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Labour market modelling in the light of the financial crisis

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Abstract

This paper revisits the empirical relationship between unemployment and output, and its evolution following the financial crisis of 2008, with the aim of drawing potential consequences for labour market modelling strategies in place within the European System of Central Banks (ESCB). First, the negative correlation between output and unemployment (Okun's law) at cyclical frequencies is found to be a robust feature of macro data across time, countries and identification schemes. Focusing on the euro area, the financial distress seems to have altered the dynamics of output and unemployment mainly at lower frequencies, interpreted as trend developments by the statistical filters used in the analysis. Looking at the implications for modelling strategies, we propose an extension of the standard labour search and matching model in which financial frictions impinge directly on the labour market rather than on the capital market, opening the way to protracted and lagged response of employment after a "financial" crisis. In terms of policy implications, the importance of the interplay between financial and labour market frictions in trend developments should be read as strong support for an ambitious structural reform agenda in Europe, so as to make our labour (and goods) markets more flexible and resilient.

JEL code: E1 E32 J64

Keywords: labour market, financial crisis, unemployment, output, macroeconomic models of the labour market

Executive summary

The dramatic deterioration in labour market conditions in several euro area countries following the financial crisis of 2008 and the slow recovery of employment relative to output seven years later call for a reassessment of the labour market modelling strategies in place within the European System of Central Banks (ESCB) and of the empirical relationships they reflect.

Should we view the protracted weakness in labour market developments as the outcome of an unusually large negative macroeconomic shock? Or has the interplay between financial and labour market frictions – the first at the heart of the crisis, the second the bane of many European countries – altered the cyclical response of employment and amplified the propagation mechanisms of standard-sized shocks?

To answer these questions, this paper takes an aggregate perspective and, in its first part, investigates the stability of the empirical relationship between output and unemployment (Okun's law). Results indicate that the negative correlation between these variables at cyclical frequencies appears to be a very robust feature of macro data across time, countries and identification schemes. This is not to say that the crisis had no bearing on these variables: trends of both output and employment dropped significantly after the crisis in many countries, but did so rapidly and in lockstep, leaving the cyclical components to co-move in a regular and predictable way.

Since lessons drawn from statistical filters are difficult to relate to structural models, the second part of the paper extends the previous analysis using the Quarterly Projection Model (QPM), a semi-structural model in which cyclical components of macroeconomic variables are identified by imposing standard cross-equation restrictions from theory. Focusing on the euro area and the US, the stability of Okun's law at cyclical frequencies survives this extension over the most recent period. If anything has changed after the financial crisis, it must be reflected in the low-frequency components of the data, which the statistical filters interpret as trend developments.

To better investigate this nexus, we augment the set of variables in the QPM with an indicator of financial distress (the Composite Index for Systemic Stress, or CISS) and allow it to enter the specification of either the trend or the cyclical components. Results indicate that for both output growth and unemployment, CISS explains a significant fraction of trend developments in the euro area, but less so in the US.

In the third part of the paper, we turn to possible consequences of this evidence for labour market modelling strategies built around the search and matching framework, which is gaining in popularity in structural macro-modelling within the ESCB.

The standard labour search and matching model is ill-equipped to reproduce the negative correlation between output and unemployment, since labour wedges – a type of "distance to market-clearing", to be explained below – are pro-cyclical in the

model and strongly counter-cyclical in the data. Moreover, workhorse models of financial frictions such as Gertler and Karadi (2010) tend to produce “job-full recoveries”, as employment typically rebounds faster than output after a slump ignited by financial factors. The paper therefore explores an extension of the Gertler-Karadi model where financial frictions impinge directly on the labour market rather than on the capital market. The extension provides a promising avenue for modelling the nexus between financial and labour market frictions, one that delivers a protracted and lagged response of employment after a “financial” crisis.

As the focus of the paper is on modelling issues, policy implications can only be derived indirectly. Nevertheless two important remarks are in order.

The first addresses how our results connect to standard macroeconomic stabilisation policy. The stability of Okun’s law at cyclical frequencies does not imply that policy should not be concerned with large output gaps and demand deficiencies. When these cyclical negative developments are protracted – as is typical after a financial crisis – calcification threatens: hysteresis turns cyclical joblessness into structural unemployment, affecting potential (i.e. trend) output growth.

The second remark relates more directly to non-standard policy measures and the ongoing debate about strategies for exiting the euro area’s current slow growth/high unemployment trap. The proposed model extension provides a potentially important role for financial frictions in explaining jobless recoveries. However, this should not be read as evidence that unemployment can be reduced more effectively by relieving financial stress than based on appropriately designed structural reforms. On the contrary, the QPM exercise shows that financial factors are considerably more important in explaining post-crisis trend developments in the euro area than in the US, where labour (and goods) markets are arguably more flexible and resilient. Thus, if anything, the data are telling us that a broad and effective structural reform agenda for Europe is more necessary now than ever.

1 Introduction

Labour market conditions in many developed economies deteriorated dramatically in the wake of the financial crisis of 2008 and, seven years on, the view is widespread that the recovery in employment lags the pick-up in output and has even to take hold in many euro area countries. The current paper, which was produced by a team of ECB and national central bank staff formed by the ESCB Working Group on Econometric Modelling (WGEM), addresses this perception and attempts to reassess modelling strategies across the European System of Central Banks (ESCB) and their underlying empirical relationships in light of these developments.

Recent labour market developments have duly been the subject of many other ESCB-related research efforts. To name the most significant, the ECB Report on “Euro Area Labour Markets and the Crisis” (see ECB (2012)), the follow up work contained in ECB (2015), the findings of the second and third waves of firm surveys launched by the Wage Dynamics Network[1], were all instrumental in shedding light on the fallout from the financial crisis on labour markets. These studies have informed policy-makers on cross-country wage developments, unemployment and labour force participation, vacancies and labour shortages across age, gender, sectors, regions, socio-professional levels and many other dimensions. However, this cross-sectional granularity comes at the cost of short sample sizes, as most of the data collected do not reach much further back than the turn of the century (“the large N, small T” problem). In contrast, this paper attempts to extract empirical regularities and lessons for time-series modelling of labour market developments by focusing on a smaller set of data extending further back in time (“small N, large T”). It focuses in particular on a well-known relationship, Okun’s Law, and views it through the lens of three types of models – reduced form, semi-structural and structural – which reflect the WGEM’s expertise and comparative advantage, and which form the basic structure of the paper.

The take-away from the paper is as follows. Firstly, we perform multiple reduced-form filtering exercises on post-war time-series of output and unemployment across many countries to investigate the robustness of the negative correlation between these two variables at cyclical frequencies. We find that this empirical regularity – Okun’s law – is robust across time, countries and identification methods, even in recent years. We infer that any change in the overall relationship between output and unemployment after the recent financial crisis must be reflected in the trend components.

Secondly, we use a semi-structural model developed by the IMF, the Quarterly Projection Model (QPM), to model simultaneously the cycle and trend components of variables. Our interest is two-fold. First, we wish to verify whether Okun’s law remains as robust when introducing other, standard macro-economic variables in the

1 The Wage Dynamics Network (WDN) is a research network consisting of ESCB economists. See https://www.ecb.europa.eu/pub/economic-research/research-networks/html/researcher_wdn.en.html

information set and more economic structure in the filtering method. Second, we explore to what extent variables that proxy for recent or previous episodes of financial stress impinge on the relationship between output and unemployment either in the trend or in the cyclical components. Results suggest that the stability of Okun's law survives a more complex model environment and point to a different role played by financial variables in making sense of recent history in the euro area and the US.

Lastly, the paper focuses on theory and investigates the consequences of these results for structural modelling. It first dissects the inner workings of standard search and matching models to emphasise a fundamental dissonance between their empirical predictions for output and unemployment and Okun's law as described in the previous sections. In short, search and matching models must be contorted to a credibility-straining extent to fit the correct correlations between output and unemployment. In a second instance, with a view to addressing the impact of financial stress on output and employment recounted in the second part, it attempts to fill a gap in the literature by describing a new model of financial frictions applied to the labour margin, and highlights the benefits of such an approach.

Each part of the paper is self-contained and includes a streamlined review of the literature. The paper concludes with some broader remarks on the way forward.

2 Cyclical co-movements of output and unemployment

2.1 Introduction

2.1.1 The origin of Okun's law

In 1962, Arthur Okun reported the empirical regularity of a negative short-run relationship between unemployment and output. The purpose of his article was purely normative and rooted in neo-Keynesian synthesis: when combined with a short-run Phillips curve, his "law" translated macroeconomic stabilisation policy into a mandate for full employment, that is the employment level attained without inflation pressures. Nevertheless, the regularity was soon reinterpreted as a stylised fact rarely to be questioned until recently. The onset of the Great Recession renewed interest in Okun's "law", as both of its arguments took the worst beating since Okun's original publication.

Okun (1962) proposed two ways of representing his law. One relates gaps of the two variables:

$$U_t - U^* = \beta(Y_t - Y_t^*) + \varepsilon_t \quad (1)$$

where U^* is a constant, equilibrium rate of unemployment (set to 4% in the original article), U_t the actual unemployment rate, Y_t actual output, Y_t^* potential output (obtained by fitting a deterministic trend to Y_t) and β the coefficient of interest. The obvious generalisation to equation (1) is to consider a time-varying equilibrium unemployment rate:

$$U_t - U_t^* = \beta(Y_t - Y_t^*) + \varepsilon_t \quad (2)$$

Okun's second representation considered instead output in percentage changes and unemployment changes in percentage points:

$$\Delta U_t = \alpha + \beta \Delta Y_t + \varepsilon_t \quad (3)$$

If the equilibrium unemployment rate and equilibrium output growth are both constant (reasonable assumptions for the sample used in the original article), the two formulations recover the same Okun coefficient β. Otherwise[2], they may come to very different conclusions about β and its stability in time. The problem arises because the equilibrium quantities in (2) are not directly observable and must be

[2] Many reasons may account for the instability of the *equilibrium rate* of unemployment and output growth. Classical economists and their intellectual heirs would link the equilibrium unemployment rate (natural rate) to time-varying tastes and labour market regulation and institutions. Keynesian economists and their descendants reject the concept of equilibrium / natural rate of unemployment and believe unemployment fluctuations fully reflect aggregate demand deficiencies (determined by self-fulfilling expectations in the modern variant). In both cases, U^* or Y* are expected to be time-varying.

estimated – either with statistical filters or with semi-structural models partly grounded in theory (see Lee (2000) for a comparison of different techniques). This extra step required for (2) likely tilts studies towards employing formulation (3).

Below, we review some of the recent papers that revisit the law in light of the Great Recession. A subset of this literature focuses more intently on whether recoveries are “jobless” in the sense that the pick-up in employment relative to output after the recession trough is slower in the latest episode than the historical average. Our reading of this literature yields an interesting message: studies that confirm the stability of Okun’s Law through the Great Recession are those based on formulation (2), i.e. with time-varying gaps in both unemployment and output. In contrast, studies based on growth rates tend to reject stability. This is in line with our own work presented in this paper.

2.1.2 Recent work

In one of the major articles on the topic since the onset of the crisis, Ball et al. (2013) use formulation (2), where the equilibrium quantities for the US are identified using various approaches (HP filters at different frequencies, the official CBO estimate of the gap). They find that Okun’s law fits US data well, is robust to rolling samples, and holds for both quarterly and annual data. They argue that “jobless recovery” is an inappropriate description of recent developments because output also recovered more slowly than in earlier episodes (Galí et al. (2012) make a similar point, as do Craigie et al. (2012) for New Zealand). Furthermore, based on a sample of advanced countries, they report that the Okun coefficient varies across countries, but is stable for a given country and not clearly related to employment protection legislation. Moreover, they find no evidence for asymmetric adjustment of unemployment in downturns and recoveries.

Brůha and Polanský (2015) confirm these results with a large dataset in time and cross-section. They find that for all 35 advanced economies in the sample, the cyclical components of output and unemployment are highly correlated, with a typical one-quarter lag for the latter.

By way of contrast, the following set of papers uses formulation (3) with growth rates or variants thereof. The IMF (2010) study finds evidence for a steepening of Okun’s coefficients in the past twenty years and interprets this as the consequence of increased labour market flexibility. It also reports an increase in the coefficient during the Great Recession. Cazes et al. (2011) perform rolling regressions on a sample of countries and confirm similar increases. Cheng et al. (2015) also provide evidence of steepening of the coefficient using non-parametric Bayesian techniques. Chinn et al. (2013) apply a sophisticated non-linear econometric model (a smooth transition error-correction model) to log-changes in US employment and GDP. Their results point to a jobless recovery, in contrast to the results of Ball et al. (2013), with cyclical factors unable to account for around a quarter of total job losses. Laeven and Valencia (2013) also point out that recoveries from financial recessions tend to be jobless.

With a more synthetic view, Owyang and Sekhposyan (2012) study the growth rate formulation (3) alongside the equation with the output gap[3] and the level of unemployment – as in (1) rather than (2) – and essentially look for structural breaks in US data. Their results suggest that patterns from the Great Recession do not depart significantly from previous downturns. Using the difference specification (3), they find an increase in the Okun's coefficient during recessions in general, but again the Great Recession is no statistical outlier. Similar findings hold for the gap specifications.

Okun's law can also be investigated using frequency-domain techniques, where coherences are the spectral analogue of correlations. Brůha and Polanský (2015) report high coherence between output and unemployment at business cycle frequencies and Andrle et al. (2013) confirm this finding for euro area data. Andrle et al. (2015) also report that at cyclical frequencies, one factor dominates the dynamics of a large set of macroeconomic variables – implying close co-movement of the cyclical components of unemployment and output – and that this feature is stable across time and space.

2.1.3 Consequences for structural modelling

We take away from this review that the co-movement between series is strong and stable at cyclical frequencies, but less so when expressed in growth rates[4]. This has several implications for structural macro-modelling of labour markets.

First, the strength of this relationship, which the Great Recession leaves relatively unaffected, is the litmus test for structural macroeconomic models that incorporate unemployment. In terms of moments, standard models struggle to replicate the very high correlation between the two variables. In terms of historical decomposition, the stability of Okun's law requires that the cyclical components of output and unemployment be explained by the same shocks (up to the sign, of course), as it strains to breaking point the underlying assumption that the otherwise multiple shocks are uncorrelated (more on this point below).

Second, the fact that studies based on growth rates tend to reject the stability of Okun's law implies that low frequencies (trend components) matter, in particular for the equilibrium level of unemployment. The evidence in Owyang and Sekhposyan (2012) suggests that trend changes can occur during and after recessions[5]. This requires a substantial overhaul of the existing modelling apparatus, as the labour blocks of standard DSGE models are not well suited to handling low-frequency movements.

3 They consider two measures of output gaps: the band-pass filter by Baxter and King (1999) and the CBO output gap.

4 This is also consistent with the views expressed by Meyer and Tasci (2012). Likewise Brůha and Polanský (2015) find on a large sample of advanced countries that the correlation between cyclical parts of output and unemployment is much stronger than the correlation between the two growth rates (see also the summary in **Figure 1** below).

5 Some recent structural papers address this issue, such as Jaimovich and Siu (2012), who model long-run structural changes in labour markets around recessions.

It is also a short step to acknowledging that low-frequency components in output and (un)employment themselves may be correlated, a point of discord with the classical view that a natural (equilibrium) rate of unemployment exists as the stationary point of unemployment, purely determined by tastes and supply-side policies (taxes, regulation). In a similar vein, in some of his recent work, Farmer (e.g. 2010 and 2013) presents clear evidence of low frequency co-movement between inflation and unemployment, and between the unemployment rate (level) and GDP measured in "wage units" in the US. These facts, he argues, militate against theories of an exogenous natural rate that cannot simultaneously explain business cycle and trend correlations. As an alternative, he proposes a modern interpretation of Keynes' animal spirits based on self-fulfilling expectations that better fits the data. Although Farmer's agenda dissents considerably from mainstream thinking, it is worth flagging as a viable alternative for future development of macroeconomic models.

2.2 Another look at Okun's law

In this part of the paper, we present our own analyses based on reduced-form approaches. These take three forms: univariate statistical filters, spectral methods and two simple bivariate models of Okun's law.

2.2.1 Statistical filters

First, we investigate the correlation between cyclical components of unemployment and output by filtering the variables separately with the band-pass Christiano-Fitzgerald filter. The data are taken from the OECD database and span close to fifty years[6]. For each country, we compute the sample correlation between output at time t and unemployment at t+1[7]. We also compute two measures of time-varying correlations: a rolling correlation coefficient with a ten-year window and a recursive orrelation with an exponential decaying factor equal to 0.95.

Table 1 reports the sample correlations for cycles and growth rates. The correlations on cycles are strong and significant for all countries: all exceed -0.5 in absolute value, except for New Zealand, where a switch in relative volatilities of the components around 1990 mechanically lowers the full-sample correlation (correlation in subsamples is correspondingly higher, again in absolute values). Italy exhibits a similar feature and records the second lowest correlation (-0.56).

6 The countries covered are Australia, Austria, Belgium, Canada, Finland, France, Greece, Italy, Japan, South Korea, the Netherlands, New Zealand, Norway, Sweden, Switzerland, the UK and the US, and the data span 1966Q1 to 2013Q4 (a few countries start only in 1970Q1). Germany is absent from this list because the structural break of reunification and the sophisticated statistical treatment it requires single Germany out too much for this simple exercise.

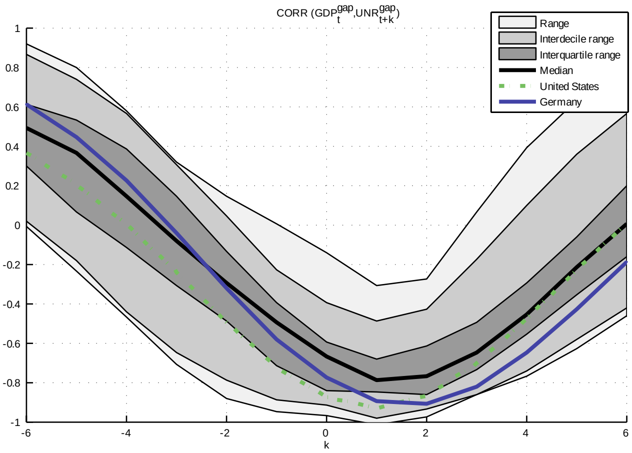
7 This choice is based on the analysis by Brůha and Polanský (2015), who find that for most countries the unemployment cycle lags the output cycle by one quarter.

Table 1

Correlation of cyclical components of $output_t$ and $unemployment_{t+1}$

	Correlation: cycles			Correlation: growth rates		
	Lower bound	Point estimate	Upper bound	Lower bound	Point estimate	Upper bound
Australia	-0.85	-0.80	-0.75	-0.43	-0.30	-0.17
Austria	-0.72	-0.64	-0.54	-0.39	-0.26	-0.12
Belgium	-0.73	-0.66	-0.57	-0.49	-0.37	-0.24
Canada	-0.89	-0.86	-0.82	-0.57	-0.47	-0.35
Finland	-0.80	-0.74	-0.67	-0.56	-0.45	-0.33
France	-0.77	-0.71	-0.63	-0.40	-0.28	-0.15
Greece	-0.49	-0.21	0.11	-0.47	-0.18	0.14
Italy	-0.65	-0.56	-0.45	-0.36	-0.23	-0.09
Japan	-0.80	-0.74	-0.66	-0.41	-0.29	-0.15
Korea	-0.81	-0.75	-0.68	-0.56	-0.45	-0.33
Netherlands	-0.74	-0.67	-0.58	-0.41	-0.29	-0.16
New Zealand	-0.46	-0.34	-0.20	-0.28	-0.14	0.00
Norway	-0.72	-0.64	-0.55	-0.33	-0.20	-0.06
Sweden	-0.86	-0.82	-0.77	-0.68	-0.60	-0.51
Switzerland	-0.70	-0.61	-0.51	-0.52	-0.40	-0.27
UK	-0.83	-0.77	-0.71	-0.53	-0.42	-0.30
US	-0.95	-0.94	-0.92	-0.64	-0.55	-0.44

Figure 1



To convey the cross-country uncertainty surrounding these estimates, **Figure 1** plots the range of point estimates of the autocorrelations between the series across countries, with the median and selected quantiles. The obvious feature is that these correlations are particularly robust.

