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Band spectrum regression on ten countries, 1913-2016

Hegelund, Erik; Taalbi, Josef

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PO Box 117
221 00 Lund
+46 46-222 00 00

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DEPARTMENT OF ECONOMIC HISTORY, LUND UNIVERSITY

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What determines unemployment in the long run? Band spectrum regression on ten countries 1913-2016*

Erik Hegelund† and Josef Taalbi‡

April 9, 2019

Abstract

This paper presents an empirical analysis of the relation between unemployment and macroeconomic performance. A strong correlation has been pointed out before, but a crucial question is over what time-horizon this holds. To the best of our knowledge, no previous cross-country study has shown that there is a long-run relationship between unemployment and macroeconomic performance over a time-period that stretches before the 1960s. To address this issue, we use wavelet analysis to decompose the time series into short, medium and long-run variations, and band spectrum regressions on the relation between unemployment, GDP, investment, long-term interest rate and TFP, covering ten countries 1913-2016. This methodology has several advantages compared to standard econometrical methods and other tools for decomposition. Our results show that unemployment correlates negatively with the long-run components of investment. This suggests that aggregate demand and capital formation influence long-term labor market outcomes. According to our estimates ca 17-percent of overall variations in unemployment and 29 percent of the long-run variations may be explained by long-run variations in capital formation.

1 Introduction

This paper presents an analysis of the correlation between unemployment, capital formation, GDP, long-term real interest rate and productivity, using band spectrum regression on time series, decomposed using wavelet analysis.

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†PhD Candidate, Department of Economic History and International Relations, Stockholm University. erik.hegelund@ekohist.su.se.

‡PhD, Department of Economic History, Lund University. josef.taalbi@ekh.lu.se

The relationship between unemployment and aggregate demand is well-known (Okun, 1962). However, there is considerable disagreement on how important these effects are over different time-horizons; and to what extent these correlations hold over different time-periods.

One central issue is to what extent exogenous shifts in macroeconomic performance may affect unemployment in the long run. Despite empirical indications of this in earlier studies, several influential theoretical works, such as Layard *et al.* (1991, 2005) and Pissarides (2000), argue that fluctuations in capital, growth and productivity should only affect labor market outcome in the short to medium run. Long-run correlations between unemployment and macroeconomic performance are however suggested by different types of theories, for instance if there are multiple equilibria in the labor market (e.g. Farmer, 2012).

The more long-term correlation with capital formation is mentioned as the "Modigliani puzzle" by Blanchard (2000), with reference to Modigliani (2000). Herbertsson and Zoega (2002) estimate the correlation between unemployment and capital formation using a sample of OECD countries 1960-1997 and common measures of labor market institutions. Stockhammer and Klär (2011) present a similar study, using more data, including different common measures of shocks. Both studies find that capital formation seems to be one of the factors, among a sample of macroeconomic measures and institutions, that correlates most strongly with unemployment in different samples of OECD countries for the period 1960 onward.

Similar results are found in Arestis *et al.* (2007) for the EMU countries (cf. Arestis and Sawyer, 2005); Karanassou *et al.* (2008) for the Nordic countries; and Bande and Karanassou (2014) for Spanish regions. Several studies also argue that main drivers behind unemployment in OECD countries from 1960 onward are different kinds of shocks, often in interaction with labor market institutions (Blanchard and Wolfers, 2000).

While there is hence a literature indicating a relationship, there is no consensus on what to make of the correlations between unemployment and macroeconomic performance, when acknowledged. Herbertsson and Zoega (2002) argue that these results are in line with standard equilibrium unemployment theory, if labor is viewed as a (quasi) fixed asset, which adjusts to low frequency variations in investment (Oi, 1962). Stockhammer and Klär (2011) claim that this supports a Post-Keynesian theoretical framework, where equilibrium unemployment is an endogenous result of unemployment outcome, driven by exogenous shifts in aggregate demand, or specifically capital formation. In line with this, Smith and Zoega (2009), building on Keynes (1937), argue that one important factor behind shifts in investment might be psychology, "animal spirits", and that this also is a main driver behind employment.

We expand on these topics using an unbalanced panel dataset going back to 1913, constructed from national accounts. While correlations between unemployment and macroeconomic performance have been observed, most studies seems to use data on OECD-countries 1960 onward. One of few exceptions include Hatton (2007) which studies United Kingdom 1877-1999. No other study, as far as we are aware of, has shown this to be a more long-run correlation. This makes the argument susceptible to the suspicion that the relationship holds only for relatively short- to medium-run variations, or only for a specific time-period.

Using a band-spectrum regression method allows us to test whether the relationship between unemployment and macroeconomic performance may be a short, medium or long-run, in greater detail than studies using standard econometrics. Using a longer time period than most studies on the subject, allows us to discuss whether these correlations hold over different time-periods.

Our results indicate statistically robust negative correlations between unemployment and investment over medium to long time periods. This would confirm the findings in some earlier studies, but also contest several influential ideas in both research and policy. While there are different theories and mechanisms that can explain such long-run relationships, the corollaries of these results are important since they suggest that private or public investment decisions and policy ambitions stimulating aggregate demand have a lasting effect on labor market outcomes.

