.88	6.90	36.83	45.88	50.23	23.65	72.44
eEC	0.00	0.00	0.00	0.00	0.00	40.65	0.00	0.00	0.00	0.00
eAWE	0.00	0.00	0.00	0.00	0.00	0.00	26.07	0.00	0.00	0.00

100q	dy	y	c	inve	w	winfEC	winfAWE	pinfobs	robs	N
ea	21.54	35.85	16.30	24.95	59.14	1.43	1.74	3.86	8.54	1.61
eb	28.22	1.70	1.92	0.53	0.79	2.53	3.09	1.43	11.55	2.92
eg	23.80	1.84	5.42	8.50	1.08	0.97	1.18	1.41	4.71	5.29
eqs	12.37	5.73	2.37	45.95	7.08	9.18	11.20	7.23	28.32	6.20
em	6.80	1.81	1.46	1.68	2.16	7.00	8.54	6.59	11.16	2.73
epinf	3.23	2.00	1.05	2.78	23.76	0.58	0.71	23.23	3.28	1.82
ew	4.03	51.08	71.47	15.60	5.99	41.12	50.17	56.24	32.45	79.43
eEC	0.00	0.00	0.00	0.00	0.00	37.18	0.00	0.00	0.00	0.00
eAWE	0.00	0.00	0.00	0.00	0.00	0.00	23.36	0.00	0.00	0.00

Appendix

usmodel_jan2010_SW_N_dwEC_GJRWsc_UR_dwAWE

0q	dy	y	c	inve	w	winfEC	winfAWE	pinfobs	robs	N	UR	labstar
ea	34.08	34.08	11.35	4.02	3.68	0.00	0.00	3.96	23.49	13.89	14.98	0.26
eb	32.74	32.74	68.22	11.33	2.69	1.82	2.69	0.86	19.63	43.05	36.90	0.13
eg	19.02	19.02	5.15	1.21	0.78	0.67	1.00	0.47	11.07	25.17	21.52	0.08
eqs	5.66	5.66	0.81	77.12	3.43	3.60	5.33	3.19	4.82	7.18	5.04	0.30
em	5.17	5.17	7.82	4.51	2.00	2.59	3.83	2.83	31.06	6.63	5.06	0.14
epinf	0.80	0.80	0.47	1.17	65.67	0.01	0.01	76.93	2.78	0.47	0.50	5.40
ew	0.01	0.01	0.24	0.06	21.04	17.55	25.98	11.71	0.69	0.10	1.17	1.76
els	2.52	2.52	5.93	0.58	0.71	0.31	0.46	0.04	6.47	3.51	14.83	91.94
eEC	0.00	0.00	0.00	0.00	0.00	73.45	0.00	0.00	0.00	0.00	0.00	0.00
eAWE	0.00	0.00	0.00	0.00	0.00	0.00	60.71	0.00	0.00	0.00	0.00	0.00

4q	dy	y	c	inve	w	winfEC	winfAWE	pinfobs	robs	N	UR	labstar
ea	32.81	47.72	30.08	7.01	16.43	0.18	0.23	5.82	15.83	4.00	5.61	2.41
eb	29.66	14.28	26.40	2.64	3.43	2.66	3.44	1.79	21.44	27.96	31.73	0.39
eg	17.73	4.71	12.89	1.96	0.67	0.97	1.26	1.11	7.53	9.72	10.88	0.20
eqs	8.09	14.47	0.32	81.53	9.82	9.94	12.87	8.39	26.47	22.00	19.37	1.79
em	5.72	8.38	10.97	4.10	4.72	6.94	8.98	7.69	16.61	15.69	15.53	0.67
epinf	1.44	2.68	2.18	1.89	47.08	0.46	0.60	42.77	3.13	3.54	0.28	8.17
ew	0.80	0.95	2.70	0.07	17.08	27.00	34.95	32.34	5.51	2.73	9.61	3.18
els	3.75	6.81	14.46	0.80	0.77	0.35	0.45	0.10	3.48	14.36	6.99	80.88
eEC	0.00	0.00	0.00	0.00	0.00	51.49	0.00	0.00	0.00	0.00	0.00	0.00
eAWE	0.00	0.00	0.00	0.00	0.00	0.00	37.22	0.00	0.00	0.00	0.00	0.00

10q	dy	y	c	inve	w	winfEC	winfAWE	pinfobs	robs	N	UR	labstar
ea	31.93	56.37	38.45	12.23	34.72	0.45	0.57	4.82	11.85	6.52	4.07	6.02
eb	29.66	5.83	9.80	1.24	2.05	2.47	3.13	1.59	16.19	14.37	19.33	0.26
eg	17.37	1.86	16.38	3.46	0.31	0.93	1.18	1.25	6.05	4.99	6.57	0.18
eqs	8.08	14.50	1.16	75.56	13.39	10.49	13.27	8.56	38.26	21.41	19.87	2.95
em	6.17	5.49	6.47	3.26	4.85	7.32	9.26	8.41	11.94	12.21	13.53	0.80
epinf	1.58	2.42	1.96	1.94	31.68	0.48	0.61	34.09	2.31	3.94	0.36	6.74
ew	1.50	4.13	7.56	1.05	12.51	30.10	38.07	41.18	10.90	12.13	32.08	3.16
els	3.72	9.40	18.22	1.27	0.51	0.33	0.41	0.09	2.50	24.43	4.19	79.90
eEC	0.00	0.00	0.00	0.00	0.00	47.42	0.00	0.00	0.00	0.00	0.00	0.00
eAWE	0.00	0.00	0.00	0.00	0.00	0.00	33.49	0.00	0.00	0.00	0.00	0.00

40q	dy	y	c	inve	w	winfEC	winfAWE	pinfobs	robs	N	UR	labstar
ea	31.76	63.51	39.93	27.00	70.30	0.98	1.22	4.58	10.87	6.83	2.24	7.74
eb	29.28	1.84	2.32	0.73	0.72	2.31	2.86	1.32	13.56	5.90	9.65	0.10
eg	17.16	0.74	17.12	8.44	0.67	1.13	1.40	1.79	6.60	2.13	3.28	0.25
eqs	8.42	7.68	4.94	51.37	9.22	10.94	13.55	8.32	36.02	9.50	10.24	1.53
em	6.32	1.85	1.68	2.03	2.07	6.82	8.45	7.11	10.11	5.12	6.84	0.30
epinf	1.74	0.85	0.55	1.25	11.96	0.72	0.89	28.31	2.03	1.71	0.25	2.35
ew	1.65	8.86	11.17	5.75	4.87	33.10	41.01	48.47	18.71	25.27	65.40	1.66
els	3.67	14.68	22.29	3.43	0.19	0.31	0.38	0.10	2.11	43.54	2.09	86.07
eEC	0.00	0.00	0.00	0.00	0.00	43.69	0.00	0.00	0.00	0.00	0.00	0.00
eAWE	0.00	0.00	0.00	0.00	0.00	0.00	30.23	0.00	0.00	0.00	0.00	0.00