Figure 2 displays the time-varying correlations. For each country, we show (i) the band-pass filtered time series of output and unemployment[8], (ii) the sample correlation, (iii) the recursive correlations, and (iv) the 5-year-centered rolling correlation along with 95% bootstrapped confidence intervals[9].

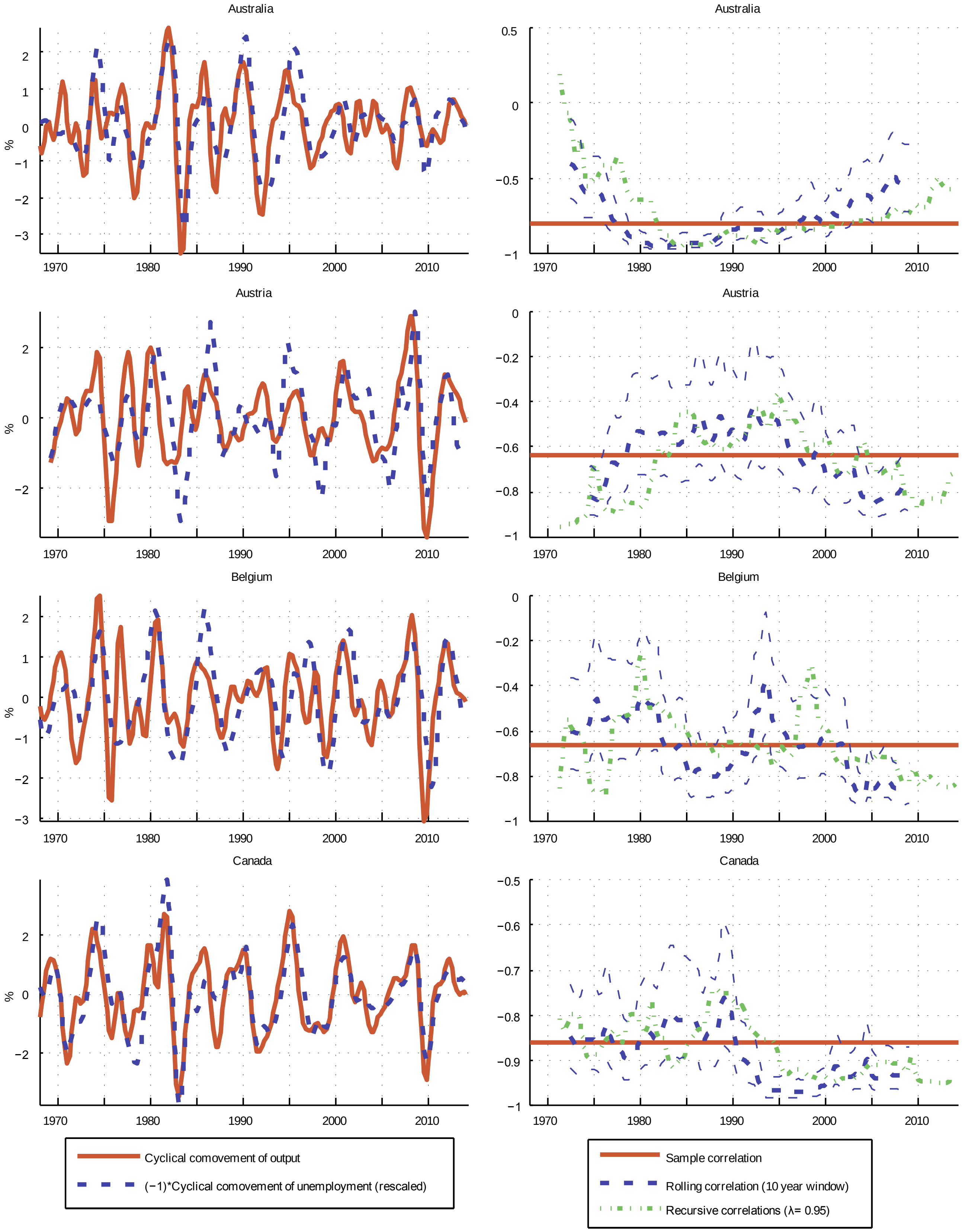
The figure makes clear that the computed statistics are well inside the confidence intervals; the exceptions occur in less than 5% of instances, which is the nominal coverage of the test. Therefore, this analysis suggests strongly that there is little evidence for time-

[8] For an easy interpretation, the unemployment cycle is multiplied by -1 and rescaled so that it has the same sample standard error as the output cycle.

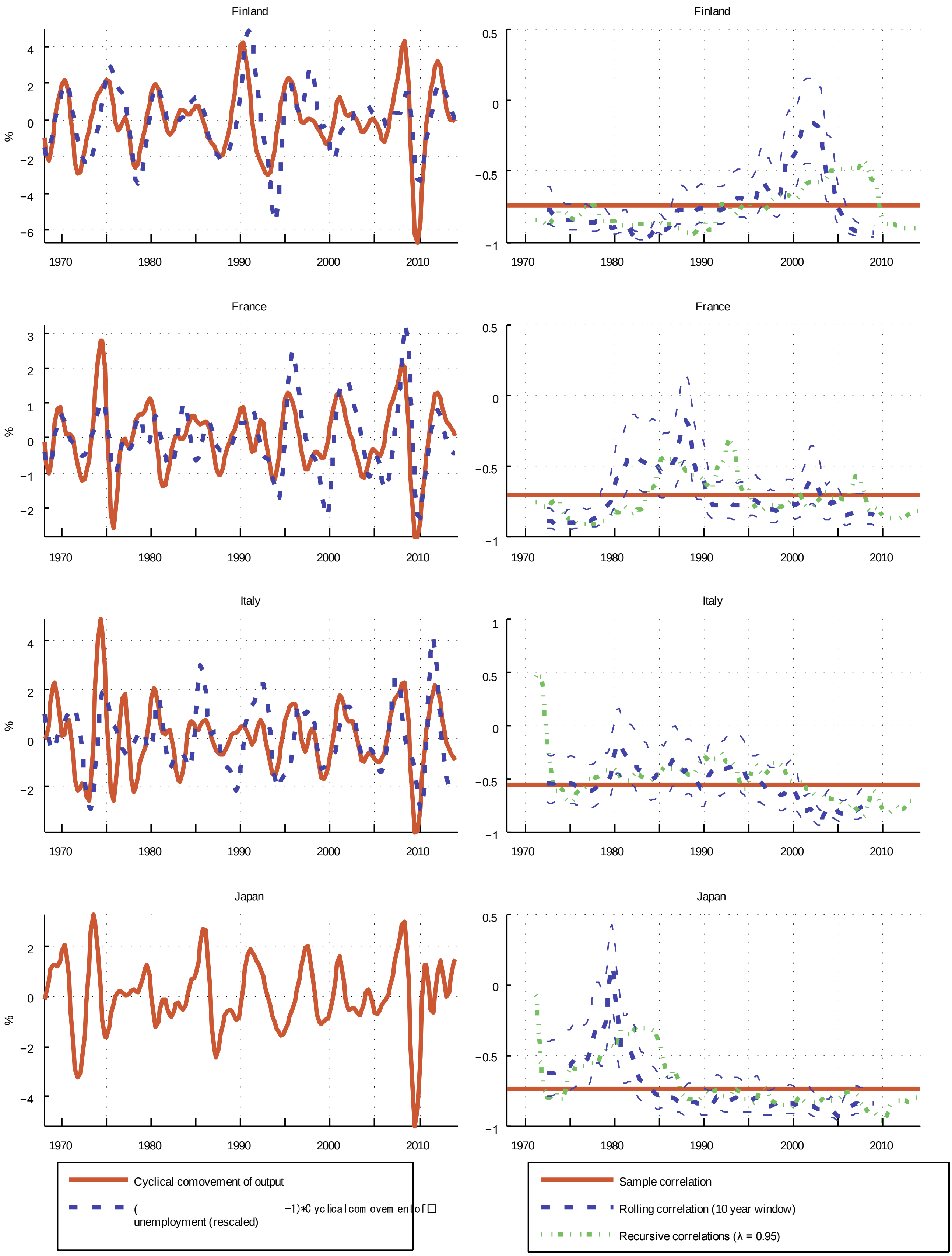
[9] To construct confidence intervals, we (i) estimate a time-invariant VAR model (using the Yule-Walker approach to exactly mimic the covariance structure of data), (ii) simulate 1000 time series and re-calculate the recursive and rolling correlations, (iii) extract the relevant percentiles for use as upper and lower bounds.

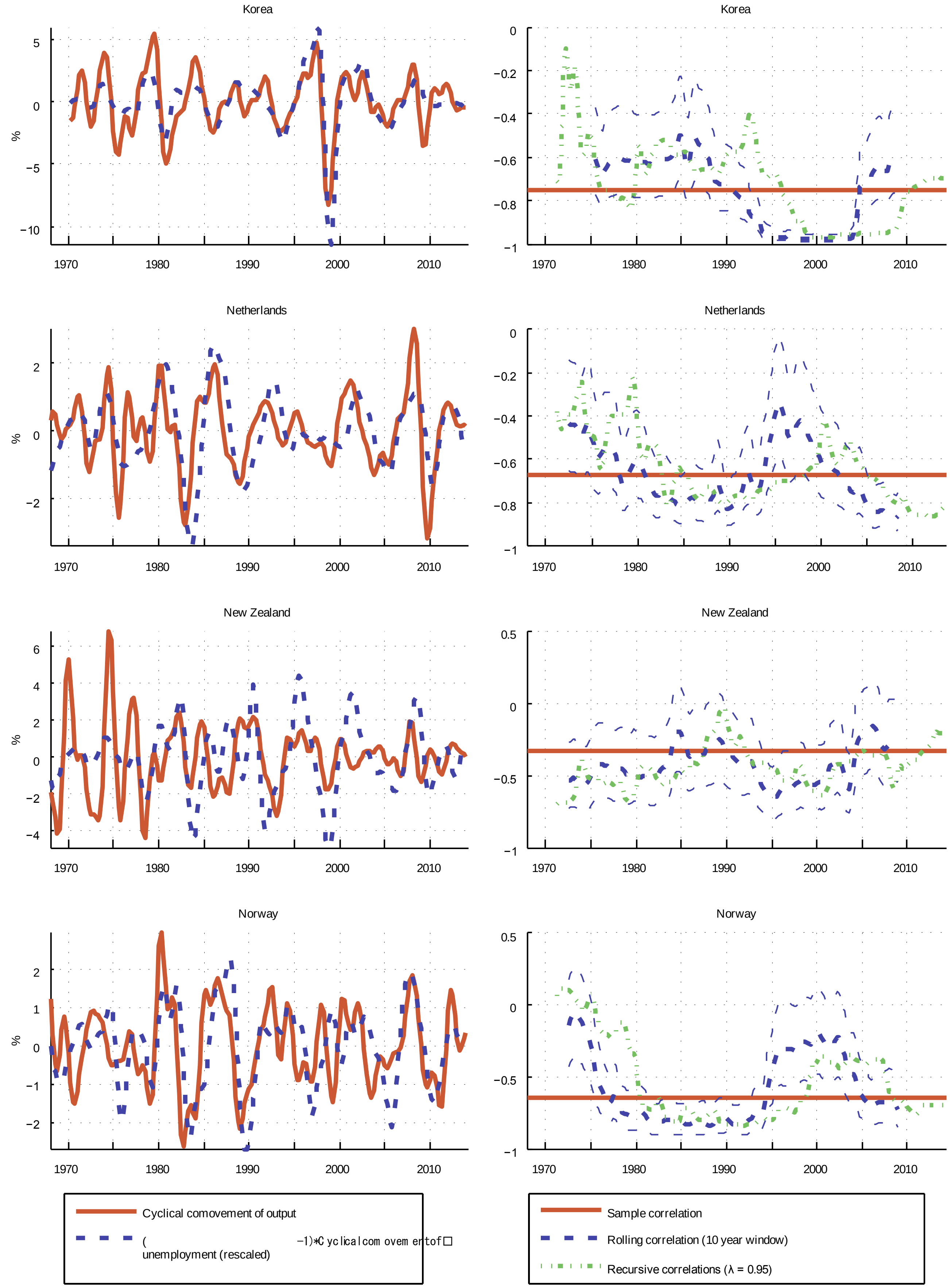
variation in correlations between cyclical unemployment and output or for structural changes post-2008, in close keeping with the conclusions from the literature review.

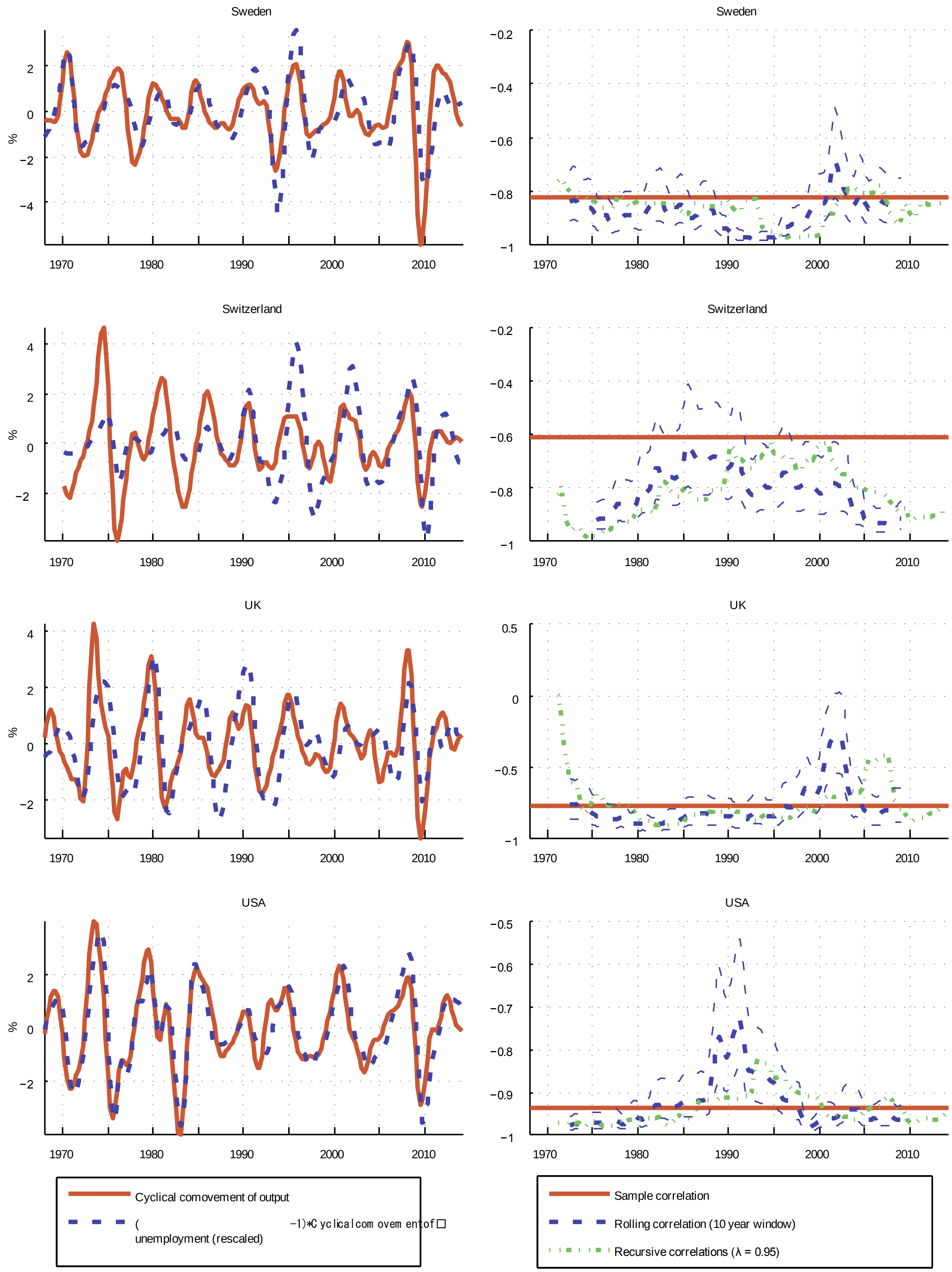
Figure 2



Australia
Austria
Belgium
Canada
%
1970
1980
1990
2000
2010
Cyclical comovement of output
(−1)*Cyclical comovement of unemployment (rescaled)
Sample correlation
Rolling correlation (10 year window)
Recursive correlations (λ= 0.95)


Finland
France
Italy
Japan
%
Cyclical comovement of output
(−1)*Cyclicalcomovementof
unemployment (rescaled)
Sample correlation
Rolling correlation (10 year window)
Recursive correlations (λ = 0.95)


Korea
Netherlands
New Zealand
Norway
%
1970
1980
1990
2000
2010
Cyclical comovement of output
(−1)*Cyclical comovement of unemployment (rescaled)
Sample correlation
Rolling correlation (10 year window)
Recursive correlations (λ = 0.95)


Sweden
Sweden
Switzerland
Switzerland
UK
UK
USA
USA
%
1970
1980
1990
2000
2010
Cyclical comovement of output
(−1)*Cyclical comovement of
unemployment (rescaled)
Sample correlation
Rolling correlation (10 year window)
Recursive correlations (λ = 0.95)

Furthermore, to be consistent with the discussion therein, we repeat the exercise with growth rates. The right part of **Table 1** shows the corresponding sample correlations, which are lower than in cyclical correlations. We also confirm from the recursive and rolling exercises that correlations between the two growth rates are less stable. Our own analysis therefore supports the conclusions from the literature, namely that Okun's law is strong when expressed in cyclical terms, but less so when applied to growth rates.

2.2.2 Spectral methods

An alternative to univariate statistical filters which isolate cycles at particular frequencies is to use spectral methods to decompose co-movements across the full range of frequencies. The corresponding tool is coherence, which is the frequency-domain analogue of correlation[10]. The crucial property of coherence for our purpose is its invariance to difference filters: in large samples, the coherences between two series in levels and in first differences are identical[11] (see Koopman, 1974, or Andrle et al., 2013). This enables us to eschew the complication of dealing with the non-stationarity of the series (definite for output, possible for unemployment) by computing coherence on their first differences directly.

[10] Coherence $c(\omega)$ is a quantity between 0 and 1 and it measures the co-movement at various leads and lags at frequency ω. The value of $c(\omega)=1$ means that there is a perfect linear relation between the two series at frequency ω. Loosely speaking, if cycles of a particular frequency are isolated, the coherence would be equal to the R-square in a bivariate regression of the two series. See Koopman (1974), or Hamilton (1994).

[11] This holds whenever the coherence of both series is defined. For $I(1)$ series this means everywhere except at the zero frequency.