While the standard methodology of deriving long-term variations in unemployment has been to use filtering methods, newer decomposition methods have emerged with wavelet analysis, allowing for decomposition of time series in short-, medium and long-run variations (Percival and Walden, 2006). Gallegati *et al.* (2011) uses wavelet analysis to estimate the long-run Phillips curve. Similarly, Gallegati *et al.* (2014) found a robust correlation between productivity and unemployment on a scale by scale basis for the USA 1948-2013. Gallegati *et al.* (2015) find a robust correlation between unemployment and productivity over short and long run using wavelet analysis for the G7 countries 1962-2012, with positive correlation for short-run terms, and negative for long-run.

Our approach is similarly based on wavelet decomposed time series, but estimates band spectrum regressions in order to specify a fuller econometric model and control for other variables as well as fixed effects (cf. Andersson, 2016).

Common explanations of long-run variations in unemployment refer to labor market institutions as determinants of long-run equilibrium (see Bassanini and Duval 2006, Baker *et al.* 2005 and Eichhorst *et al.* 2008 for literature reviews). As part of our robustness analysis we also test regression models using data on labor market institutions for the period 1960-2014.

The rest of this paper: Section 2 give a brief overview of some key theoretical aspects. Section 3 describes our data. Section 4 describes our methods, wavelet decomposition and band spectrum regression. Section 5 presents our empirical results and section 6 makes some concluding remarks.

2 Theoretical framework for equilibrium unemployment

There is a well-known possible connection between demand shocks and unemployment in the short to medium run, often described as a deviation from long-run equilibrium unemployment. The return to equilibrium may take long time, due to hysteresis/persistence (Roed, 1997).

Hysteresis may be caused by several factors, such as capital formation, e.g., if firms reduce their capital stock and prices or technology does not adapt fast enough (Drèze and Bean, 1991). A recent argument in this vein is found in Galí (2015, 2016) who argue that the unemployment rate in Europe 1970-2014 does not fit any structural equilibrium unemployment theory, and instead suggests that a New-Keynesian DSGE model with strong hysteresis better fits the data.

One may also expect a long-run negative correlation between unemployment and growth or between unemployment and capital formation, if labor and capital is harder to substitute in production. Rowthorn (1999) illustrates how the wage- and price-setting equation framework in Layard *et al.* (1991), but instead of their Cobb-Douglas production function uses a CES production function and substitution elasticity below one ($\sigma < 1$), results in a negative long run correlation between unemployment and capital formation (cf. Rowthorn, 1977, 1995).

Kapadia (2005) gives a similar example using a Cobb-Douglas production function, taking capacity utilization into account, where returns to labor vary depending on capital-intensity. Sigurdsson (2013) show how a negative long run relationship between unemployment and capital formation can be expected within a two sector search and matching model, with capital production and CES production, $\sigma < 1$. Christodoulakis and Axioglou (2017) derive a negative relation within an overlapping generations model with labor market frictions, for both a Cobb-Douglas production function, and a CES with $\sigma < 1$.

Another argument for a connection between equilibrium unemployment and exogenous shifts in aggregate demand is if we have multiple equilibria in the labor market. Common search- and matching models (Pissarides, 2000), and wage- and price-setting equations frameworks (Layard *et al.*, 2005) are often described as having one unique equilibrium, determined by long term exogenous institutional factors, affecting wage and price flexibility and bargaining, matching technology and competition in goods and service markets. In the case of multiple equilibria the present long-run equilibrium may be described as an endogenous outcome of actual unemployment. Many arguments for this has been proposed in different settings (Blanchard and Summers, 1988).

In common versions of the search and matching models, there may exist multiple equilibria, for instance due to external effects in the search process, or increasing returns in the search and matching process, or production technology (Mortensen, 1989; Diamond, 1982; Weitzman, 1982).

The presence of hysteresis may also result in multiple equilibria due to external effects, such as when unemployment increases, the expected profitability of posting extra vacancies decreases and thereby shift long-run equilibrium unemployment, even if the newly unemployed eventually leave the labor force (Pissarides, 1992). Manning (1990, 1992) shows how increasing returns in the production technology and imperfect competition between companies may result in multiple equilibria in a static price- and wage-setting equation model.

If multiple unemployment equilibria exist, and capital formation may shift for psychological reasons, i.e. "animal spirits", Farmer and Nicolò (2018) argue that these psychological shifts may be considered a long-term fundamental factor, which result in self-fulfilling expectations, which thereby also alter unemployment in the long run.

Equilibrium unemployment, case 1: To sum up the different theories above, we may describe two cases. Case 1 being that unemployment at time t, u_t, could theoretically be described as consisting of a short-run $\left(u_t^{SR}\right)$, medium-run $\left(u_t^{MR}\right)$ and long-run $\left(u_t^{LR}\right)$ component. According to standard equilibrium theory described above, unemployment in the short run is the result of short-run macroeconomic performance, m_t^{SR}, such as production, investment and productivity. If we have hysteresis in the labor market, we may have correlation between unemployment and different macroeconomic measures over at least the medium run. Long-run unemployment equilibrium is the result of structural and institutional factors, X_t (e.g. Pissarides, 2000; Layard *et al.*, 2005)