Figure 3

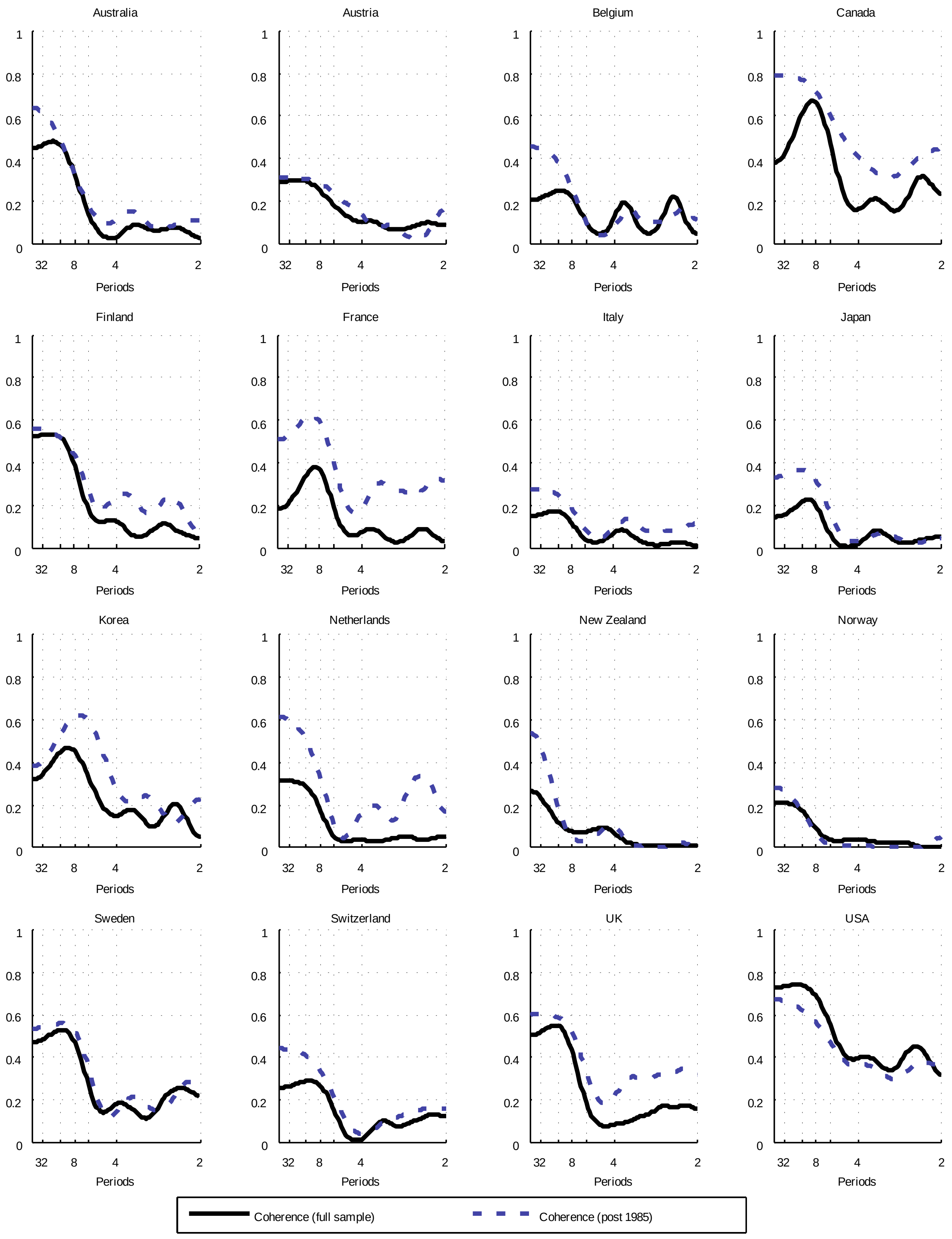

Australia
Austria
Belgium
Canada
Finland
France
Italy
Japan
Korea
Netherlands
New Zealand
Norway
Sweden
Switzerland
UK
USA
1
0.8
0.6
0.4
0.2
0
32
8
4
2
Periods
Coherence (full sample)
Coherence (post 1985)

Figure 4

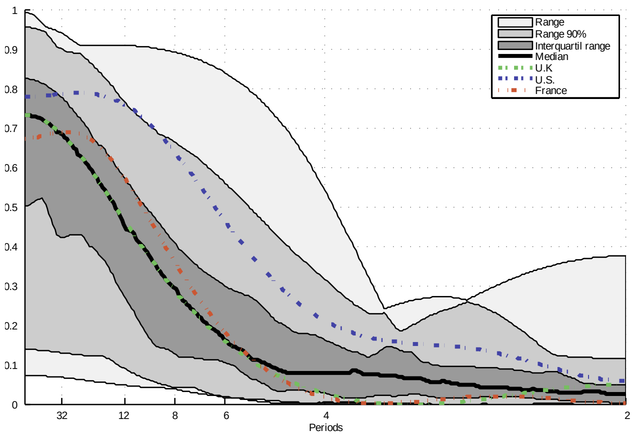
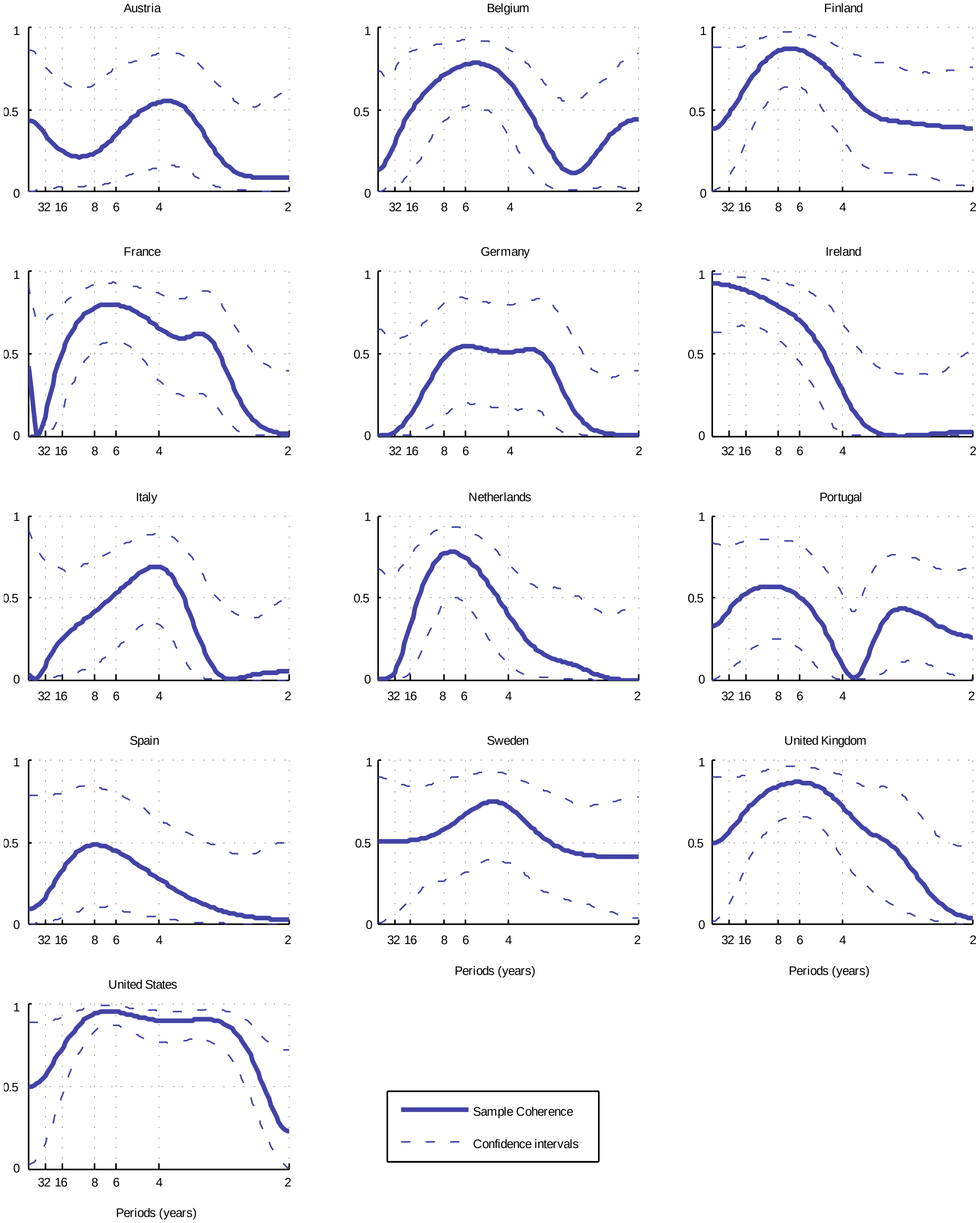


Figure 3 displays the results, produced with the OECD dataset (quarterly data) that was used in the previous subsection. The figure shows the coherence estimated for the full sample and for the subsample since 1985, when the volatility of the two series appears to change in a majority of countries (thus reducing the full sample coherence). Nevertheless, for many countries, this measure of co-movement is high at business-cycle frequencies (8 to 32 quarters). This is clearly conveyed in **Figure 4**, which plots the range of point estimates of the coherences across countries, with the median and selected quantiles.

Lastly, we use a longer dataset on unemployment and output – merged from OECD and Eurostat annual figures and reaching back to the early 1950s for some countries – to inquire about coherence at lower frequencies, with an eye to Farmer's arguments described in the literature review. **Figure 5** reports individual country results from Eurostat annual data[12]. These are mixed: some countries, such as the US and the UK, display high coherence at very low frequencies, but others such as Belgium or Japan show otherwise. Moreover, the confidence intervals (computed using the Wild bootstrap) are very wide at those frequencies. **Figure 6**, however, shows the heterogeneity of point estimates, and the cross-country uncertainty at low frequencies appears less pronounced than at the individual level. Hence, the evidence is tantalising, but admittedly not conclusive enough to establish low-frequency co-movements between unemployment and output as a stylised fact for advanced countries.

[12] The figure looks very similar with the OECD data.

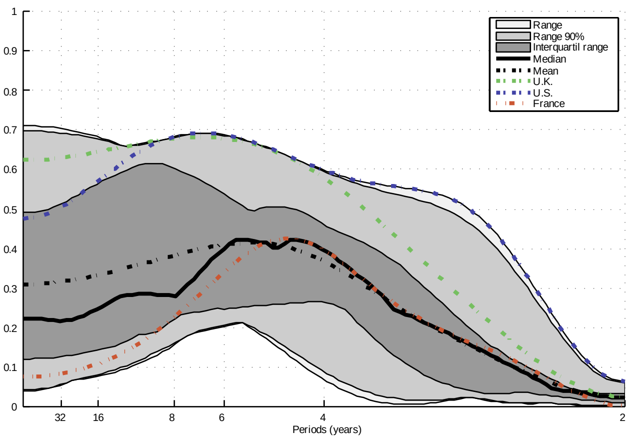
Figure 5


Austria
Belgium
Finland
France
Germany
Ireland
Italy
Netherlands
Portugal
Spain
Sweden
United Kingdom
United States
1
0.5
0
32 16 8 6 4 2
Periods (years)
Sample Coherence
Confidence intervals

2.2.3 Semi-structural bivariate filters

We now turn to a different approach to identifying the trends and cycles behind Okun’s law. Instead of filtering the variables separately, we estimate cycles and trends jointly from a bivariate model of output and unemployment, where some minimal structure is imposed to discipline the correlations. We provide two such filtering exercises.

Figure 6



The first is an unobserved-components (UC) model where output and unemployment are characterised by independent stochastic trends and dependence of the unemployment cycle on lags of the output cycle. This dependence is imperfect in the sense that the model allows for an idiosyncratic component to the unemployment cycle (the equation for the unemployment cycle includes an error term). Thus, in theory, the model carries the possibility of completely orthogonal processes for output and unemployment. The assumption of independent random walks rules out by design the results from the previous section on high pairwise coherence at low frequencies.

The second model is a celebrated one, the Blanchard-Quah (BQ) decomposition (Blanchard and Quah, 1989), which launched the literature on structural vector autoregressions (SVAR). The original application of this technique was specifically on Okun’s law. The authors showed that Okun’s one-equation relationship was a mongrel one (their term) in that it conflated in the single regression error term (and thus in Okun’s slope) the effects of two structural shocks with radically different consequences for the observables. In effect, they warned of the perils of reducing the dimension of a system (from bivariate to univariate) without careful analysis of the information loss. The trend-cycle identification in this exercise is grounded in basic theory, namely that one of the structural disturbances – the “demand” shock – should have no long-run effect on the level of output. Okun’s law is then captured by correlating the components of output and unemployment exclusively due to this shock. In contrast to the UC exercise, the BQ identification scheme does allow trend and cycle of the same variable to be correlated, since they can both be affected by the same structural disturbance.

The econometric details of these two models are described in the annexes. Suffice it to say that they represent very different identification schemes for trends and cycles from the purely statistical ones analysed in the previous two sections. The models are estimated for 16 countries over samples of different lengths (due to data availability), but always long enough so as to identify at least three cycles (which usually requires more than 15 years of quarterly data – more on this below). For each country, we perform recursive estimations (from 2008 onwards) of the cyclical components extracted from these two models. The following set of figures describes the results.

Figure 7

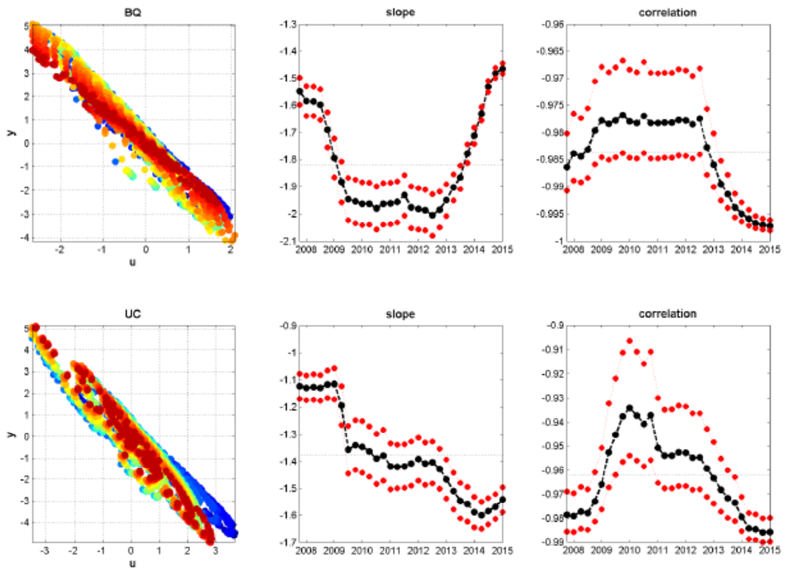


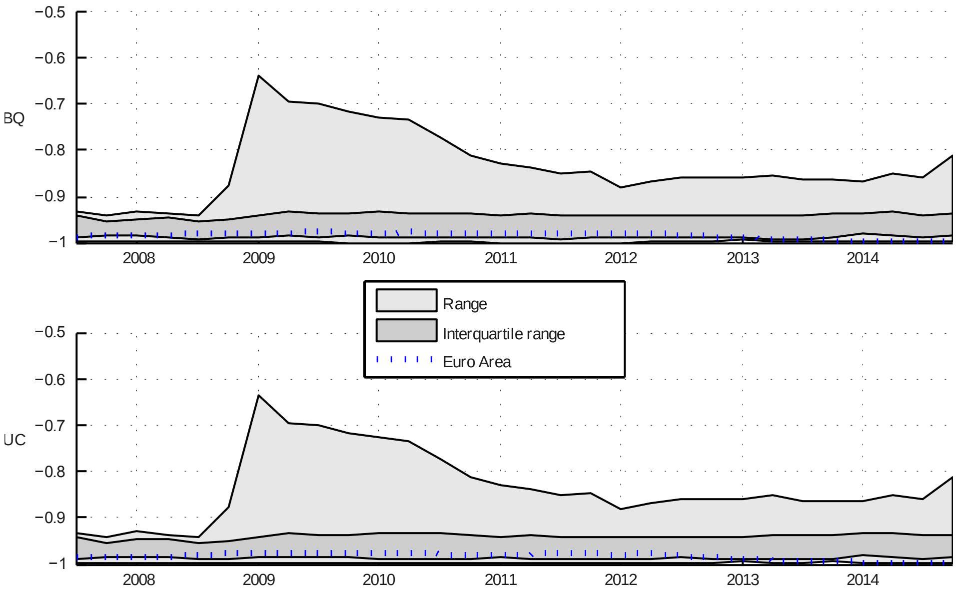
Figure 7 shows the output for the euro area as a typical example. The top row reports results for the BQ exercise, the bottom for the UC exercise. The left-hand charts depict the scatterplots between the cyclical components of output and unemployment for the different recursive runs, colour-coded accordingly. The corresponding slopes are Okun's coefficients, which are plotted time-wise in the second column with standard-error bands[13]. The third column reports the correlation coefficients. It is clear that Okun's law is robust, as evidenced by the absolute value of the correlation coefficients throughout the runs, and visually by the tightness of the scatterplot across the recursions. The confidence intervals are also very tight and suggest some structural break in correlation, but a look at the scale confirms that this is a clear case of statistics overreaching beyond economic relevance. Interestingly, for the unobserved component model the scatterplot shows a steepening across runs, reflected in the downward trend in the slope. To better understand this result, let's recall the relationship between slope β and correlation coefficient ρ: $\beta = \rho \frac{\sigma_y}{\sigma_u}$.

Given that the correlation coefficient (plotted in the third graph) does not show any visible trend, the steepening in the slope must be due to an increase in the variance of cyclical output relative to that of unemployment. That is, as the sample lengthens with new data, the model is re-allocating the fluctuations in unemployment more to the trend and less to the cycle than is the case for output. Note that the model could choose to accommodate new data into the cyclical error term rather than the stochastic trend term, a pattern that would be reflected in a looser scatterplot over the runs. That it does not do so is the sense in which we characterise Okun's law as

13 Unfortunately, the exercises were run switching output and unemployment in formulation (1), such that the slopes reported here are related to the inverse of β from section 1.1.1.

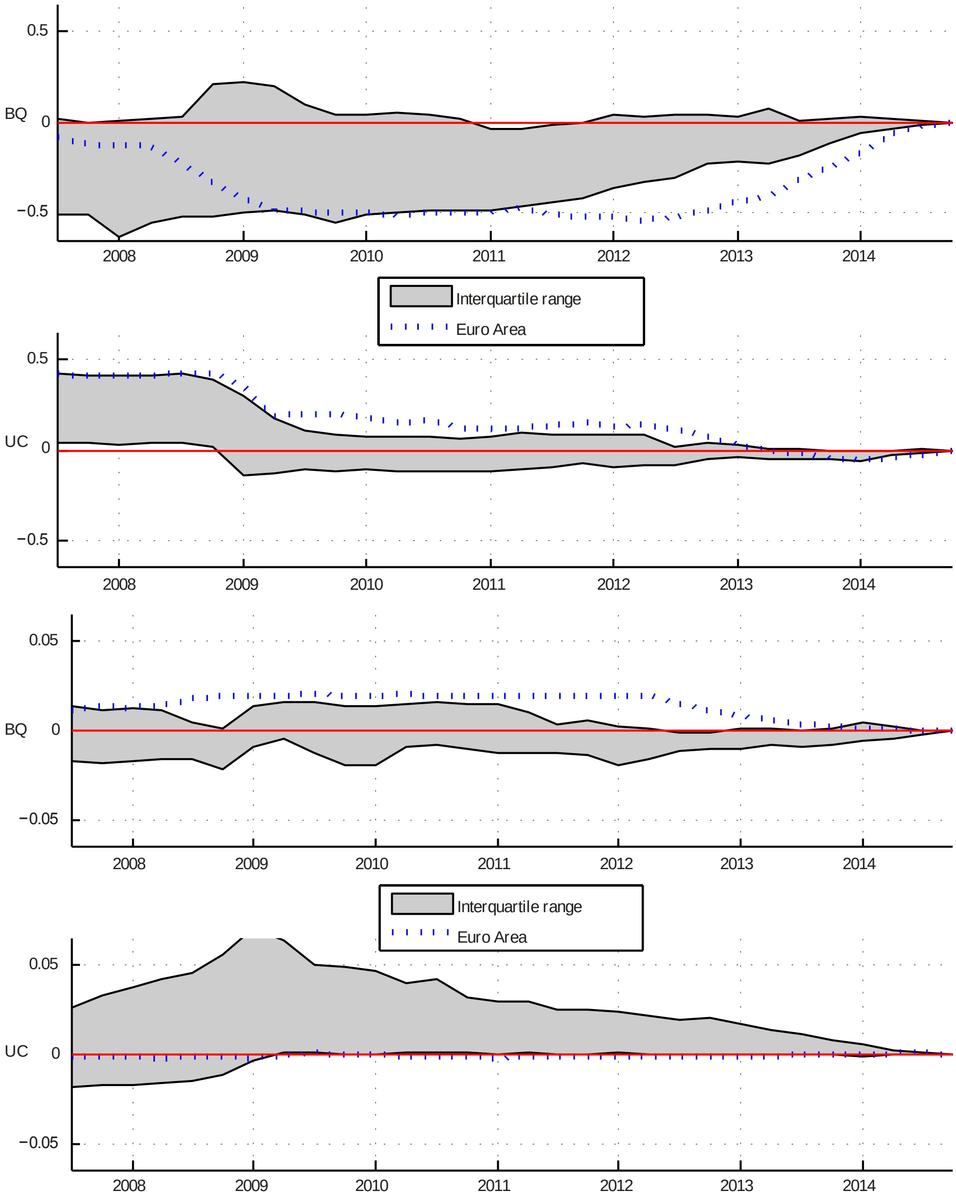
robust at the cyclical frequency. However, the steepening of the slope signals that some of the recent fluctuations in output and unemployment are trend developments, and the model down-weighs the in-sample cyclical history accordingly. For the BQ model, Okun's law appears very robust and stable in time.

Figure 8



With such a description in mind, **Figure 8** plots the interquartile range of slopes and correlations from the two exercises in the cross-section of countries (to eliminate aberrant estimates). The distinctive trait of the two sets of charts is the stability of the range of slopes (however wide it is) and the very negative correlation coefficients across countries. To get a sense of how these slopes and correlations evolve over time, Figure 9 normalises them by the countries' estimate from the longest sample (for 2014Q4). Thus, values below zero indicate that slopes have flattened and correlations have weakened in absolute terms (as reported for the EA above). Accordingly, the Blanchard-Quah exercise indicates that slopes have somewhat flattened on average, while the unobserved component exercise points to some steepening right at the onset of the crisis but stable runs thereafter. Nevertheless, the fact that the interquartile range for the most part straddles the zero line suggests that across countries estimates are relatively stable across runs. The same figure for correlations shows greater stability. Furthermore, units on the vertical axis (percentage point deviations from the last estimate) show that correlations are far more stable than slopes. In the light of the discussion above, this suggests that the models are both re-allocating historical developments towards trends while maintaining stable correlations between cycles.

Figure 9



lA note on sample selection is required at this point. The countries for which the bivariate exercises were run are, in random order, US, UK, EA, DE, FR, IT, ES, NL, SWE, FI, CZ, SK, PT, EE, IR, LT, LV, GR and SL. The reason we list them is that not all were able to produce results. Specifically, despite their best efforts, teams from the last four countries encountered insuperable complications in estimation because of non-cooperative data (short samples, structural breaks, extreme developments). This implies some survivorship bias in our reporting, since results will be tilted towards stability.

2.2.4 Intermediate conclusions

The upshot of these multiple reduced-form and simple bivariate filtering exercises is that Okun's law appears to be a very robust feature of macro data across time, countries and trend-cycle identification schemes. From our own analysis, there appears to be little change in this relationship at cyclical frequency since the onset of the Great Recession. Admittedly, slopes have changed over time in some countries. Paired with stable correlations, however, this signals that if something is different in the recent development of the overall relationship between output and unemployment, it must be in the trend components.

3 Towards a theory of cyclical co-movements and trend components

In this section, we broaden our perspective by analysing jointly cyclical and trend components of the variables of interest. To do so, we make use of a workhorse, semi-structural model originally developed by the IMF – the Quarterly Projection Model – whose econometric *raison d'être* is precisely to model macroeconomic variables as the sum of two such components. We focus on the relationship between output and unemployment in this richer setup with two objectives in view. Firstly, we examine whether and how the correlation survives at cyclical frequencies when we pit it against more variables and tighter behavioural restrictions based on standard macroeconomic relationships. Secondly, we investigate whether the trend components, which are originally purely stochastic and devoid of economic interpretation, can be given some theoretical content by linking them to financial variables.

We first describe the origins and uses of the Quarterly Projection Model (QPM) before adapting it to our purpose.

3.1 The Quarterly Projection Model

A Quarterly Projection Model (QPM) is a multivariate trend-cycle filter where restrictions are imposed on the cyclical components that capture the spirit of typical macro-behavioural relationships such as IS curves, Phillips curves and monetary policy rules. Although they are not directly derived from microeconomic foundations, they can often be reverse-engineered from a DSGE model for plausible calibrations. This class of model is suitable for generating forecasts at a quarterly frequency with good overall projection properties.

In terms of applied research, the Bank of Canada led the way in operationalising QPM (Poloz, Rose and Tetlow, 1994; Black, Laxton, Rose and Tetlow, 1994). In the UK in the mid-1990s, the NIESR and the Bank of England implemented small-scale, open-economy models with a similar structure and philosophy, with a view to examining the implications of inflation targeting for inflation and output (Batini and Haldane, 1999). The Czech National Bank pioneered the use of QPMs as a core forecasting tool (Beneš, Hlédik, Vávra and Vlček, 2003), with shadow projections available in 2001 and the fully-fledged apparatus launched in mid-2002.

QPM models gained momentum in 2008 when IMF staff moved to improve the toolkit for analysing domestic and cross-country linkages. The initial framework built on a closed-economy setting, estimated for the US (Carabenciov et al., 2008a), but soon evolved to a multi-country environment, also comprising the EA, and Japan (Carabenciov et al., 2008b). More countries were added, and by 2013 a large QPM-type model covered around 85% of world output (Carabenciov et al., 2013). This model features six large world regions, namely the US, EA, Japan, emerging Asia, five Latin American countries, and the rest of the world. More recently, the EA region was decomposed into Germany, France, Italy, Spain, and the rest of the euro area (Jakab, Lukyantsau and Wang, 2015).

The structural simplicity and tractability embedded in QPM-type models enables users to focus on specific regions, countries and topics, examples of which are remittance inflows, terms-of-trade effects via commodity prices, dollarisation, or fiscal dominance. Carabenciov et al. (2008c) augment a QPM with oil prices, while a version developed by the National Bank of Hungary incorporates the effect of foreign exchange denominated loans on aggregate demand (Szilágyi et al., 2013). Andrle, Garcia-Saltos and Ho (2014) evaluate macro-financial linkages and cross-border spillovers between Poland and the euro area through the lens of a QPM. Financial variables and equations capturing macro-financial linkages have always had pride of place in the framework. There have also been interesting applications of semi-structural models with labour market linkages calibrated for European economies, such as Proietti and Musso (2007) or Brůha, Pierluigi and Serafini (2011).

QPM's structure and philosophy overlaps that of DSGE models, but not fully. **Table 2** lists focal similarities and differences.

Table 2

Comparison of features of QPM and DSGE models

QPM models	DSGE models
Similarities	
Expectations are model-consistent. Variables of interest are endogenous and depend on the entire structure of the model. Interest rate rules include tractable forward-looking elements, e.g. Taylor rules. Forecasting and policy analysis are feasible outcomes. All variables may be subject to a model-based decomposition. Macro-financial linkages can be added. The system of equations is jointly estimated, namely by Bayesian techniques. A mix of calibration and estimation is a standard working assumption.	
Differences	
Fiscal block is not usually treated.	Fiscal block is often treated.
Flexible for alternative economic environments, but not based on first-principle derivations.	Require first-principle derivations.
The macroeconomic structure is typically captured by a small number of equations, facilitating estimation, including in short samples.	The macroeconomic structure is in most cases characterised by a large number of equations, in which identification problems may be an issue.
No pre-defined steady state.	With pre-defined steady state.
Standard trend-cycle decomposition of GDP, with flexible treatment of trend components.	The trend-cycle decomposition of GDP is less standard, but allows for alternative counterfactual GDP levels, under e.g. "perfectly competitive economy", "monopolistic economy with flexible prices and wages".
Labour market extensively based on Okun's law.	Okun's law is not usually assessed; labour market equations, when present, are always derived from first principles, such as e.g. search and matching.
Can be extended to a large number of interacting economies, with different exchange rate regimes.	Creates tractability issues when the model is extended to a large number of economies.
Business cycle fluctuations are derived from shocks that are residuals from equations.	Business cycle fluctuations are derived from structurally identified shocks.
The out-of-sample forecasting accuracy of the model is often evaluated.	The out-of-sample forecasting accuracy is often ignored.

The key common features are (i) the extensive use of rational expectations, in which all forward-looking expectations are model-consistent; (ii) the stochastic nature of shocks driving the system; (iii) the accommodation of measures of uncertainty for forecasting and simulation purposes; and (iv) the system estimation by Bayesian techniques and application of the Kalman filter. Crucially, QPM differs from DSGE models in its lack of micro-foundations underpinning the behavioural equations, even though each equation has an economic interpretation (Berg, Karam and Laxton, 2006). In addition, shocks in QPMs remain reduced-form in spirit as, depending on the equations, they do not map one-for-one with the deep fundamental disturbances of a related DSGE model. Thus, QPMs gain greater flexibility to fit the co-spectral properties of the data at the cost of looser-knit economic readings.

3.2 Okun's law in QPM

3.2.1 Benchmark runs

All of the examples of QPM described above include Okun's law in trend-cycle form in their set of behavioural equations, but the relation is never emphasised. In fact, it is introduced mainly as a way to identify more sharply the output gap, which in turn is one of the core variables of interest with inflation, interest rates and whatever other topical variable of the moment. Instead, our purpose is to flip the focus away from the New Keynesian setup back to Okun's law. That is, we investigate whether the other core variables of a standard QPM have any influence on the joint trend-cycle decomposition of output and unemployment. Viewed from this angle, QPMs are a spiced-up version of the UC model of the previous section, with extra variables and expectational components in the cycles. The spicing up, however involves a big step in complexity because the forward-looking components must be solved for in the rational expectations sense. As a consequence, the QPM will have far more cross-equation restrictions imposed on the parameters of Okun's law and a richer dynamic specification than the simple moving average structure in the cycles in the bivariate UC model[14]. There is, however, a crucial aspect common to QPM and the UC filters: both represent stochastic trends as uncorrelated random walks. That is, all the economic structure carried by the cross-equations applies only to cycles. Thus, the exogenous disturbances to the trends can truly be interpreted as measures of our ignorance, as we have no economic handle on them. This will turn out to be important in interpreting results when we introduce financial stress below.

We first focus on a QPM for the euro area modelled as a closed economy. The observable variables are output, the inflation rate, the nominal policy rate and the unemployment rate. Cyclical equations reflect elements and trade-offs of the IS curve, Phillips curve, Taylor rule and Okun's law (see the Annexes for a more

[14] Forward-looking components tend to add non-trivial moving average components to the dynamic specifications, changing AR(p) processes into ARMA(r,q) ones.

structured description of the model). In the following we will refer to such a bare-bones version of the QPM as our "benchmark".

Figure 10

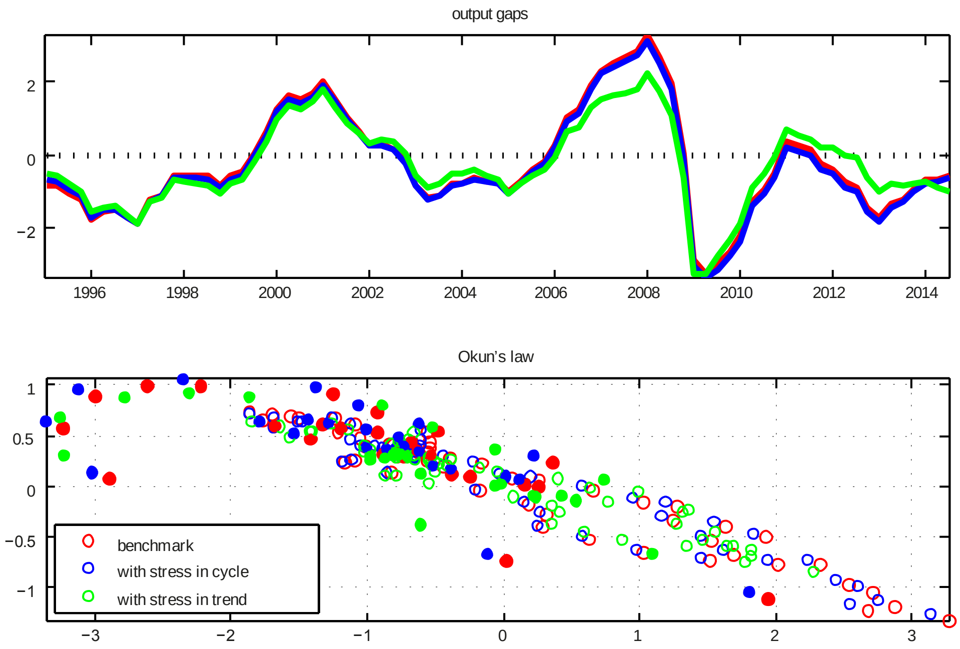


Figure 10 displays some of the output of a run of this benchmark on data up to 2014Q4. The focus for the moment is on the bottom chart, the scatterplot of the output gap against the unemployment gap – Okun's law. In the scatterplot, the filled circles represent the last 24 data points of the sample, namely the scatterplot for data since 2008Q4. Clearly the overall cloud of points is tight, and the subsample does not jut out in a way that would signal a structural change in the tilt or the breadth of the cloud (except admittedly at the trough of the recession, reflected in the upper left-hand corner). Recall again that, as in the UC setting, the model could have chosen to interpret the data in the idiosyncratic component of unemployment. That it does not do so implies that Okun's law is again a tight relationship that survives the onset of the crisis.

While the cyclical behaviour of output and unemployment appears stable, this is less the case for trends. Turning first to the top chart in **Figure 11**, which plots the sample path of year-on-year output growth, the yellow-shaded area represents the estimated historical contribution of trend growth (red bars are explained below). The step down in this contribution is unmistakable: the model interprets a larger part of output growth since the crisis relative to history as unexplained by the joint behaviour of all the observable variables. This is also true for unemployment, albeit to a lesser extent, as revealed by the similar chart in **Figure 12** that depicts year-on-year unemployment growth.

Figure 11

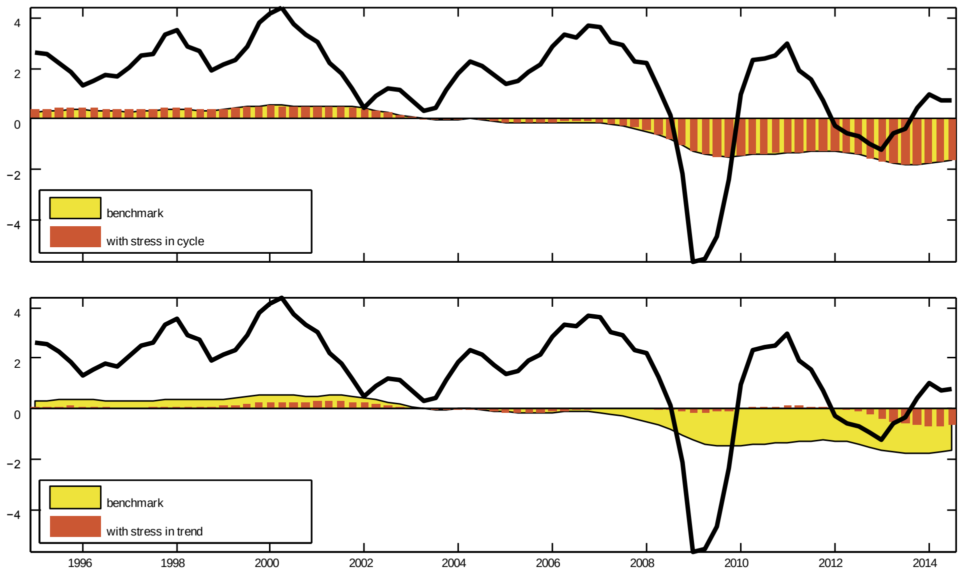
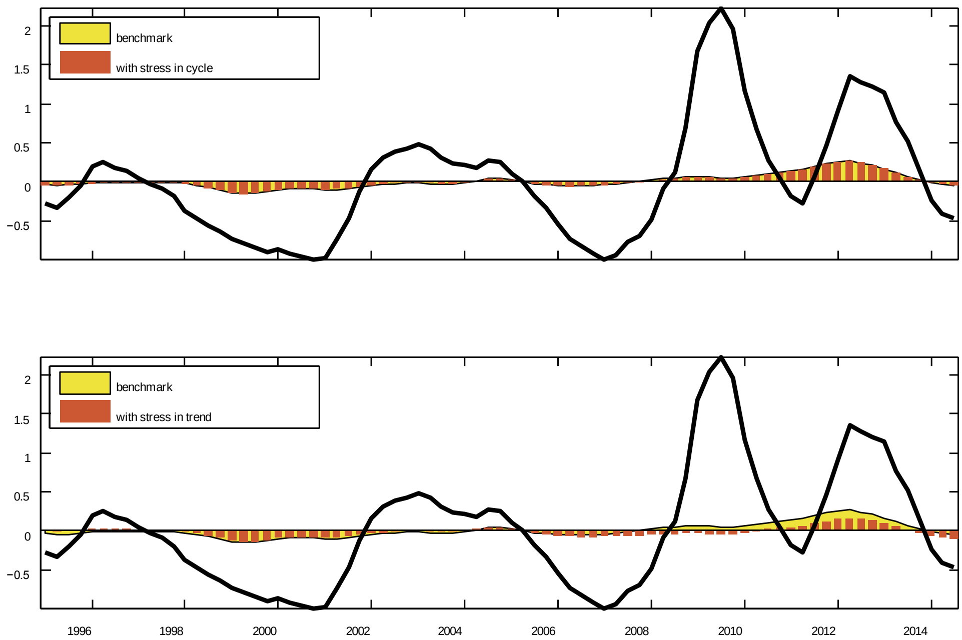


Figure 12



We run the same model for the US. Figures 13-15 display the relevant output. Of note is the absence of a trend in unemployment: the model chooses to interpret that variable as pure cycle. This feature notwithstanding, the message from the figures is the same: cyclically, Okun's law is robust, and trend output growth slows considerably in the wake of the Great Recession. For the euro area and the US, where trends are concerned, this time is different.[15]