$$u_t = u_t^{SR} + u_t^{MR} + u_t^{LR} \tag{1}$$

$$u_t^{SR} = \alpha_1 m_t^{SR} \tag{2}$$

$$u_t^{MR} = \alpha_2 m_t^{MR} + \alpha_3 u_t^{LR} \tag{3}$$

$$u_t^{LR,\text{ Case 1}} = \alpha_4 X_t \tag{4}$$

Equilibrium unemployment, case 2: But if we allow for long-run equilibrium unemployment, u_t^{LR}, to be affected by shifts in long-run macroeconomic performance, m_t^{LR}, e.g., variations in long-run capital formation, k_t^{LR}, e.g. due to labor and capital being complements in the production process (cf. Rowthorn, 1995), we may instead describe it as:

$$u_t^{LR,\text{ Case 2}} = \alpha_4 X_t + \alpha_5 m_t^{LR} \tag{5}$$

where we still may assume a unique long-run equilibrium unemployment. If we assume that exogenous psychological shifts ("animal spirits") is an important factor behind long-run capital formation k_t^{LR}, this is a similar story to the argument that short-run shocks pushes the unemployment rate between multiple equilibria (cf. Farmer, 2012).

3 Data

To estimate our model we use an unbalanced annual panel dataset for ten countries, covering at most 1913-2016 for Australia, Belgium, Canada, Denmark, Finland, Netherlands, Norway, Sweden, UK and USA. Our dependent variable is the unemployment rate, for which data is taken from OECD for the years 1956-2016 for all countries, using the standard measure, covering 15-74-year-olds. By adding the change in older observations to the OECD data, we are able to construct longer time series indicators for this variable. Some older data consists of unemployment rates for members in trade unions or unemployment insurances, which we adjusted downward in accordance with earlier studies. See table 4 for sources. Linear interpolation was used to estimate values for Belgium 1914-1920 and 1940-1944; Canada 1914-1915; and Norway 1942-1945.

Data on total factor productivity was taken from Bergeaud *et al.* (2016). Data on GDP growth, investment as percent of GDP, long-term interest rate and inflation is taken from Jordà *et al.* (2016), where we use their nominal interest rate and inflation to construct the real rate. We use gross fixed capital formation from Groote *et al.* (1996) to estimate investment ratios in the Netherlands during the world wars. Linear interpolation was used to estimate investment ratio for Denmark for 1915-1921, for Norway 1940-1945 and for Belgium 1914-1919, 1940, 1942, 1944, and 1945.

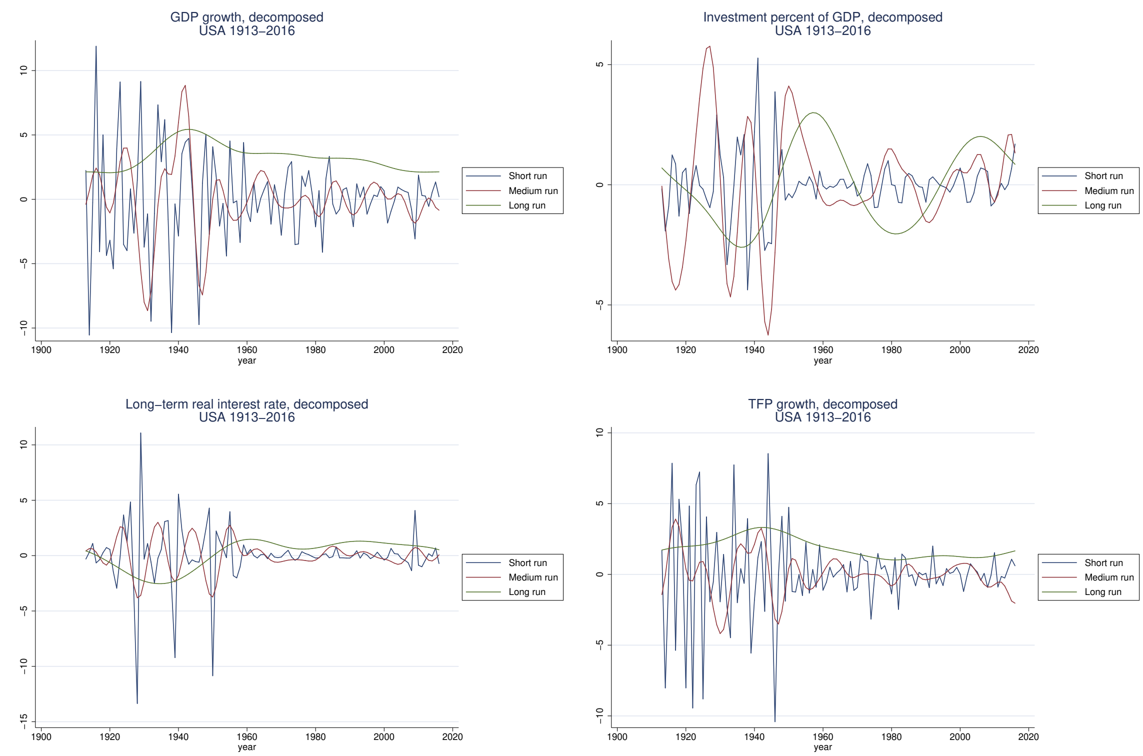
Labor market institutions include wage bargaining level, coordination and centralization (variables "level", "coord" and "cent" from Visser, 2016), collective bargaining coverage ("adjcov" from Visser, 2016), union density ("ud" and "ud_s" from Visser, 2016, linked), unemployment gross replacement rate ("grr" from OECD, average of their two measures when applicable, and otherwise linked). Many institutional measures of this kind are measured every second year or even more seldom. From the 440 original observations we used linear interpolation to add 243 observations to the bargaining coverage measure, 32 observations to the centralization measure and 200 observations to the gross replacement rate measure. Our estimates for these variables are mainly used for comparison with earlier studies. All of these institutional variables, or similar ones, as well as the econometrical approach used here, are common in earlier studies (Bassanini and Duval, 2006; Eichhorst *et al.*, 2008). Panel stationarity is for some of these only supported when using data for later years, and we therefore focus on this time period in our empirical analysis.

Summary statistics of main variables are presented in table 3 and descriptive graphs are found in figure 3. Decomposed series, with three components each, are shown for GDP growth, capital formation as percent of GDP, long-term real interest rate and TFP growth in figure 1.

As is clearly visible in our data, the early period, covering the world wars and The Great Depression, was more tumultuous in most countries than later years. Also visible in the graphs, is that the period after World War 2 up until around 1975, when unemployment rates were relatively low, correlate with a peak in investment as percent of GDP. Investment increases after the wars, remain high for some time and towards the end of the time period there is a somewhat new shift, where investment decreases somewhat and unemployment increases.

All variables are tested for cross sectional dependence using Pesaran (2004) general test. Results indicate, statistically significant cross sectional dependence for all our main variables. All variables are tested for panel unit roots using Im-Pesaran-Shin (IPS) and Fisher Dickey-Fuller (FDF). Test results for panel stationarity for the investment ratio (k) is somewhat sensitive to the selection of countries and therefore treated as non-stationary and detrended, see below. Decomposed series for k are shown in figure 1 using three components, where the longest wave-component excludes the trend-component for these two variables. The treatment of k as stationary or not does not seem to affect overall results

Figure 1: Examples of wavelets



Source: see text.

presented here (additional results available upon request).

4 Method

4.1 Wavelet decomposition

To study relationships in terms of frequency bands on time series data, we use a band spectrum regression approach on the basis of wavelet transforms of the explanatory variables. Wavelet decomposition has considerable advantages in the context of detecting cycles in economic data compared to other common methods. As opposed to traditional Fourier analysis, which are local only in frequency, but not in time, wavelets are local in both frequency and in time. The Fourier transform also assumes that time series repeat themselves deterministically. By contrast, wavelet transforms allow for time series whose underlying process may change over time. For introduction to the use of wavelet decomposition on time series, see Andersson 2008, 2016; Crowley 2007; Percival and Walden 2006.

A wavelet transform $\mathcal{W}$ transforms a time series vector $\mathbf{X}$ of length N from the time domain to the frequency domain, as $\mathbf{W} = \mathcal{W}\mathbf{X}$, with $\mathbf{W}$ a column vector of length N. Commonly the Haar and Daubechies filters are used, whose coefficients make up the transform matrix. A multiresolution analysis, decomposing the time series in the time domain, can be obtained by reversing the process (see e.g., Percival and Walden 2006 for details). In our case the multiresolution analysis decomposes the time series y_t into $J+1$ number of components

$$y_t = D_{1t} + D_{2t} + ... + D_{Jt} + S_t \tag{6}$$

where D_j for $j \in \{1, 2, ..., J\}$ are details and S is a smooth trend. Each component D_{jt} of the time series y_t has frequency bands $\frac{1}{2^{j+1}}$ to $\frac{1}{2^j}$ i.e. cycles with length 2^j to 2^{j+1}. Hence, the first detail consists of cycles lasting 2-4 years, the second 4-8 years, etc.. The present analysis employs the maximum overlap discrete wavelet transform (MODWT) using the Daubechies wavelet basis function and $J = 5$. We decompose our time series in three parts, which we call short, medium and long run, defined as 2-8 year fluctuations, 8-32 year fluctuations and 32+ year fluctuations. Since the real interest and investment ratio is non-stationary, we measure long-run cyclical variations with the use of the 32-64 year fluctuations. Main regressions results for k are similar also when the trend-component, S_t, is included in our long-term cyclical component. As a robustness test we also run our regressions using five to six wavelet components.

Discrete wavelet transforms allow a decomposition of variance (also called energy decomposition), which can be used to understand to what extent different cycles in the series contribute to the overall variation in the dependent variable. One of our main variables of interest is investment as percent of GDP. Our results for investment suggest that between around 25-50 percent of the variation in investment is accounted for by long-run variations (see table 2).

4.2 Band spectrum regression

The next step is to test the correlation between unemployment and our short, medium and long-run variables, which is done using a band spectrum regression (Engle, 1974; Andersson, 2016). Band spectrum regression means that, in our case, unemployment in country i at year t, u_{it}, is estimated on a wavelet decomposed regressor x_{it}^j, where $j \in 1, 2, ..., J$ is the n-th detail. In our case, the details are rearranged to the short, medium and long-run components of x, such as

$$u_{it} = \beta_0 + \beta_1 x_{it}^{SR} + \beta_2 x_{it}^{MR} + \beta_3 x_{it}^{LR} + \epsilon_{it} \tag{7}$$

In our model, equations 1-5, unemployment is hypothetically affected by short, medium and long-run macroeconomic performance as well as more long-term exogenous institutional factors. We use wavelet decomposed GDP growth (y_{it}), investment as percent of GDP (k_{it}), total factor productivity growth (tfp_{it}) and real long-term interest rate (r_{it}) as indicators of macroeconomic performance .