Figure 13

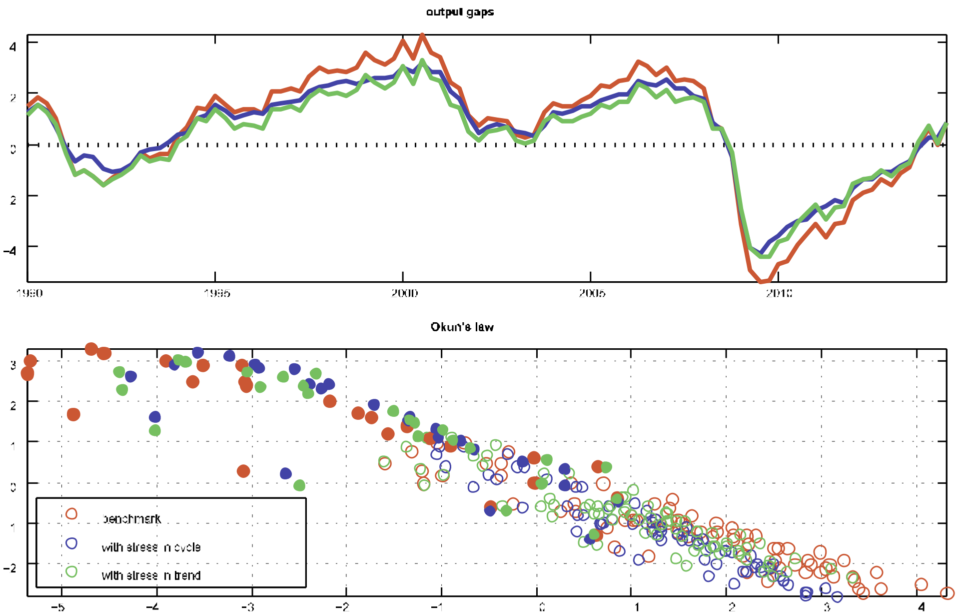
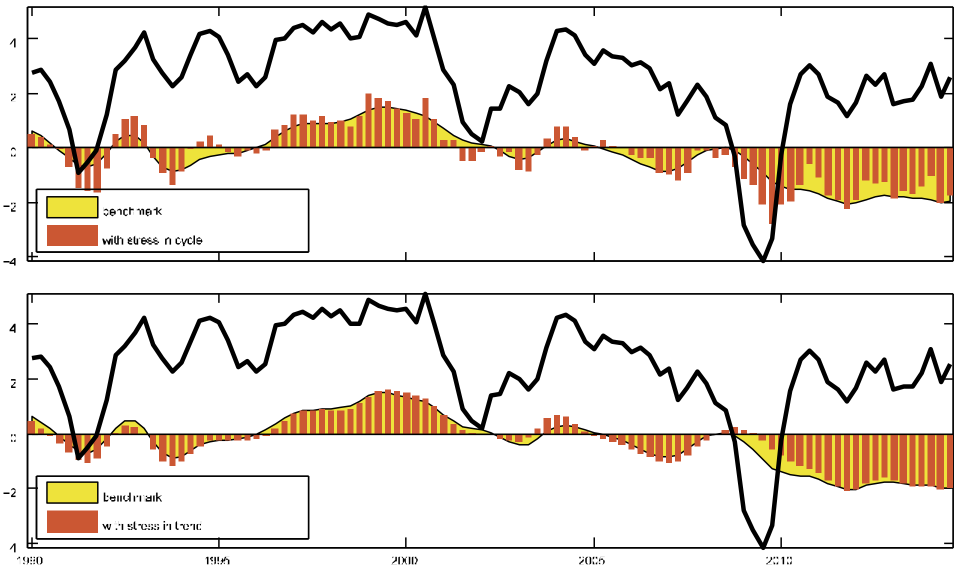
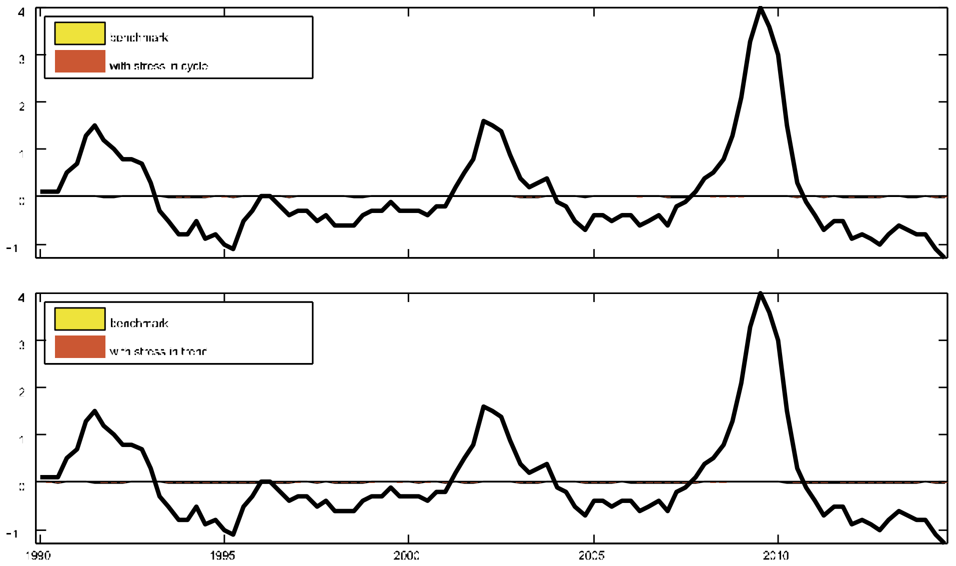


Figure 14



15 Famous last words.

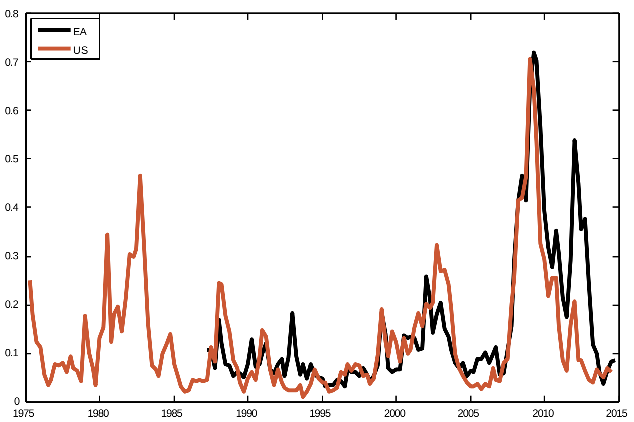
Figure 15



3.2.2 Introducing financial variables

Admittedly, the previous subsection's results rest on full in-sample fit, and regression will have biased the conclusions towards stability. In Section 1 of the paper, we analysed Okun's law in the light of the financial crisis by running recursive estimates of various models over the post-2008 period and checking for stability. Here we instead inquire whether including proxy variables for financial crises in the benchmark model affects the relationship. This approach requires two clarifications.

Figure 16



First is the choice of the variable to include. We opt for a specific measure of financial stress, the Composite Indicator of Systemic Stress (CISS), developed at the ECB for the euro area and the US (Holló, Kremer and Lo Duca, 2012). Both series are displayed in **Figure 16**. The notable feature is that these indicators do not look like financial cycle indicators but rather like financial crisis indicators and, as such, behave much more like step functions or ARCH processes. We will discuss this feature below.

Second is the choice of how to introduce CISS in the model. First, we project it onto the output gap, so as to net out possible feedback from cyclical influences. We then introduce the residual in either the trends of output and unemployment, or the cycles as defined by Okun's law and the IS curve (relating the output gap to the real interest rate gap). Thus ex ante this methodology is agnostic as to whether the financial variable is most useful to explain the trend or the cycle. To get a feel for the difference, recall that the most basic unobserved component decomposition of y can be written as:

$$y_t = \frac{1}{1-L}\epsilon_t + \frac{1}{1-\varphi L}u_t \quad (4)$$

where the trend is the first term on the right with the unit root, while the cycle – the second term – earns its stability from the stable root φ<1. The question is whether the model will prefer to add the financial stress indicator in ε or in u. To the best of our knowledge, proceeding this way is new in the literature.

With this in mind, **Error! Reference source not found.** reports the log marginal likelihood for the benchmark and the log Bayes factor (the gain in log points) for the QPM with financial stress in the cycles, and the QPM with stress in the trends. For the euro area, the model with stress in the trends is clearly preferred to the alternatives, while introducing stress in the cycles makes little difference to the benchmark. Returning to Figures 10 and 13, the scatterplots of output and unemployment are little changed in terms of slope and precision, whether stress is in the cycle or the trends. In this sense, Okun's law is robust to the inclusion of this variable.

Table 3

Log-marginal likelihoods of estimated QPMs

QPM Models	B	C - B	T - B
Euro area	-29.9	-0.8	7.2
US	-602.4	4.7	1.0
Finland	-218.7	5.7	4.3
Sweden	-413.4	-2.4	6.7

Note: B is benchmark, C is QPM with financial stress in cycles, T is QPM with financial stress in trends.

Nevertheless, that stress matters in the trends has important consequences for the euro area. The estimates of the output gap from the benchmark and the QPM with cyclical stress are very close, but the cycle obtained from introducing stress in the trends reads differently, particularly in the latter part of the sample. Given the tightness of Okun's law, this must also be true of the unemployment gap. The reason is that the trend is now significantly influenced by the stress variable. This is made clear by the red bars in **Figure 11**, which represent the historical contribution of the exogenous trend shock to output growth. In the case of stress in the cycles, there is little revision to this contribution, because the model basically discards stress as an explanatory variable for the cyclical components (in terms of the basic equation above, it rejects adding it to u). In contrast, the historical contribution of the exogenous trend shock is considerably reduced when stress is introduced in the trends. The model essentially substitutes the unexplained part of output growth with the stress component, and the model's log marginal likelihood bears witness to this revision.

For the US, the picture is different. The (log) marginal likelihoods suggest some preference for the QPM with stress in the cycle, but this is not particularly apparent in the set of figures. While Okun's law remains tight, the QPM seems to view financial stress as little more than noise, with little to pick between adding it to trends or cycles. Thus estimated gaps and historical decompositions are essentially unchanged.

3.2.3 The Finnish-Swedish experience

For comparison purposes, we also report results for Finland and Sweden. We pick these countries for two reasons. The more prosaic is that they advertise the flexibility of the QPM framework, which we adapt to model these countries as small open economies – one in a monetary union, and the other with its own free-floating currency[16]. The more interesting reason is that both countries suffered from severe financial crises in the 1990s in addition to the most recent one, handing us two valuable historical precedents.

The crises in Finland and Sweden differed in magnitude, but shared many common features. In particular, both countries experienced several years of rapid growth in the second half of the 1980s on the back of a series of deregulatory reforms – including the lifting of credit controls – that sparked lending booms. This credit expansion was channelled into quickly overheating property and stock markets. A subsequent sharp rise in real interest rates in the wake of the dissolution of the Soviet Union and reunification of Germany weighed heavily on asset prices and both economies came to a screeching halt. The cumulative fall in GDP from peak to trough was almost 5 percent in Sweden and over 12 percent in Finland.[17] In Sweden, unemployment rose from 2-3 percent to around 10 percent and the stock market fell by almost 50 percent. In Finland, the unemployment rate surged from 3 to 17.5 percent while the stock market fell by two-thirds. Both countries were forced to shore up their banking systems and subjected them to considerable restructuring. In addition, their currencies suffered damaging speculative attacks that led them eventually to abandon their fixed exchange rate regimes. All in all, the crises in Sweden and Finland in the 1990s were severe, and particularly so for Finland.

The recent recession, while also "great", ran differently, as it was mostly imported. Notably, the rise in unemployment was more moderate, from 6 percent to 9 percent in Sweden and from 6 percent to 10 percent in Finland. The contrasting nature of the two episodes is largely explained by the initial state of the financial sectors. In 2008, banks were on average less leveraged than in the late 1980s, and formally Sweden and Finland have not experienced a full-blown banking crisis. This sequence of events is well-captured by the Swedish and Finnish equivalents of CISS.

With these narratives in mind, we run QPM on Finnish and Swedish data. We use two measures of CISS as proxy variables for financial stress – one for the domestic economy in the model and one for the euro area. To capture potential spillovers, we now allow for the domestic variables to be affected by both domestic and foreign financial stress.

[16] The euro area is the other, "large", economy in the two models – large in the sense that it is assumed to be unaffected by the developments in the small open economy, while the opposite is not true.

[17] The Finnish economy peaked in the last quarter of 1989 and the Swedish economy one quarter later. In both countries growth was negative until the first quarter of 1993.

Results indicate that Okun's law is tight in both countries (see the scatterplots in Figures 17 and 18). However, in both cases, the subsample from 2008Q4 onwards signals a possible change in the cloud's tilt (see the filled circles). Moreover, Okun's law seems flatter in this subsample than during the 1990s depression (connected circles in **Figure 18** mark the period 1990Q1-1996Q4 for Finland).

Figure 17

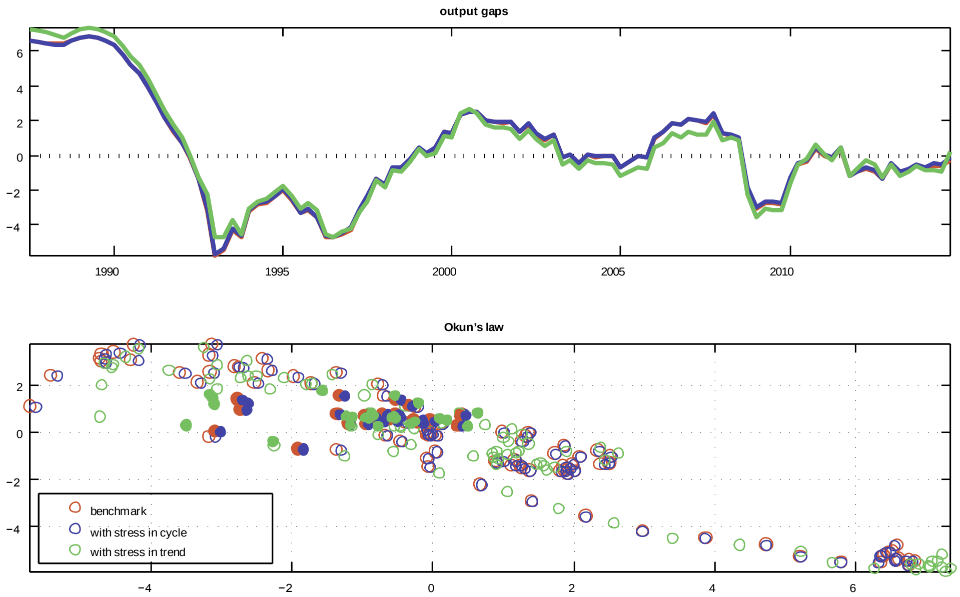
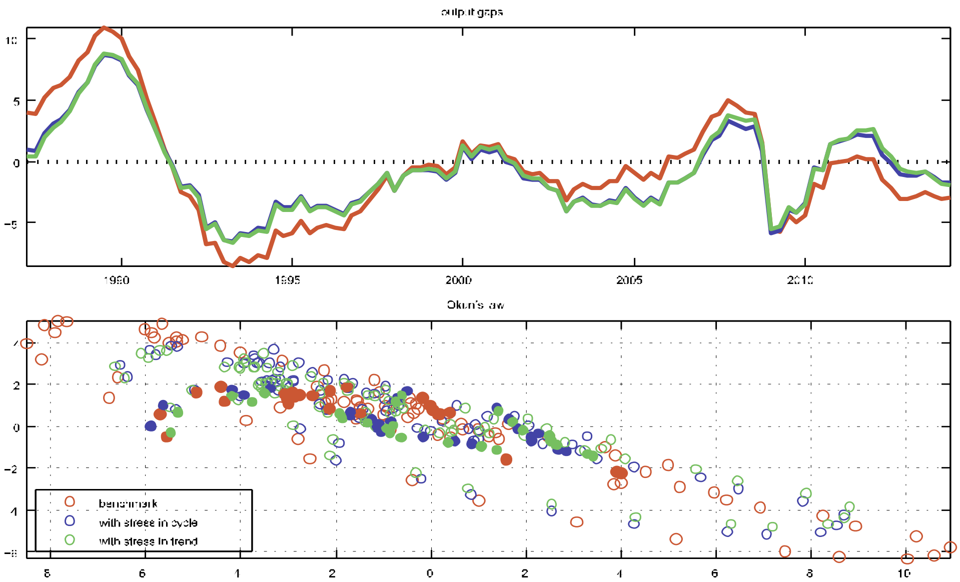
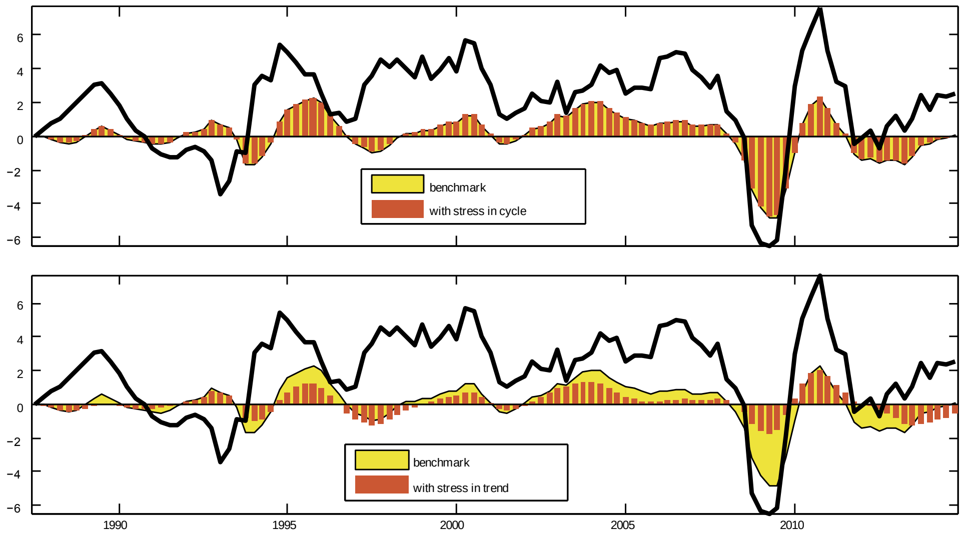


Figure 18



In the case of Sweden, including financial stress in the trend clearly reduces the contribution to output of the exogenous trend shock, while it does little when added to the cycles (compare the red bars to the yellow area in **Figure 19**). This is borne out in the log marginal likelihoods reported in **Error! Reference source not found.**. The trend shock contribution shrinks considerably in the latest crisis, but it does so only marginally during the 1990s crisis. This result reflects the narrative above.

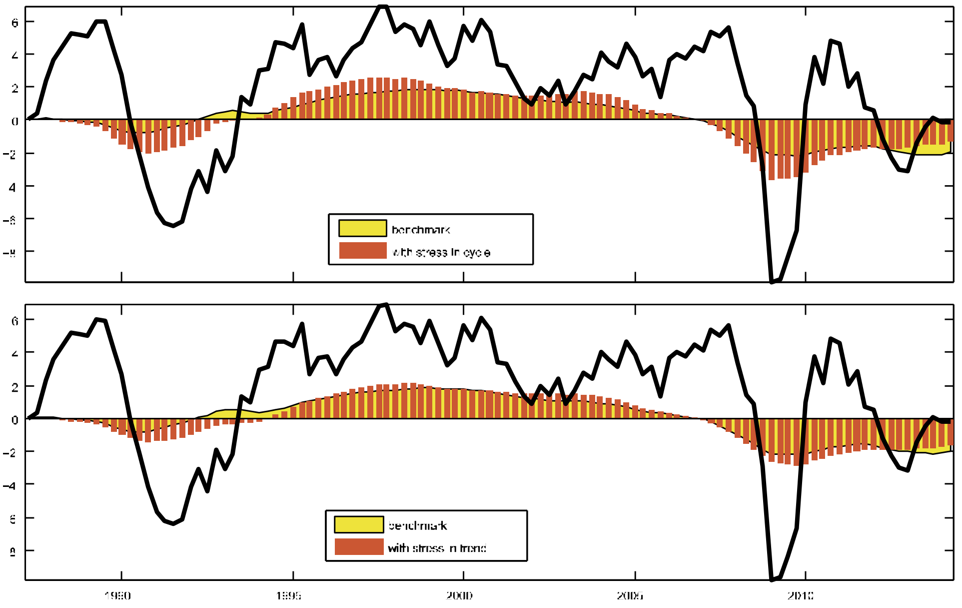
Figure 19



For Finland, trend output growth appears to slow considerably in the wake of the Great Recession (**Figure 20**). The Finnish experience in the past few years is notably different from the depression of the 1990s, where the trend slow-down was shorter-lived and considerably less pronounced. The log marginal likelihoods suggest some preference for the QPM with stress in the cycle rather than in the trend[18]. Incorporating financial stress shrinks the output gap in the boom of the late 1980s and in the depression of the 1990s (upper chart of Figure 20). Nevertheless, Okun's law appears to be remarkably similar across models.

[18] The financial stress indicator for Finland is taken from Huotari (2015).

Figure 20



In both countries, QPM essentially interprets unemployment as purely cyclical – as was the case for the US – making it difficult to distinguish any impact of financial variables. For this reason, we do not show the relevant decomposition.

3.3 Comments

It is useful to return to equation (4) to take stock of these results. Again, QPMs are vectorised versions of this basic decomposition, where all of the economic "theory" is concentrated in the cycle and the trend is the intellectual residual. Accordingly, one can think of the logic of the exercise as first measuring our ignorance of output and unemployment fluctuations – the orthogonal trend components – and attempting to relieve part of it by introducing some measure of financial friction, captured by the stress variable. In the case of the euro area, it appears that we can. Furthermore, these frictions are allocated to the trend components, implying that trends are no longer exogenous but correlated, with stress as the common factor. Of course, given the very stylised nature of the model, one should not take it at face value that financial stress will have permanent effects on output growth. Rather, it does seem to operate at lower frequencies than the standard cyclical ones in the QPM. In effect, equation (4) shows that there is a stark choice between allocating to a stationary u or to a unit root ε. We take it that financial stress operates in the frequency space in between. In the case of the US, the effects of financial stress are less obvious.