We use a cross-country panel dataset with the baseline two-way fixed effect model

$$u_{ti} = \beta_0 + \sum_j \beta_{1,j} y_{ti}^j + \beta_{2,j} k_{it}^j + \beta_{3,j} \text{tfp}_{it}^j + \beta_{4,j} r_{it}^j + \beta_5 F_t + \beta_6 F_i + \epsilon_{it} \quad (8)$$

where j is the short, medium and long-run components of each variable. F_t and F_i is time- and country-fixed effects, i.e. the addition of $T-1$ and $I-1$ number of dummies in respectively case, T and I being the total number of years and countries in the dataset.

Capital formation, GDP growth, TFP and real interest should capture the overall effect of shifts in macroeconomic performance. If the real interest rate capture expected shifts in capital formation due to institutional conditions, residual variance in this variable may capture exogenous shifts. Capital formation as percent of GDP is one out of several possible measures and is used in several earlier studies (cf. Herbertsson and Zoega, 2002; Stockhammer and Klär, 2011). The inclusion of TFP and GDP growth in the same model might be problematic or hard to interpret since they are based on the same data, and our main estimations therefore includes them one at the time. An optimistic interpretation of estimating both of them in the same model is that TFP controls for the true productivity growth rate, or productivity shocks, in the form of deviations from long-run averages since country dummies are included, as is commonly done in earlier studies (cf. Blanchard and Wolfers, 2000).

Many earlier studies on unemployment focus on labor market institutions, using data from around 1960 onward. As part of our robustness analysis we estimate models, which at most covers the period 1960-2014 with the decomposed main variables of interest and a collection of common measures of institutions.

To control for the deviation between unemployment and long-run unemployment equilibrium, we follow previous literature and compare different methods. There is no consensus for how to capture long-run equilibrium, and no method is necessarily more suitable than the other (cf. Staiger *et al.*, 1997). We consider all of these as part of our robustness testing.

One approach is to include inflation change, $\Delta\pi_{it}$ in our model specification. The logic is that in periods when unemployment is below equilibrium, inflation will tend to increase, as per the traditional Phillips curve, hence giving a relationship:

$$\Delta\pi = a(U^* - U) + \nu \quad (9)$$

where $\Delta\pi$ is inflation (first-differences), U unemployment, U^* is the non-accelerating inflation rate of unemployment (NAIRU), ν are short-run shocks (residuals) and a is a parameter.

Estimating a regression of observables $\Delta\pi$ and U, and solving out $U^* + \nu/a = \Delta\pi/a + U$, it can be seen that long-run equilibrium unemployment, or the NAIRU, can be estimated empirically by applying a low-pass filter to the right hand side (cf. Ball and Mankiw, 2002; Flaig and Rottmann, 2013). One possible interpretation is then that a long-run unemployment equilibrium, or the movement between several equilibria, is estimated as the long-run components of the right-hand side in equation 8.

As part of our robustness analysis, besides the use of $\Delta\pi$, we estimate our short-, medium- and long-run components against 5 and 10 year moving averages of unemployment respectively, as well as the wavelet trend components of unemployment. This kind of estimations may capture both the the possible connection between macroeconomic performance and one unique long-run equilibrium unemployment; and the possibility that we have more than one long-run equilibrium in the labor market, and that macroeconomic performance may push unemployment between these. In this sense, our regression can be interpreted as one out of several indications of the possible endogeneity or exogeneity of long-run unemployment equilibrium to aggregate demand and productivity.

5 Results

We start by looking at the structure of the simple correlation coefficient between the long-run component (D_{5t}) of unemployment and the investment ratio, with up to ten lagged or leading values for investment, such as $cor\left(u_{D_5}, k_{D_5}\right)$. We can here think of the D_5 component as the long-run trends, and somewhat simplified as a proxy for the, perhaps unique, long-run equilibrium unemployment rate. This gives us a first overview of the correlation between these two variables, see figure 2 for a description of the coefficients for each country with 95% confidence intervals. For seven out of ten countries, negative correlation coefficients seem to dominate the interval between 10 lags and leads, with less negative coefficients when comparing greater lags or leads, and in some cases non-different from zero. Most countries have negative coefficients in the interval of lag 5 years and 0. Finland and Sweden have negative coefficients for around 5-10 lags. They also have positive correlation coefficients for greater leads, i.e. around 5 and over, suggesting that periods of high unemployment are typically succeeded by periods of high investment. For the UK, most correlation coefficients in the graph is found to be around, or non-different from zero.

Table 1 summarizes our main estimation results. The first model estimates a fixed effects model, where short-run and long-run investment explain 17% of the variations in unemployment (measure . The long-run component alone accounts for 16.9% of variations in unemployment, and 28.8% of long-run variations in unemployment (cycles of 32 years and longer). To control for common trends in the data we also include time-dummies and introduce control variables inflation, rate of interest, GDP and TFP growth in models 2-5. Among all variables, and taking into consideration all our estimations and results, the most consistent results are found for the long-run cyclical component of investment ("Investm. LR" in the table). The other variables, GDP growth, long-term real interest rate and TFP growth show statistically significant negative correlations in some estimations, and then mainly for the long-run component. But results are in general less robust, and in several models we instead find a positive correlation.