We now revisit the question: why CISS? Its defining feature is that it captures second moments rather than first moments of financial data – volatilities rather than means. Formally, it is constructed as a time-varying weighted average of several financial market stress measures that reflect risk spreads, volatilities, market player uncertainty, investor disagreements or information asymmetries. All of these symptoms are specifically those that are difficult to correlate with typical macro cyclical variables. The received wisdom is that the financial crisis has opened a Pandora's box of non-linearities, which QPMs are ill-equipped to analyse because they are linear – as are first-order-approximated DSGE models, for that matter. For want of a full-blown ARCH QPM, we opted for an indicator sharing the relevant features. This is why we preferred it to a bank lending conditions index, which has been extensively used by the IMF in QPM-based analyses, or a financial cycle variable à la Borio et al. (2013).

In light of our modelling and data choice, our results for the US recall a dissenting but weighty position on the topic. Stock and Watson (2012) analyse the Great Recession through the lens of a large-scale dynamic factor model and find that forward predictions of standard macro variables from the model estimated prior to the onset of the crisis line up closely with realisations. Since their factor model is linear and parameters are not re-estimated, they interpret these results as saying that the economy reacted in a historically predictable way to macro shocks that were simply larger than usual – in other words, they find no evidence of non-linearities in the macro-transmission mechanisms or structural breaks in parameters. However, they do find that financial variables in their factor models behaved differently to predictions. In this sense, some instability is present in their framework. This is very similar in spirit to our exercise: CISS is de facto a factor model of multiple financial stress variables that appears to have no cyclical properties, and thus is difficult to predict from other cyclical macro variables. Nevertheless, Stock and Watson note that conditional on the behaviour of their financial block, the linear, cyclical macro side appears as it ever was. Furthermore, they attribute much of the slow recovery of output to a secular slowdown in labour force growth – interpretable in our QPM as an exogenous component of the stochastic trend – which accords closely with our own results.

4 Output and unemployment in fully structural macroeconomic models

We now investigate to what extent our empirical findings in the two sections above can be reproduced in the current generation of macroeconomic structural models in use in academic macro-labour research and routinely adopted in many policy-making institutions. We focus on aggregate models featuring search and matching frictions in the labour market. This is the dominant paradigm currently used to study the role and place of unemployment in business fluctuations.

We first outline a brief track record of the methodology and highlight two important issues of this approach in light of the empirical results of the previous sections. We then propose a modified version of a search and matching model that lines up more closely with the empirical evidence and fleshes out a role for financial variables in shaping the correlation between output and unemployment.

4.1 The search and matching approach

4.1.1 Real models

Search and matching models have enjoyed tremendous popularity and been extended in many directions since Merz (1995) and Andolfatto (1996) integrated the original Diamond-Mortensen-Pissarides framework into a standard general equilibrium model. The appeal of these models is due largely to the fact that market-clearing RBC models were by design unable to explain unemployment and the co-existence of unfilled vacancies and unemployed workers. They were also unable to explain high volatility of hours worked together with low volatility of wages without assuming implausibly high labour-supply elasticities. In contrast, search-based models, with their micro-foundations for labour flows and wage determination, permitted analysis of standard labour market policies that were otherwise ruled out. Many of these analyses, however, were geared towards comparative statics and policy analysis, and much less towards fitting time series. After the first wave of acceptance, Shimer's (2005) critique sparked a lively debate on whether search models could replicate the volatility and persistence observed in the data. In a nutshell, Shimer argued that under Nash bargaining, wages are too flexible and absorb too large a portion of labour productivity fluctuations. This desensitises firms' incentive to post vacancies and dampens the volatility of employment and vacancies relative to data.

Multiple solutions to the Shimer puzzle have been proposed. Mortensen and Nagypal (2007) highlighted the role of on-the-job search. Hagedorn and Manovskii (2008) proposed an alternative parameterisation of workers' outside options and bargaining power that solves the puzzle. Hall (2005) put forward a different wage "norm". Gertler and Trigari (2006) use staggered wage contracts. Christiano et al. (2013) build a model where wage inertia obtains as an equilibrium outcome. In essence, these approaches aim to rigidify real wages (more on this below). Other solutions involve alternative assumptions for vacancy posting costs. Fujita and Ramey (2007) propose sunk costs for vacancies, and Rotemberg and Trigari (2006) and Yashiv (2006) assume vacancy costs that fall with the number of postings. Pissarides (2009) shows how adding a fixed component to vacancy posting costs (i.e. a sort of "training" cost paid independently of the duration of the vacancy) solves the Shimer puzzle even when wages of new hires (which are the relevant ones for job creation) are volatile (they are more volatile than aggregate wages in the data). Ljungqvist and Sargent (2015) characterise much of this literature on wage rigidities and vacancy postings as affecting the "fundamental surplus" – the fraction of firm profits allocated to create vacancies – which is the primordial source of amplification and persistence of unemployment in these models. These solutions to the Shimer puzzle have been proposed in real models, but they can be – and are – widely applied in New Keynesian models with search frictions.

4.1.2 New Keynesian models

Blanchard and Galí (2010) analyse the effects of search frictions in a bare-bones but highly tractable New Keynesian framework. They assume a firm's hiring costs to be increasing in labour market tightness.[19] They show that employment is invariant to productivity shocks in constrained efficient allocation[20], and that this result carries through if prices and wages are flexible (the latter determined by Nash bargaining). While this result echoes the Shimer puzzle, the reasoning is different: the wage and the marginal rate of substitution both move proportionally with productivity (while the latter is constant in the models criticised by Shimer), thus to each other, leading to constant employment and no bite from the frictions.[21] Only with real wage rigidities can their model generate output and unemployment fluctuations similar to those in the data.

Walsh (2005) and Trigari (2006) develop more explicit micro-foundations than Blanchard and Galí, and fruitful extensions of their work involve different forms of wage determination. These include wage rigidities as proposed by Hall (2005) and alternative bargaining games.[22] For instance, Christoffel and Linzert (2005) and Christoffel and Kuester (2008) show how a departure from Nash bargaining can

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19 They define tightness as the number of new hires divided by the number of unemployed. Note that this corresponds to the probability of a worker finding a job (job-finding rate) in other models and is different from the more standard definition of labour market tightness as a ratio of vacancies to unemployed. Moreover, vacancies in their model are filled instantly by paying the hiring cost.

20 This is because both the marginal rate of substitution and social marginal rate of transformation increase proportionally with productivity, while employment stays constant.

21 If the marginal rate of substitution were allowed to increase with productivity, but by less than one-for-one, this would amplify the Shimer puzzle in the Blanchard and Galí type of model.

22 For instance, the implications of different bargaining arrangements are investigated by Christiano, Eichenbaum, and Trabandt (2013), who build on Hall and Milgrom (2008) and show how realistic dynamics in a New Keynesian search and matching model can be obtained without relying on the assumption of exogenous wage rigidity.

restore the channel from wages to inflation. Gertler, Sala and Trigari (2008), building on a real model of Gertler and Trigari (2006), introduce staggered nominal wage bargaining with employment adjustment on the extensive margin.[23] An attractive feature of their framework is that wage-setting frictions do not have a direct impact on existing firm-worker relations, but they do affect the firm's effort of searching for new workers. Christoffel et al. (2009) thoroughly analyse the implications of various modelling choices and their ability to replicate dynamics of wages, inflation, and employment observed in the data.

4.1.3 Models integrating search with credit market frictions

A small handful of models feature both credit market frictions and labour search. Typically, credit frictions relate to capital formation, which affect employment indirectly through fluctuations in investment. For instance, Christiano, Trabandt and Walentin (2007) develop a model in the spirit of Bernanke, Gertler and Gilchrist (1999), with entrepreneurs having to borrow funds from banks. Unemployment is introduced as in Gertler, Sala and Trigari (2008), thus preserving the feature that wages have an effect on hiring new workers.[24]

Monacelli, Quadrini, and Trigari (2011) also integrate labour search with financial frictions, where firms can issue debt under limited enforcement. Interestingly, their model implies that higher debt gives employers more bargaining power, enabling them to negotiate lower wages and stimulating job creation accordingly. This channel causes firms to reduce hiring after a credit shock, even if they are flush with funds. Unemployment persists not because firms cannot hire, but because they are unwilling to when their bargaining power is low.

Even fewer models integrate credit frictions on the labour margin directly. One such model is Petrosky-Nadeau (2014), where firms must borrow to finance vacancies. A new channel opens through which credit frictions affect vacancy postings and employment directly rather than indirectly via the capital margin. Costlier external finance raises unemployment in equilibrium. In terms of dynamics, any shock reducing the external finance premium required to fund vacancies will increase postings and employment directly. A second, indirect channel works by dampening the effect of labour market tightness on wages in Nash bargaining. This wage channel is a feature of credit frictions and not of the bargaining scheme.

In a similar spirit, Petrosky-Nadeau and Wasmer (2013), building on a static model of Wasmer and Weill (2004), integrate search frictions on both the credit and labour markets. They show that adding financial imperfections increases the sensitivity of labour market tightness to shocks by a factor that depends on financial frictions and

[23] Adjustment on the extensive margin means that wage rigidity affects employment and implies that existing employment is efficient. Therefore, it is not susceptible to Barro's 1977 critique that models that use rigid wages for allocation in an environment where there are ongoing relationships between workers and firms ignore potential mutual gains from trade.

[24] Unlike Gertler, Sala, and Trigari (2008), Christiano, Trabandt and Walentin model wage rigidities using Taylor-type contracts, with nominal wages determined by Nash bargaining occurring infrequently.

can result in large amplification. With a small prospective gain from entering into the matching market, even a small change in productivity can have substantial effects. Petrosky-Nadeau and Wasmer (2015) extend the setup, using search frictions on the goods, labour and credit markets. The extra dimension enables them to reproduce data features in terms of both persistence and volatility.[25]

4.2 Labour wedges and Okun's law

4.2.1 The labour wedge

This review presents the reader with a dizzying *embarras de richesses* that will likely leave him or her wary of the next contortion in the literature. It turns out that there is a useful and increasingly popular way to evaluate competing models against data, compellingly promoted by Shimer (2009). Furthermore, it ties into our results on Okun's law in an important way for structural modelling.

Recall that in the standard RBC framework, labour demand arises from firms' marginal product of labour (MPL) schedule, while labour supply is captured by households' marginal rate of substitution (MRS) between consumption and leisure. Market clearing requires $MPL(L^{-}, z^{+}) = w = MRS(L^{+}, x^{+})$

where the superscripts indicate the sign of the slope and x and z are exogenous supply and demand shifters. The gap between the MPL and the MRS – which we call Δ – is the labour wedge. By definition, this gap is zero for the standard RBC model, and this is the formal condition to pin down labour $\Delta(L^{-}, x, z) \equiv MPL - MRS = 0 \rightarrow L^{*} = L(z^{+}, x^{-})$

Shimer argues that, with a minimal and uncontroversial set of RBC parameters, this labour wedge can be constructed from standard macro variables (more on this below). Accordingly, as an observable, it can be used to discriminate between models. Essentially, its variation in time then shows to what extent the data depart from what the market-clearing benchmark would have expected. From the most basic principles – downward-sloping demand, upward-sloping supply – the wedge is decreasing in labour, as it traces out the excess labour supply quadrant in a standard Marshallian plot. Shimer shows for the US that the wedge is indeed strongly counter-cyclical. The results presented in 4.2.4 below indicate that this extends to basically all countries in our sample. Thus Shimer's challenge is for models to explain this feature.

As an example, consider the labour market representation in the Galí, Smets and Wouters model with an extensive margin. In steady state the MPL is marked up over the real wage, which is itself marked up over the MRS (in logs): $MPL(L^{-}, z^{+}) = w + \mu_p$

[25] The friction on the goods market creates persistence in the incentives to hire workers, resulting in hump-shaped responses.

$w = MRS(L^{+}, x^{+}) + \mu_w$

Thus the model implies a positive labour wedge and underemployment relative to the frictionless benchmark $\Delta(L^{-}, x, z) = \mu_p + \mu_w \rightarrow L = L(z^{+}, x^{-}, \mu_p^{-}, \mu_w^{-}) < L^{*}$

An increase in mark-ups reduces employment. Of course, the model has no predictive power for the wedge because the mark-ups are unobserved and exogenous: they are backed out of the data precisely to fit the wedge.

Consider now the basic search model. Although it is usually written in different economic language, its representation of the labour market can be recast in terms of supply and demand as above (see annex). In essence, the labour demand schedule is a re-arrangement of the job creation condition according to which the firm marks up the MPL over the wage to cover the expected cost of opening a vacancy. Similarly, the labour supply schedule is a re-arrangement of the wage-bargaining equation which marks up the wage over the worker's MRS by the bargained fraction of the match profit. Thus we can write

$MPL(L^{-}, z^{+}) = w + \mu_p(L^{+})$

$w = MRS(L^{+}, x^{+}) + \mu_w(L^{+})$

where the mark-ups are the expected vacancy cost and the fraction of the match profit, respectively. Crucially, both mark-ups are increasing in employment, because the search process implies that a tighter labour market reduces the probability of filling a vacancy and increases the duration and value of a match. This is what marks search models apart from the standard New Keynesian ones: mark-ups are endogenous.

However, computing the implied labour wedge immediately reveals the problem, $\Delta = \mu_p(L^{+}) + \mu_w(L^{+})$

that is, the model counterfactually predicts that the labour wedge is pro-cyclical.

The logic is clear. Search models are akin to models of labour adjustment costs[26]. Accordingly, optimal behaviour will require smoothing quantities and letting prices adjust. Yet the data show otherwise – sticky wages and volatile employment. According to the search framework, matching frictions from the perspective of the firm should be minimal in times of economic slack, as there are too many unemployed workers chasing too few jobs. Thus hiring costs should be low, spurring firms to hire, reducing unemployment and decreasing the labour market wedge (a similar point is made by Michaillat, 2012). That the data point completely in the

[26] Flow accounting requires that the change in employment equal new hires minus separations:

$L_t - L_{t-1} = p_t V_t - s L_{t-1}$

where hires are the product of total vacancies *V* and the fraction of them filled *p*. Replace in the profit function of firms, with cost *c* of posting a vacancy, and the parallel is immediate with models of labour adjustment cost (where the cost is now itself endogenous, via the matching probability *p*):

$\Pi_t = F(L_t) - w_t L_t - cV_t = F(L_t) - w_t L_t - \frac{c}{p_t}(L_t - (1-s)L_{t-1})$

opposite direction is Shimer's damning evidence against the basic search framework.

4.2.2 Implications of Okun's law

How does this relate to our results in the previous sections? The endogenous propagation mechanism of the basic search model operates in the wrong direction. A manifestation of this deficiency is that, to the extent that the exogenous shifters z and x summarise all the shocks that would yield a perfect fit for output fluctuations – suppose they captured all of the historical decomposition of output – the endogenous propagation mechanism would dampen employment volatility and reduce its correlation with output. This is precisely the opposite result we would aim for, given the extremely robust results we highlighted for Okun's law across time, countries and filtering schemes. The basic model simply cannot explain the cyclical components of output and unemployment with the same shocks.

As always, when a particular endogenous amplification mechanism is found wanting, an exogenous shifter is added to it. In this case, we would need to add two shifters to μ_p and μ_w, namely a vacancy cost shock and a matching shock, respectively. However, these shifters would have to more than counteract the effects of the shifters z and x via the deficient adjustment mechanism – implying that they would be perfectly negatively correlated with them and nullifying the assumption that shocks should all be orthogonal. A recent paper by Andrle (2014) builds on this logic to suggest using correlations of filtered shocks to test formally for model misspecification – and such a simple fixing of the basic search model would fail spectacularly such a test.

4.2.3 Wage rigidities

One possible reconciliation of theory and data involves real wage rigidities. Shimer (2010) suggested such an approach, as do many wage rigidity papers that precede him chronologically.

The simple analytics are the following. Suppose that wages are rigid at $\bar{w}$. Employment is then determined by the search model's labour demand equation

$$\bar{w} = MPL(L^{-}, z^{+}) - \mu_p(L^{+})$$

Simple comparative statics yield $\frac{d\Delta}{dz} = \left(\mu_{pL} - MRS_L\right)\frac{dL}{dz}$ and $\frac{d\Delta}{dx} = (MPL_L + \mu_{wL})\frac{dL}{dx}$

where subscripts indicate the derivative argument. Thus it is possible to obtain counter-cyclical labour wedges $\frac{d\Delta}{dL} < 0$, or at least dampen them, if the configuration of elasticities is right for the given shock. This is not obvious. For example, models tend towards constant returns to scale, implying flat labour demand curves (small MPL). Accordingly, it requires little action from the matching framework (a positive μ_{wL}) to generate positive correlation between the labour wedge and employment conditional on supply shocks. Thus the very high and negative unconditional correlation of the labour wedge with output remains hard to match.

Furthermore, a step back reveals that this line of inquiry attempts to offset employment rigidity and wage flexibility that arises naturally from a model with adjustment costs on quantities with wage rigidities and employment flexibility arising from a similar model of costs on prices. This is irredeemably Ptolemaic in spirit (and practice), as wage epicycles are layered anew onto labour epicycles, when all that is asked is to get the basic correlation between output and unemployment right[27].

4.2.4 Decomposing the total wedge

Karabarbounis (2014a) performs the thorough analytics of the intuition described above and decomposes the total labour wedge Δ into the two sub-wedges: the ratio of the MPL to wage μ_p and the ratio of the wage to the MRS μ_w. The first wedge is basically the inverse of the labour share, which in US data is slightly counter-cyclical. It is therefore unlikely that the puzzle could be solved with better modelling of the labour demand side[28]. Instead, the overall wedge Δ inherits its properties from μ_w, leading Karabarbounis to argue that business cycle theories of the labour wedge should primarily focus on improving the labour supply block of models. In that sense, the behaviour of the three wedges provides an additional test for structural macroeconomic models of labour market.

Karabarbounis' focus is the US. We extend his exercise to a broader set of countries, compute the three labour market wedges and assess their cyclicality. We use the dataset from Brůha and Polanský (2015)[29]. We compute the labour wedge assuming Cobb-Douglas production and separable preferences (as Shimer, 2009 or Karabarbounis, 2014):

$$U = \ln(c) + \alpha n^{1+\phi}$$

where c is consumption, n is hours worked and ϕ is the parameter of intra-temporal substitution (the inverse of the Frisch elasticity of labour supply). In log terms, the labour demand wedge is then proportional to the inverse of the labour share s_t:

$$\mu_{pt} = -\ln(s_t)$$

where we drop constants. The labour supply wedge is:

$$\mu_{wt} = \ln(s_t) - (1+\phi)\ln(n_t) - \ln(q_t)$$

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27 Alternatively, this is another example of the whack-a-mole theory of filters, where any bulging piece of data must be whacked back into place with another well-chosen friction.

28 To solve the puzzle by labour demand side would require the strongly pro-cyclical labour share, which is untrue for advanced economies.