To analyze the possibility of different dynamics over sub-periods, models 6 and 7 presents results on the periods 1913-1964 and 1965-2016 respectively. The negative long-run correlation for investment is statistically significant in both cases. Similar results are found if data is broken up at earlier or later years. In models 8-11, we also control for labor market institutions from 1960-2014.The data on labor market institutions used here are available from 1960 or later. The correlation results for the long-term cyclical component of investment are robust with different combinations of labor market institutions. Using a limited dataset with relatively few countries, the results for the labor market institutions presented here is primarily intended as a robustness test for our measures on macroeconomic performance. Among the institutional variables, higher levels of unemployment seem to correlate with lower level wage bargaining level (more centralized) and lower unemployment replacement rate (contrary to standard equilibrium theories). These results tend to be statistically significant in several of our models, but also somewhat unrobust in our limited setup.

Other robustness tests performed, but not shown here, include using five wavelet components, instead of three; models were estimated with each country excluded, one at the time. Regression models were also estimated with, a moving average over 5 and 10 years; and a long-run wavelet components of unemployment (D_5, S_5 as proxy for U^*) as dependent variables, with overall similar results. All of these are available upon request.

6 Concluding remarks

We find statistically significant negative correlations between unemployment and investment, measured as percent of GDP. These correlations seem to hold for the long-term cyclical component of the decomposed investment time-series, indicating that there are real aggregate determinants of long-run changes in unemployment. Results for other variables, such as long-term real interest rate, GDP growth and TFP growth seem sensitive to the choice of time period and model design, having both positive and negative correlations in different model specifications. A possible interpretation of these results is that, contrary to commonly used and influential theories on unemployment, long-run variations in capital formation, or macroeconomic performance in general, is crucial to understand unemployment.

These results have important corollaries for economic policy, in the sense that to lower unemployment, governments might need to boost growth and capital formation. However, our results are compatible with different theories, such as a long-run correlation between capital formation and a unique unemployment equilibrium (Rowthorn, 1999; Sigurdsson, 2013), or a correlation due to exogenous shifts in growth, and shocks, pushing unemployment between multiple equilibria (Farmer, 2012). Therefore, more precise policy recommendations should be made with care.

This caution is also motivated since, there is no general explanation of changes in capital investment or growth in the long run. It is well known that there has been a general divergence in GDP levels among countries in the world

Figure 2: Correlation structure: Long-run wavelet components for unemployment and investment ratios

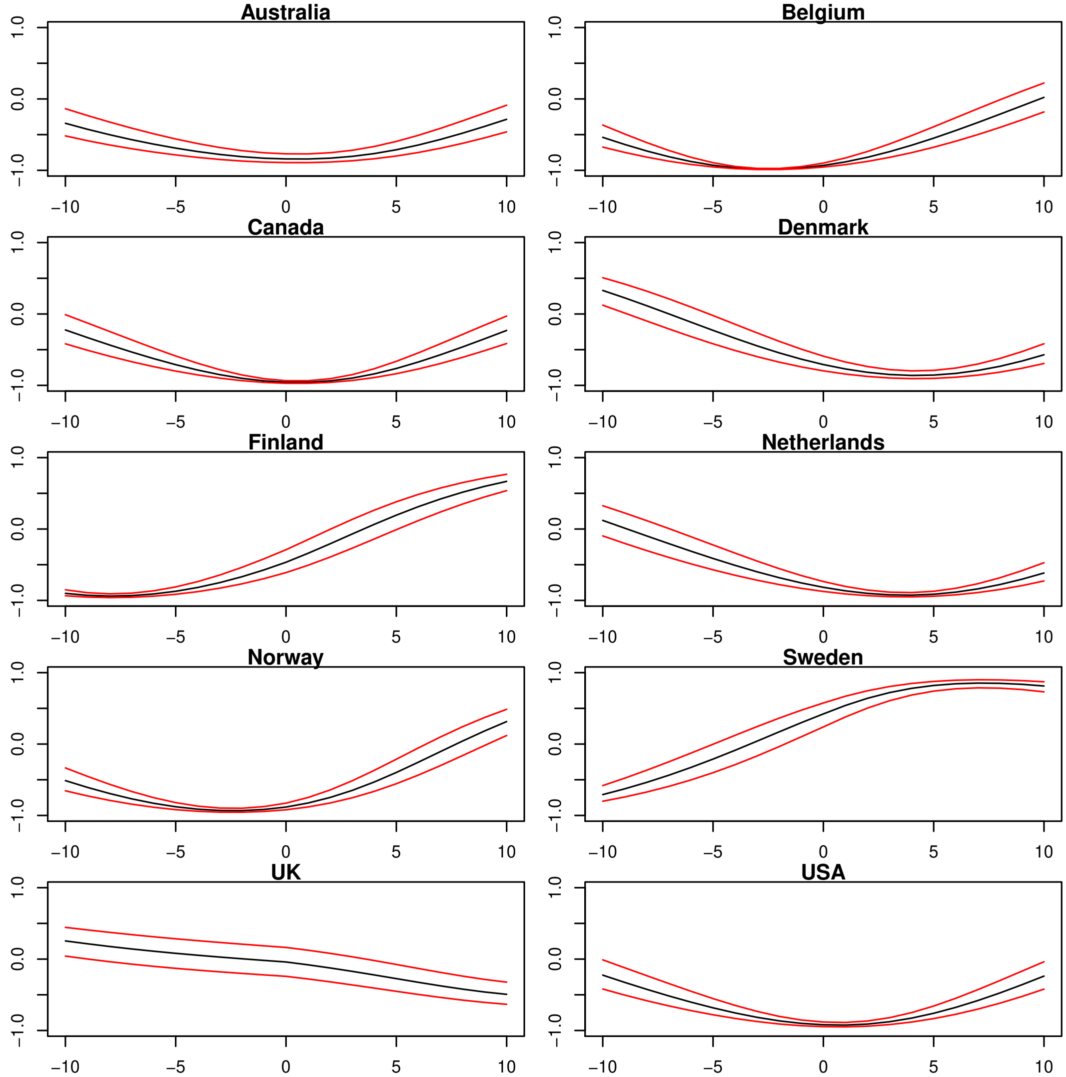


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Table 1: Estimation result. Fixed effects models. Dependent variable: unemployment

	(1) 1913-2016	(2) 1913-2016	(3) 1913-2016	(4) 1913-2016	(5) 1913-2016	(6) 1913-2016	(7) 1913-1964	(8) 1965-2016	(9) LMI 1970-	(10) LMI 1970-	(11) LMI 1970-
Investm LR	-0.87***	-0.89***	-0.24***	-0.25***	-0.24***	-0.24***	-0.23**	-0.40***	-0.20*	-0.20*	-0.46***
	(-14.45)	(-14.60)	(-3.57)	(-3.66)	(-3.54)	(-3.50)	(-2.56)	(-4.65)	(-1.67)	(-1.94)	(-4.49)
Investm SR		-0.26***	-0.13**	-0.13**	-0.13**	-0.11	-0.10	-0.31***	-0.38***	-0.39***	-0.36***
		(-3.17)	(-2.04)	(-2.00)	(-2.03)	(-1.63)	(-1.25)	(-3.37)	(-3.26)	(-3.93)	(-3.69)
Investm MR		0.09*	-0.15***	-0.14***	-0.16***	-0.13***	-0.03	-0.26***	-0.37***	-0.29***	-0.22***
		(1.77)	(-3.30)	(-2.95)	(-3.40)	(-2.87)	(-0.43)	(-4.61)	(-4.99)	(-4.51)	(-3.65)
Long interest SR			0.00	0.00	0.00	0.00	0.00	-0.00		-0.02	-0.02
			(0.38)	(0.37)	(0.39)	(0.31)	(0.36)	(-0.04)		(-0.26)	(-0.33)
Long interest MR			0.01	0.01	0.01	0.01	0.01	0.47***		0.52***	0.48***
			(1.26)	(1.43)	(1.13)	(1.46)	(1.50)	(6.40)		(6.88)	(6.62)
Long interest LR			-0.04**	-0.04**	-0.04**	-0.04**	-0.06**	0.99***		1.24***	1.11***
			(-2.03)	(-2.06)	(-2.00)	(-1.97)	(-2.57)	(10.36)		(11.30)	(10.74)
Infl SR			0.00	0.00	0.00	0.00	0.00	-0.01			
			(0.51)	(0.44)	(0.48)	(0.25)	(0.21)	(-0.26)			
Infl MR			-0.09***	-0.10***	-0.08**	-0.06*	-0.04	-0.39***			
			(-2.67)	(-2.95)	(-2.27)	(-1.71)	(-1.01)	(-2.86)			
Infl LR			0.37	0.40	0.45*	0.44	-0.80*	-0.73**			
			(1.44)	(1.48)	(1.68)	(1.64)	(-1.89)	(-2.12)			
GDP growth SR				-0.02		-0.06	-0.01	-0.00			-0.06
				(-0.85)		(-1.36)	(-0.67)	(-0.01)			(-0.62)
GDP growth MR				-0.04		-0.36***	-0.06*	-0.10			-0.36***
				(-1.43)		(-5.40)	(-1.88)	(-1.11)			(-2.61)
GDP growth LR				0.07		-0.04	0.05	0.19			1.50***
				(0.59)		(-0.21)	(0.35)	(0.92)			(4.42)
TFP growth SR					-0.01	0.05					0.14
					(-0.34)	(1.08)					(1.31)
TFP growth MR					0.03	0.40***					0.31
					(0.94)	(5.33)					(1.62)
TFP growth LR					0.09	0.10					0.56**
					(0.92)	(0.66)					(2.39)
Wage-set. coord									0.07	0.12	0.10
									(0.46)	(0.99)	(0.85)
Wage barg. level									-0.36**	-0.20	-0.01
									(-2.18)	(-1.41)	(-0.06)
Barg. coverage									0.00	0.02	0.03*
									(0.23)	(1.38)	(1.95)
Wage barg. cent.									-0.02	-0.05***	-0.04**
									(-1.12)	(-3.03)	(-2.52)
Union density									0.10***	0.10***	0.15***
									(4.23)	(4.69)	(6.87)
Replacement									-0.00	-0.04***	-0.03**
									(-0.23)	(-2.83)	(-2.29)
Constant	5.32***	5.32***	3.11***	3.08***	3.04***	3.48***	3.03***	1.07	-0.46	-0.69	-11.26***
	(53.21)	(53.46)	(4.34)	(4.17)	(4.18)	(4.76)	(3.92)	(1.06)	(-0.39)	(-0.68)	(-5.78)
N	1040	1040	1040	1040	1040	1040	520	520	418	418	418
R^2	0.17	0.18	0.65	0.65	0.65	0.66	0.70	0.73	0.63	0.74	0.78
adj. R^2	0.16	0.17	0.60	0.60	0.60	0.61	0.66	0.69	0.57	0.69	0.74
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Countries	10	10	10	10	10	10	10	10	10	10	10
Max years per country	104	104	104	104	104	104	52	52	42	42	42

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

SR, MR, LR = Short, medium and long-run. Investm = investment % GDP. Infl.chg = percentage point change inflation. LMI = labor market institutions.