29 This dataset contains quarterly data on labour market and national accounts for 35 advanced and transition countries. The countries are: Australia, Austria, Belgium, Bulgaria, Canada, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, the United Kingdom, Turkey, and the United States. The data for different countries have different time spans: for the US, data begin in the 1960s, while data for some transition countries start in the 2000s.

where q_t is the ratio of nominal consumption to nominal GDP. The total wedge is equal to the sum of the two wedges (in logs):

$$\Delta_t = \mu_{pt} + \mu_{wt} = -(1+\phi)\ln(n_t) - \ln(q_t)$$

Table 4

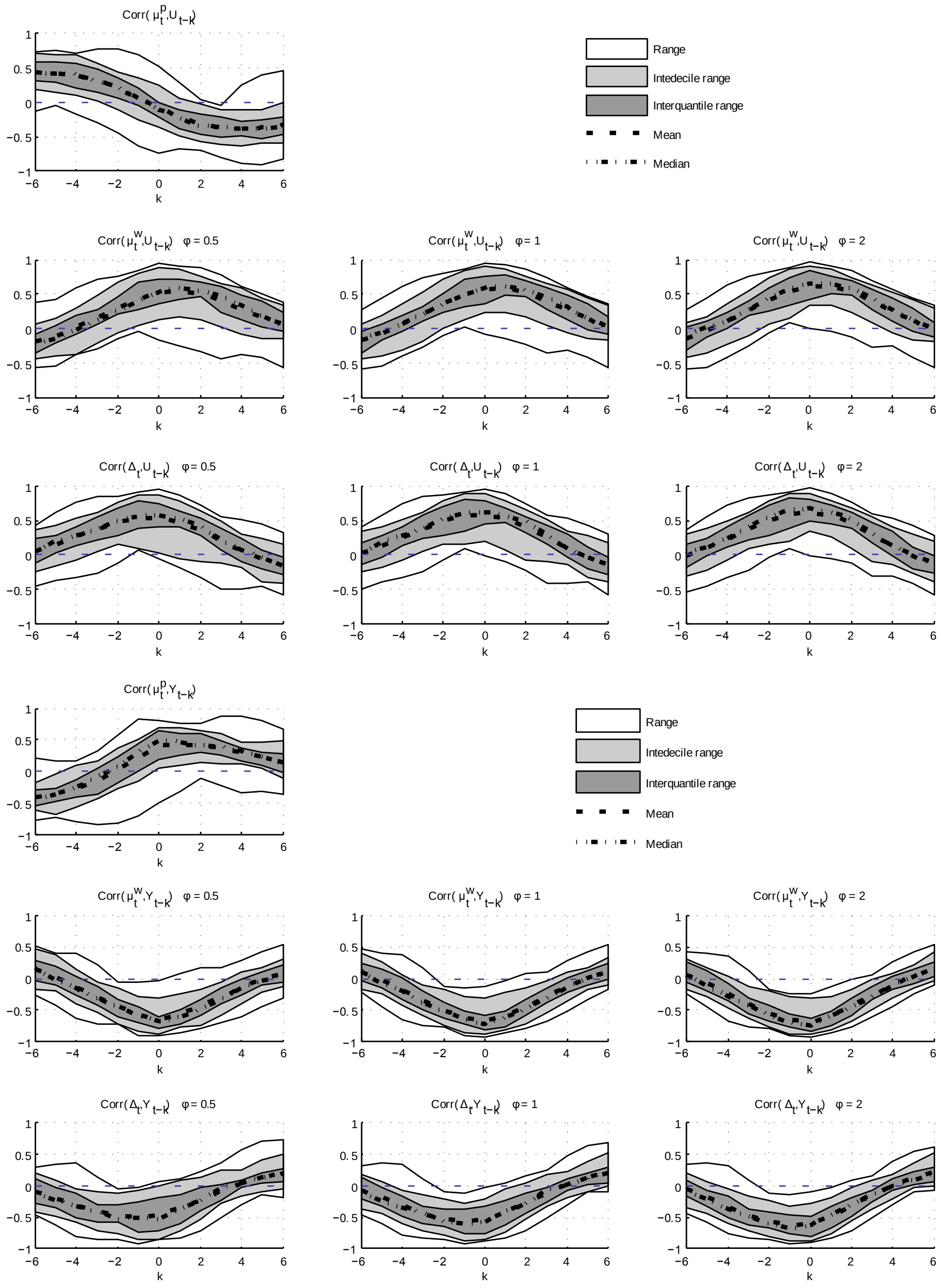
Correlation of wedges with output and unemployment (HP-filtered, Φ=1).

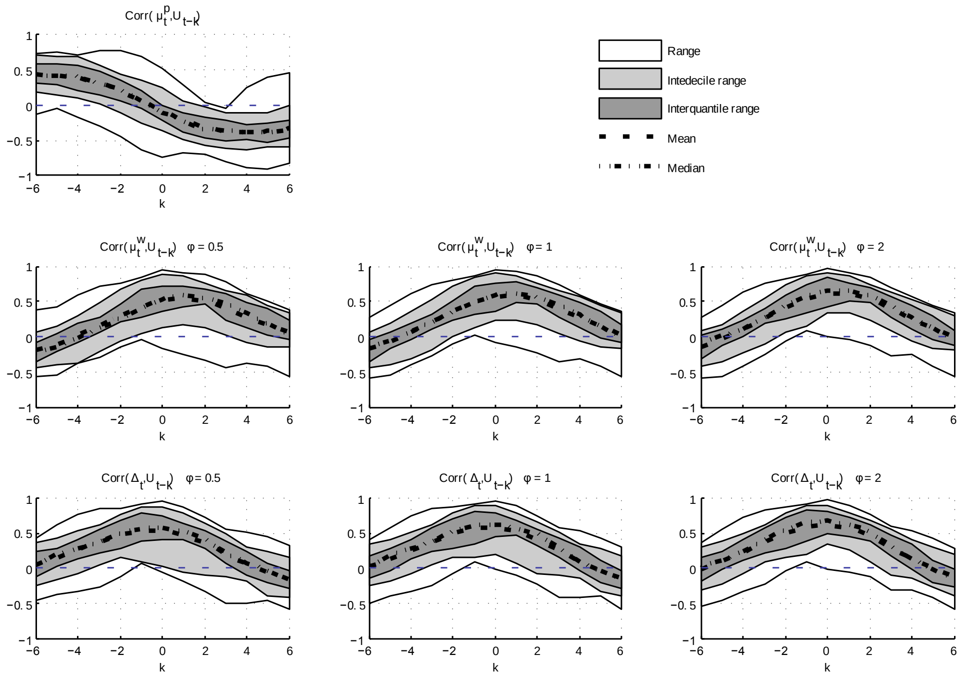
	Correlation: wedge and output			Correlation: wedge and unemployment		
	μ_p	μ_w	Δ	μ_p	μ_w	Δ
Australia	0.253	-0.589	-0.474	-0.041	0.755	0.768
Canada	0.554	-0.721	-0.607	-0.362	0.696	0.651
Luxembourg	0.617	-0.293	-0.018	-0.147	0.055	-0.010
Turkey	0.806	-0.880	-0.841	-0.737	0.889	0.887
United States	0.191	-0.891	-0.842	0.054	0.955	0.960
Austria	0.686	-0.556	-0.205	-0.168	0.225	0.179
Cyprus	0.515	-0.872	-0.802	-0.120	0.608	0.689
Czech Republic	0.066	-0.135	-0.114	0.283	-0.090	0.002
Denmark	0.636	-0.595	-0.233	-0.213	0.591	0.461
Estonia	0.405	-0.915	-0.866	-0.145	0.897	0.930
Finland	0.669	-0.752	-0.405	-0.030	0.609	0.664
France	0.644	-0.764	-0.626	-0.258	0.637	0.654
Germany	0.680	-0.718	-0.331	-0.001	0.333	0.426
Greece	0.027	-0.694	-0.782	0.278	0.286	0.528
Hungary	0.128	-0.257	-0.220	0.172	0.353	0.450
Ireland	0.317	-0.825	-0.645	-0.036	0.916	0.857
Italy	0.547	-0.702	-0.565	-0.096	0.451	0.521
Japan	0.634	-0.811	-0.758	-0.115	0.340	0.392
Latvia	-0.511	-0.784	-0.868	0.525	0.752	0.849
Lithuania	-0.102	-0.636	-0.569	0.260	0.749	0.713
Netherlands	0.575	-0.686	-0.400	-0.125	0.499	0.484
Poland	0.035	-0.780	-0.647	0.203	0.555	0.604
Portugal	0.339	-0.618	-0.556	-0.028	0.539	0.596
Slovakia	0.481	-0.430	-0.217	-0.105	0.339	0.317
Slovenia	0.724	-0.764	-0.561	-0.214	0.543	0.567
Spain	0.136	-0.838	-0.877	-0.430	0.889	0.808
United Kingdom	0.466	-0.713	-0.577	-0.354	0.803	0.780

Note: μp is the labour demand wedge, μw the labour supply wedge, and Δ = μp + μw. Φ is the inverse Frisch labour supply elasticity.

Table 4 shows point estimates of correlation of the three wedges with output and unemployment on HP-filtered cycles. The correlation of the second and the third wedge with output is negative for all countries. Graphically, our findings are illustrated in **Figure 21**, where we show the correlation between output cycle and wedge cycles at various leads and lags. The first row shows the correlation of GDP with the labour demand wedge, the second row with the labour supply wedge (for various values of ϕ), and the last with the total wedge. In each subfigure, we show the mean, median, and selected quantiles of dynamic correlations for our set of countries. Clearly, for most countries the total wedge is counter-cyclical and this is caused mainly by the dynamics of the second labour supply wedge. Hence, we confirm Karabarbounis' conclusions.

Figure 21


Corr(μ_t^p,U_{t-k})
Range
Intedecile range
Interquantile range
Mean
Median
Corr(μ_t^w,U_{t-k}) φ = 0.5
Corr(μ_t^w,U_{t-k}) φ = 1
Corr(μ_t^w,U_{t-k}) φ = 2
Corr(Δ_t,U_{t-k}) φ = 0.5
Corr(Δ_t,U_{t-k}) φ = 1
Corr(Δ_t,U_{t-k}) φ = 2
Corr(μ_t^p,Y_{t-k})
Range
Intedecile range
Interquantile range
Mean
Median
Corr(μ_t^w,Y_{t-k}) φ = 0.5
Corr(μ_t^w,Y_{t-k}) φ = 1
Corr(μ_t^w,Y_{t-k}) φ = 2
Corr(Δ_t,Y_{t-k}) φ = 0.5
Corr(Δ_t,Y_{t-k}) φ = 1
Corr(Δ_t,Y_{t-k}) φ = 2
k



4.2.5 Alternative views

Other attempts to provide an explanation for the counter-cyclical wedge rely on non-separable preferences, either between consumption and leisure (Hall, 2009) or between home and market production (Aguiar et al., 2013; Karabarbounis, 2014b). Yet another line of research tries to explain this stylised fact by heterogeneity of productivity across individuals (e.g. Chang and Kim, 2007 or Coble, 2015). Bils et al. (2014) offer a different perspective. They present evidence that the labour wedge also holds for self-employed workers, for which the matching or wage frictions should be small (in comparison to employees). They also analyse the cyclicality of other inputs (material, energy) and inventories. Relying on this evidence, they propose that the labour wedge may reflect not inefficiencies in the labour market, but rather inefficiencies in the goods market, such as sticky prices of final products that do not fall enough during recessions.

In any case, the research on labour wedges is a promising direction that yields powerful tests of competing structural macroeconomic models.

4.3 Financial frictions in a search model

We now turn to the implications of our second set of results from the QPM section, namely the effect of financial stress on low-frequency movements in output and unemployment. To this end, we must understand how Okun's law maps onto structural models. Recall that this law is simply a very robust regularity. However, from the point of view of structural models, it is an equation that summarises all the linkages between labour and goods markets as a relationship between their two main quantity indicators. This is clear when comparing QPM and a standard DSGE model (see **Table 2** again). Both share an IS curve, a Phillips Curve and a Taylor Rule. However, the DSGE model would also include a labour demand schedule and a labour supply curve that determine wages, a production function that links output with the labour inputs (hours and employment), and a resource constraint disciplining allocations. Essentially, all these relationships are folded into Okun's law in QPM. From this perspective, it is therefore quite remarkable that these multiple linkages merge into such a stable, simple correlation. It is also remarkable, as argued in the previous section, that it appears so difficult to reverse-engineer these channels (and their shocks) to fit this correlation.

Financial frictions add yet another dimension to DSGE models that would be subsumed under Okun's law. Accordingly, one can view our QPM exercise with banking stress as a means of shedding light on this extra dimension. We saw that banking stress appeared to operate at lower frequencies than the standard macro ones. We propose now to see what reverse engineering is needed to match this evidence.

4.3.1 Labour dynamics in the Gertler and Karadi model

There are models galore of financial frictions to choose from. We pick the Gertler and Karadi (2010) model, as it holds pride of place in central banks' policy instrumentarium, owing to its compelling view of the unfolding of events in the crisis and rationalisation of non-standard policy-making. Furthermore, it puts the onus squarely on banks: the financial friction operates at the level of financial intermediaries, not the end-users of funds, as is customary in first-generation Bernanke-Gertler-Gilchrist and Kiyotaki-Moore models. This concept seems to map better onto CISS, the variables we used in the QPM exercise, as this stress indicator reflects tensions in markets dominated by financial intermediaries. Of course the overlap is imperfect, but we suspend disbelief for a moment and assume, as in Gertler and Karadi, that only financial intermediaries may transfer funds from providers to users and that only they are the source of financial friction.

This model was clearly developed with the capital margin in mind. The underlying logic is that a negative shock to asset values reduces drastically the net worth of banks, prompting them to raise the required rate of return on claims they hold on the capital stock and curtailing investment. Thus begins the asset price spiral that dissolves only when banks have rebuilt their equity. One way to understand what is going on in this model is to reason in terms of average and marginal q. In a standard model of investment, marginal q is its shadow value and depends on its expected future marginal productivity, while average q is inconsequential (standard models do not track the market value of capital). In the Gertler-Karadi framework, however, the mechanism is flipped around. Average q is related to asset values, thus to the state of the balance sheet of intermediaries, since these own the claims to the productive capital stock. More specifically, average q is pinned down by bank leverage which, according to the asymmetric information setting, depends on current equity and future excess returns earned by the intermediaries. Thus investment dynamics are dominated not by expected future productivity of productive capital but by banking dynamics – a very different set of drivers. This feature enables Gertler and Karadi to recount accurately the depth of the stock market crash, the collapse of investment together with elevated risk premia and banking stress. Nevertheless, in the original Gertler and Karadi paper there is no mention of any labour market variable.

Accordingly, we revisit this model and adapt it slightly to uncover its implications for labour dynamics. The original model's labour block was bare-bones frictionless RBC; we add wage stickiness to obtain the standard wage Phillips curve (labour supply curve).

Figure 22

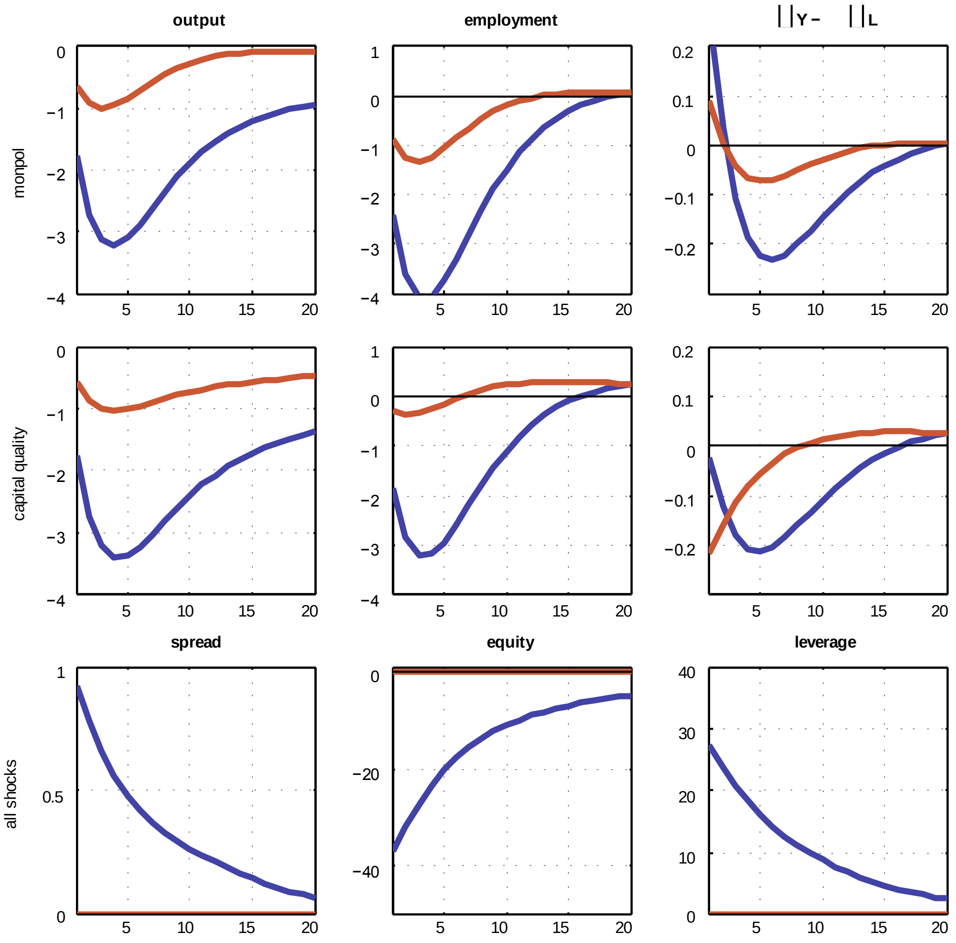


Figure 22 plots the impulse responses of output and employment to several shocks. The red line is the response of variables to shocks in the model with the banking friction switched off, the blue line with the friction on. The first line depicts the responses to a monetary policy shock. The output response that we obtain (already with wage stickiness) is identical to the one reported in the original paper: the presence of financial frictions greatly amplifies the response of output to a monetary tightening. What was missing was the second chart on the top line – the response of

employment. Clearly the same shock in the presence of frictions also causes massive unemployment relative to the benchmark (formally, lower equilibrium hours in this RBC setting). This arises because labour demand shifts inwards with the drop in capital; with sticky wages and a flat labour demand curve, employment drops dramatically.

The second line is the reaction to a capital quality shock, which according to Gertler and Karadi captures the exogenous decrease in the value of claims on productive capital – the sudden realisation that mortgages were rotten. Again, the response to output is identical to that in the original paper and shows the collapse in output that comes from the asset price spiral described above. We also plot the missing response to employment, which likewise drops considerably.

Finally, we note on the bottom line that banking variables – excess returns, equity and leverage – react identically to the two types of shock when the friction is operating: in the model, monetary tightening and bad apples are the same from the point of view of financial intermediaries.

Importantly in view of our QPM results, responses to these "crisis" shocks are lengthened in the presence of frictions. Thus, recoveries appear more protracted. In this sense, we can recover the idea that banking stress operates in the lower-than-average frequency space[30].

What interests us most, however, are the two charts in the last column, which plot the relative growth rate of output and employment – alternatively the growth of productivity. They measure the relative slope of the IRFs of the charts on the left. And they suggest that employment recovers much more quickly than output from the downturn. Thus, although the model can generate more persistent slumps than otherwise when frictions are operating, it cannot explain jobless recoveries. This feature is robust across many parameterisations and shocks, in particular these two shocks that best capture the essence of the Great Recession.

The logic is clear. Financial frictions on the capital margin tautologically make capital more expensive. Of course, labour collapses along with output as described above, but the frictions on the capital market decrease the cost of capital only slowly while banks demand high returns on their holdings (claim to capital) to rebuild their equity, leading firms to substitute towards labour. Interestingly, the model without frictions is also unable to explain jobless recoveries (although to a lesser extent – see the red lines). The reasoning is similar: investment adjustment costs also smooth the capital build-up, leading firms to substitute towards labour. Thus it is not so much the presence of frictions that accounts for this feature, but the fact that capital is a stock subject to adjustment costs, while labour is a flow.

[30] Clearly, we would never be able to recover a full unit root response from a cyclical DSGE model.

4.3.2 Intermediary frictions in a standard search model

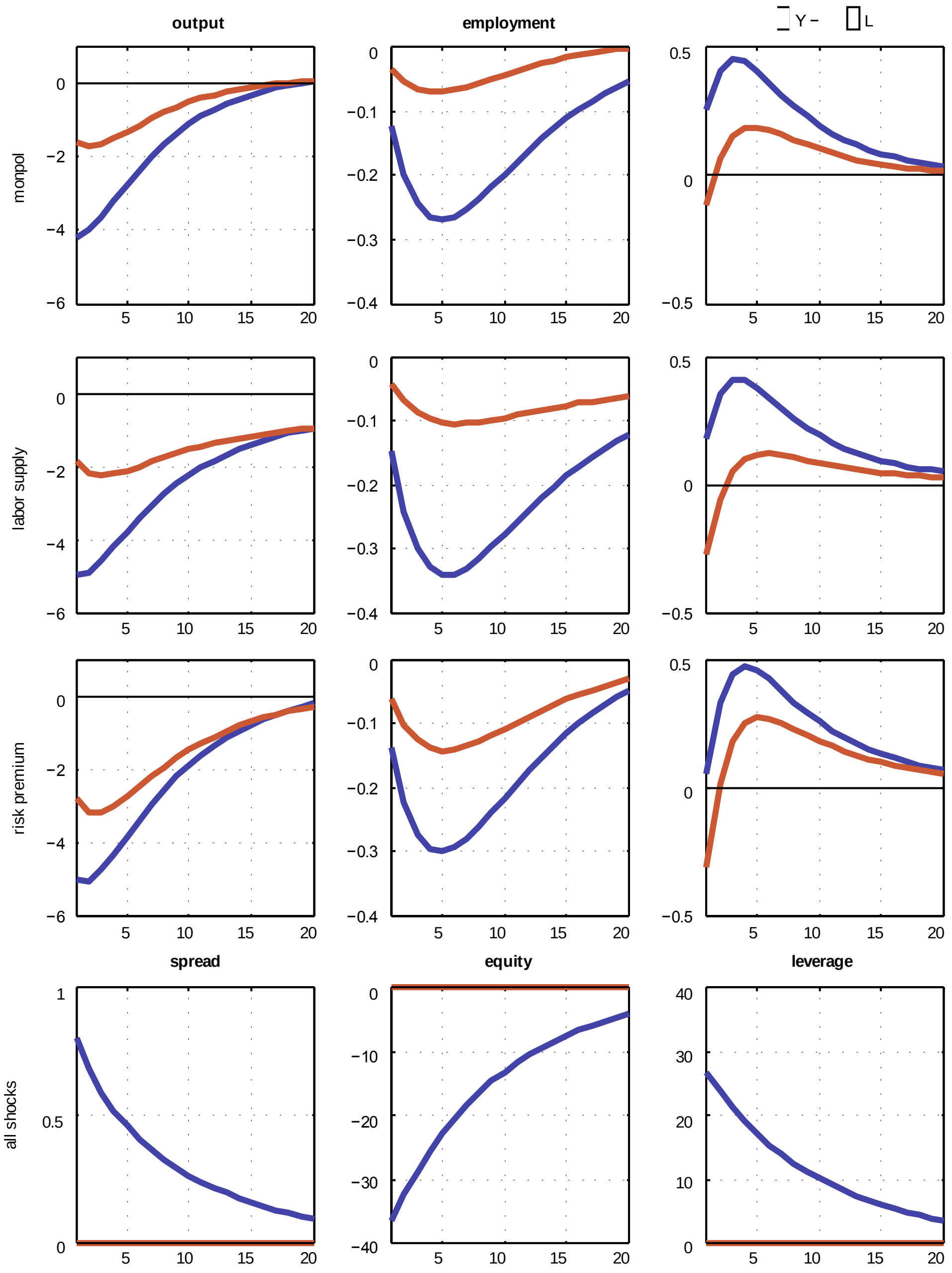
This analysis suggests introducing financial frictions on the labour margin directly. As we noted in the literature review of this section, such models are few and far between. We propose now to adapt the Gertler-Karadi model just described to a setting with search and matching frictions and investigate the consequences of such a modelling choice. This adjustment turns out to be surprisingly simple, once two issues are accounted for.

First, the connection between a labour search model and a standard RBC model of capital is far tighter than their idiosyncratic vocabulary suggests. A search model characterises the employment margin as a stock subject to inflows (matches) and outflows (separations), in clear parallel to capital, investment and depreciation. Accordingly, labour-firm optimisation links vacancy openings (hence matches) to the shadow value of a job, just as capital-firm optimisation relates investment to its shadow value. Furthermore, these shadow values are expected discounted marginal productivities of the relevant stock. Finally, with homogeneity of production and cost functions, firm valuation is the market value of its productive asset (shadow price times stock). That is, average q equals marginal q.

Second, in the Gertler-Karadi set-up, the friction operates at the level of financial intermediaries whose sole purpose – from the dynamic, not normative, point of view – is to request excess returns over their cost of funds. Intermediaries compute these returns from trading claims to the stream of profits of the asset in place. Whether the latter is capital or labour – or inventories, or land, or housing, for that matter – is immaterial. Hence the punchline: in complete parallel to the set-up for capital, job creation in this adaptation is pinned down by marginal q, which in turn is determined not by marginal labour productivity but by intermediaries' leverage and spreads.

There are nevertheless several modelling choices to be made. In particular, we opt for one with no capital, but a meaningful choice of hours (the intensive margin). We must then select how the latter are derived: by efficient bargaining (where hours are negotiated jointly with wages) or by right-to-manage (determined by the firms' wage schedule). It turns out that the results presented in Figure 23 for output and employment are robust to a large parameter space and to the bargaining scheme. We show below the IRFs from a version with right-to-manage. To complete the parallel with the capital version of the model, note that employment takes the role of capital as a stock, while hours assume that of labour input as a flow. The annex gives some of the details of the relevant relationships.

Figure 23



In **Figure 23**, we show the impulse responses of the same variables as in **Figure 22**. We dispense with analysis of the banking variables, shown on the last line, as they react identically to shocks as in the capital version of the model. Responses to a contractionary monetary policy shock are displayed on the top line. As in the capital-based model, the presence of frictions at the intermediary level amplifies the responses of output and employment considerably. Furthermore, it appears that the relative drop in employment is larger than that in output. Clearly, in light of the analysis above, the important chart is the third one, showing that output recovers much faster than employment: a jobless recovery is the benchmark, further amplified when frictions operate.

In this model without capital, the equivalent disturbance to the capital quality shock is a shock to labour supply. This sounds unintuitive, but the capital quality shock functions like a drop in utilisation: a fraction of any physical unit of capital is shut down for productive purposes, which is akin to a shock to capital supply. Utilisation is the intensive margin of capital, as hours are to labour. An exogenous drop in hours effectively shuts down a fraction of employment for productive purposes. Therefore, the exogenous shock to labour supply that we show on the second line is the appropriate equivalent. Responses are of the same nature: output drops considerably in the presence of frictions, employment even more so, and recoveries are jobless.

Finally, we show a shock to the risk premium. This shock can be interpreted as an increase in the spread of alternative assets that are not formally modelled (the capital stock) over the safe rate, and is another way to interpret the crisis in this labour-based model. Again, responses are as above.

4.3.3 Comments

We have just shown that DSGE models with financial frictions tend to deepen and lengthen responses of output and unemployment to shocks that are proximate causes of a financial downturn. Such increased persistence is precisely what would cause a trend-cycle filter such as a QPM to interpret events following a banking crisis as a trend development rather than a cyclical one. This ties in nicely with our results in the QPM section. Of course, this result is not new: Laeven and Valencia (2013) highlighted the special nature of recessions ignited by financial factors on a large panel of annual data. We have added to this body of work by providing more econometric and theoretical back-up.

Furthermore, as mentioned in Section 1, Laeven and Valencia pointed out that recoveries from financial recessions tend to be jobless[31]. Calvo, Coricelli and Ottonello (2012) suggested that this feature depends on the nature of the friction involved. We have just shown in fully-blown DSGE models with the same friction operating on different margins that this is indeed a powerful test to discriminate among competing versions of financial frictions. In particular, models with frictions on the capital margin are structurally unlikely to generate jobless recoveries. In contrast, models with frictions on the labour margin can increase volatility and persistence of unemployment relative to output.

The friction we presented, operating through intermediaries, also ties in nicely with the large body of micro-labour work of Davis and Haltiwanger over the years, showing how job creation tends to happen in small and young firms, precisely those which are likely to have to fund themselves via intermediaries rather than on the market directly. A recent paper that provides direct evidence of this effect is Popov and Rocholl (2015) who, within a quasi-controlled experiment on German data, track employment growth in firms with credit relationships with banks under duress.

[31] Although, note that Ball et al. (2013) dispute this characterisation for the Great Recession in the US.

We set up this analysis pitting one margin against another. Another possibility is for all margins to be affected by financial frictions at the same time. Much work done by Stiglitz and Greenwald in this vein decades ago appears to have been forgotten. It could be fruitfully revived, along the many models of frictions applied to capital margins waiting to be adapted to labour (see references in the WGEM reports on financial frictions from a few years ago).

5 Concluding remarks

In order to draw conclusions from the above analysis, it is useful to recall the paper's objectives. The WGEM's mandate required that the team "…investigate the potentially time-varying nature of the relationship between output and unemployment (Okun's law) … re-assess labour market modelling strategies in the macroeconomic models maintained within the ESCB and of their underlying empirical relationships … review alternative strategies for modelling unemployment (incl. search and matching frictions) with a view to assessing their ability to explain slow (and possibly jobless) recoveries".

Our analysis suggests that Okun's law is a very tight relationship at cyclical frequencies – across time, countries and methods of cyclical identification. In particular, it appears to survive the Great Recession unscathed. Its robustness is remarkable given the multi-dimensional disruptions in labour and goods markets reported in the cross-sectional work alluded to in the introduction. It is even more so given its simplicity, as it summarises in a single equation so many theoretical inter-linkages between goods and labour markets. None other than the current Fed Chair testified recently to the importance of this rule of thumb as an input to policy-making[32].

Nevertheless, cycles are only one component of the variable of interest. Stability in cycles does not imply stability in trends, as evidenced by estimated slowdowns in potential output growth in some countries in the past few years. In a more developed framework, we uncover some relationship between measures of financial stress and this slowdown, in particular for the euro area.

We then analyse to what extent the latest generation of labour macro-models can match these features of the data. First, it turns out that the tightness of Okun's law is surprisingly difficult to reproduce structurally. This result indicates that labour macro-modelling fails at the most basic level, and militates in favour of redoubling research efforts in this direction. Second, we emphasise that structural modelling of financial frictions on the labour margin is still in its infancy. We offer one possible reading of the empirical evidence, through the lens of a model of banking frictions. This field of research is still wide open and likely to bear fruit quickly.

We end with a word of caution and two apologies.

First, it is tempting to read our story as suggesting that addressing "banking" frictions would suffice to exit the slow growth/high unemployment path the euro area appears to be embarked on. One should be wary, however, of jumping to such a conclusion. Empirically, we uncovered correlation, not causation. Structurally, we constructed a model that would indeed reproduce this correlation as a product of causation. But we have not ruled out alternative explanations for the potential slowdown, and there is

[32] In her speech last March, Janet Yellen (2015) appeals directly to Okun's equation (1) to argue that the current monetary policy stance is neutral.

nothing in our empirical and theoretical set-up that is incompatible with the structural reform agenda promoted by European institutions, whether in the banking sector or labour markets. Our model does highlight a hitherto overlooked by-product of non-conventional measures, namely that they may address protracted unemployment directly rather than indirectly via the capital margin. But such measures, while necessary, are not sufficient.

Second, this paper has been exclusively about quantities in the goods and labour markets – output and unemployment. There has been no reference to their relative price, namely the real wage. As we argued above, Okun's law subsumes the behaviour of wages. Therefore, a priori, the latter are likely to have empirically little to say about the former. Inversely, the former may indeed have much to say about the latter. Investigating this point would have required doubling the length of the report.

Third, the analysis has focused entirely on the unemployment rate, rather than its level, and we have omitted any reference to the participation decisions of households, whose behaviour is crucial for both positive and normative considerations in the light of the crisis. More to the point, from an accounting point of view the unemployment rate is equally determined by the dynamics of employment and by developments in households' participation[33]. Therefore, to properly separate out the contribution of employment dynamics from that of households' participation, all of the empirical results we conducted would have to be re-run with the employment level replacing the unemployment rate. Addressing this dimension would have quadrupled the length of the paper.

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[33] One can write output per capita as:

$$\frac{Y}{N} \equiv \frac{Y}{E}\frac{E}{P}\frac{P}{N} = \frac{Y}{E}(1-u)p$$

where *N* is total population size, *Y/E* is labour productivity (output per employee), 1-*u*=*E/P* is the employment rate (employment per labour market participant), and *p*=*P/N* is the participation rate out of the total population. From this decomposition it is clear that the unemployment rate *u* is determined by *E* and *P* in equal measure.

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Annexes

Bivariate model descriptions

For the UC model, the observable vector consists of log-GDP and the unemployment rate (in percent). The state-space representation is as follows:
$\begin{bmatrix} lnY_t \\ U_t \end{bmatrix} = T_t + C_t$

Where trends follow uncorrelated random walks (with drift)
$\Delta T_t = \begin{bmatrix} \mu_y \\ \mu_u \end{bmatrix} + \begin{bmatrix} \epsilon_{yt} \\ \epsilon_{ut} \end{bmatrix}$

the output cycle is an exogenous AR(2) process, $C_{yt} = \rho_1 C_{yt-1} + \rho_2 C_{yt-2} + u_{yt}$

and the unemployment cycle is an MA(3) process in the output cycle (to capture lags), $C_{ut} = \phi_0 C_{yt} + \phi_1 C_{yt-1} + \phi_2 C_{yt-2} + u_{ut}$

This model is estimated with Bayesian methods.

For the Blanchard-Quah model, a vector auto-regression is set up in output growth and unemployment:
$A(L) \begin{bmatrix} \Delta lnY_t \\ U_t \end{bmatrix} = \epsilon_t$

The VAR is inverted to obtain the Wold decomposition (MA(∞)):
$\begin{bmatrix} \Delta lnY_t \\ U_t \end{bmatrix} = [A(L)]^{-1} \epsilon_t$

To extract the demand shock, we impose that it has no long-run effect on output:
$[A_{12}(1)]^{-1} = 0$

This model is estimated using the Shapiro and Watson method with instrumental variables.

QPM description

The observable vector X_t^{obs} consists of (log)-output, the unemployment rate, the GDP deflator, the policy rate, and the indicator of financial stress. The state-space representation is that of a multivariate unobserved components model:
$X_t^{obs} = X_t^T + X_t$

where trends follow uncorrelated random walks (with drift μ and possible AR terms)
$\mathrm{A(L)} \Delta X_t^T = \mu_t + u_t$

The cyclical components in X_t reflect different relationships loosely derived from economic theory. In particular:

- an IS curve, $E_t(1 - \rho_y L)(1 - \phi_y F) y_t = \alpha_{yr} r_t + \epsilon_{yt}$

  where the real rate is $r_t \equiv i_t + E_t \pi_{t+1}$,

- a Phillips curve: $E_t(1-\rho_\pi L)(1-\phi_\pi F)\pi_t = \alpha_{\pi y} y_t + \epsilon_{\pi t}$

- a Taylor rule (when the country is modelled as a closed economy)
$$(1-\rho_r)(i_t - r_t^T - \pi) = \alpha_{i\pi}\pi_t + \alpha_{iy} y_t + \epsilon_{it}$$

or alternatively a UIP condition (for a country within the euro area)

$$i_t = i_t^F = r_t - E_t\pi_{t+1} = r_t^F - E_t\pi_{t+1}^F$$

- An Okun's law in dynamic form
$$E_t(1-\rho_u L)(1-\phi_u F)u_t = \alpha_{uy} y_t + \epsilon_{ut}$$

These equations characterise the benchmark QPM. When we add the financial stress indicator, we model it as a cyclical process with leads and lags which we cleanse of cyclical fluctuations by regressing on the output gap:
$E_t(1-\rho_b L)(1-\phi_b F)b_t = \alpha_{by} y + \epsilon_{bt}$

We then use the residual ϵ_{bt} as a regressor either in Okun's law and the IS curve:
$E_t\big(1-\rho_y L\big)\big(1-\phi_y F\big)y_t = \alpha_{yr} r_t + \alpha_{yb}\epsilon_{bt} + \epsilon_{yt}$

$E_t(1-\rho_u L)(1-\phi_u F)u_t = \alpha_{uy} y_t + \alpha_{ub}\epsilon_{bt} + \epsilon_{ut}$

or in the trend components of output and unemployment:
$\mathrm{A(L)}\Delta y_t^T = \mu_{yt} + \alpha_{yb}\epsilon_{bt} + u_{yt}$

$\mathrm{A(L)}\Delta u_t^T = \mu_{ut} + \alpha_{ub}\epsilon_{bt} + u_{ut}$

Mapping of basic search model into RBC framework

We provide the mapping for the steady state. The search model's key ingredients are:

- A job creation condition, equating the firm's flow cost of posting a vacancy to the expected marginal profit from filling the job (marginal product minus wage, times probability of filling the job, which depends on market tightness): $c = p(\theta)(mpl - w)$

- A surplus sharing rule from Nash bargaining, according to which the worker is paid a share of the profit above his or her outside option (the marginal rate of substitution), with this share increasing in his or her probability of finding a job: $w = mrs + \delta(q(\theta))(mpl - w)$

- A Beveridge curve, equating labour inflows and outflows, where $U = 1 - \mathrm{L}$ is unemployment, s the separation rate, and $\mathrm{q}(\theta)$ the job-finding probability: $q(\theta)(1-L) = sL$

- A matching function relating vacancies to unemployment, and thus market tightness to employment, where $\mathrm{p}(\theta)$ is the vacancy-filling probability: $q(\theta)(1-L) = p(\theta)V = p(\theta)\theta(1-L)$

It should be clear from the last two equations that market tightness is increasing in employment. Furthermore, re-arrangement of the job-creation conditions shows we can interpret it as a labour demand curve with a mark-up of marginal product over wage equal to the vacancy cost discounted by the vacancy duration: $mpl = w + \frac{c}{p(\theta)}$

Finally, substituting the job-creation condition in the wage determination equation yields a pseudo-labour supply curve with a mark-up of wage over marginal rate of substitution reflecting the worker's outside options: $w = mrs + \delta(q(\theta))\frac{c}{p(\theta)}$

Since job-filling and job-finding probabilities are decreasing and increasing in market tightness, respectively, both mark-ups are themselves increasing in tightness, hence in employment.

Gertler-Karadi model applied to search and matching.

For the model of Section 3, we describe only the equations that differ from the standard search and matching framework. First, we take directly Gertler and Karadi's set-up for banks. The crucial relationships are that:

- Leverage ϕ is defined as the ratio of assets QS to equity N. With the number of claims on assets S normalised to *1*, the price of a claim is $Q_t = \phi_t N_t$
- Leverage is an expected forward function of the household's discount factor Λ and the excess return over the safe rate $R_n - R$, $\phi = E_t F(\Lambda_{t,t+1}, R_{nt} - R_t)$
- Equity accumulates with excess returns on assets $N_t = (R_{nt} - R_t)Q_{t-1} + R_t N_{t-1}$
- Banks' realised required return is defined as $R_{nt} = \frac{D_t + Q_t}{Q_{t-1}}$

On the production side:

- Firms maximise cum-dividend value $V_t^c = Q_t + D_t = \sum_{i=0} \Lambda_{nt,t+i} D_{t+i}$
- Dividends are output net of wage bill and vacancy costs $D_t = a_t L_t - w_t L_t - cV_t$
- Since claims are held exclusively by banks, the relevant discount rate is theirs $\Lambda_{nt,t+1} = 1/R_{nt+1}$
- The shadow (marginal) value of a job is the excess of productivity over the wage paid plus tomorrow's value discounted by the firm's discount rate and survival rate of the match $(1 - \rho)$, $J_t = a_t - w_t + (1 - \rho)E_t \Lambda_{nt,t+1} J_{t+1}$

Homogeneity of production and costs yields that labour's marginal value equals its average value (marginal *q* equals average *q*): $J_t = \frac{V_t^c}{(1-\rho)L_{t-1}}$

Yet, since $V_t^c = Q_t + D_t = R_{nt} Q_{t-1}$, we have $J_t = R_{nt} \frac{Q_{t-1}}{(1-\rho)L_{t-1}}$

Thus, since Q_{t-1} and L_{t-1} are predetermined, the value of a job is pinned down by the required rate of return of banks – which, from the banking block, will depend on future leverage (thus excess returns), and past equity – rather than the present discounted value of profits $a_t - w_t$, as is usually the case in the search model.

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