Table 2: Variance decomposition for investment ratios

Source: see text.

since the early 1800s; and some convergence among similar countries (such as those in the OECD) during the late 1900s. Several factors also seem to correlate with GDP, investment and growth, but there is no short answer explaining the major share of these variations over long time periods or countries (Acemoglu, 2009). A considerable amount of long-run variation is thought to be due to innovation and protracted major technology shifts, usually measured as TFP; but results seem highly dependent on methods and assumptions, such as the aggregate production function (Crafts and O'Rourke, 2014).

Long-term changes have also been attributed to institutional differences, but there still seem to be considerable work left to explain exactly what effect institutions might have, and how to define these institutions in more detail, especially in interaction with each other (Ogilvie and Carus, 2014). It is also well-known that no small share of the changes in investment or growth can be linked to history-specific processes, such as the post-war Marshall Plan, the expansion of the welfare state and long-run commitments to public infrastructure projects.

In short, due to the complexity involved, if we wish to address how policy can affect labor market outcome, precise policy measures must involve careful analysis of whether to stimulate innovation, institutional change or public consumption or investment commitments.

References

Abildgren, K. (2010). *Quantitative studies on the monetary and financial history of Denmark*. Ph.D. thesis, Department of Economics, University of Copenhagen, Kbh., oCLC: 763103859.

Acemoglu, D. (2009). *Introduction to Modern Economic Growth*. Princeton: Princeton University Press.

Andersson, F. N. G. (2008). *Wavelet Analysis of Economic Time Series*. dissertation, Lund University.

— (2016). Identifying and modelling cycles and long waves in economic time series.

Arestis, P., Baddeley, M. and Sawyer, M. (2007). The Relationship Between Capital Stock, Unemployment and Wages in Nine Emu Countries. *Bulletin of Economic Research*, **59** (2), 125–148.

— and Sawyer, M. (2005). Aggregate demand, conflict and capacity in the inflationary process. *Cambridge Journal of Economics*, **29** (6), 959–974.

Baker, D., Glyn, A., Howell, D. R. and Schmitt, J. (2005). Labor Market Institutions and Unemployment: Assessment of the Cross-Country Evidence. In *Fighting Unemployment*, Oxford Scholarship Online, pp. 72–118.

Ball, L. and Mankiw, N. G. (2002). *The NAIRU in theory and practice*. Tech. rep., National Bureau of Economic Research.

Bande, R. and Karanassou, M. (2014). Spanish Regional Unemployment Revisited: The Role of Capital Accumulation. *Regional Studies*, **48** (11), 1863–1883.

Bassanini, A. and Duval, R. (2006). *Employment Patterns in OECD Countries: Reassessing the Role of Policies and Institutions*. OECD Social, Employment and Migration Working Paper 35, OECD Publishing.

Bergeaud, A., Cette, G. and Lecat, R. (2016). Productivity Trends in Advanced Countries between 1890 and 2012. *Review of Income and Wealth*, **62** (3), 420–444.

Blanchard, O. (2000). The Economics of Unemployment. Shocks, Institutions, and Interactions. *Lionel Robins Lectures*.

— and Wolfers, J. (2000). The Role of Shocks and Institutions in the Rise of European Unemployment: The Aggregate Evidence. *The Economic Journal*, **110** (462), C1–C33.

Blanchard, O. J. and Summers, L. H. (1988). Beyond the Natural Rate Hypothesis. *The American Economic Review*, **78** (2), 182–187.

Boyer, G. R. and Hatton, T. J. (2002). NEW ESTIMATES OF BRITISH UNEMPLOYMENT, 1870–1913. *The Journal of Economic History*, **62** (3), 643–675.

Butlin, N. G. (1984). *Select comparative economic statistics 1900-1940 : Australia and Britain, Canada, Japan, New Zealand and U.S.A.* Canberra : Australian National University.

Christodoulakis, N. and Axioglou, C. (2017). Underinvestment and Unemployment: The Double Hazard in the Euro Area. *Applied Economics Quarterly*, **63** (1), 49–80.

Coen, R. M. (1973). Labor Force and Unemployment in the 1920's and 1930's: A Re-examination Based on Postwar Experience. *The Review of Economics and Statistics*, pp. 46–55.

Crafts, N. and O'Rourke, K. H. (2014). Chapter 6 - Twentieth Century Growth. In P. Aghion and S. N. Durlauf (eds.), *Handbook of Economic Growth*, *Handbook of Economic Growth*, vol. 2, Elsevier, pp. 263–346.

Crowley, P. M. (2007). A GUIDE TO WAVELETS FOR ECONOMISTS*. *Journal of Economic Surveys*, **21** (2), 207–267.

DataMarket (2014). Civilian unemployment rate, 1890 to 1974.

Denham, J. and McDonald, P. (1996). Unemployment Statistics From 1881 to the Present Day. *Labour Market Trends*, pp. 5–18.

Diamond, P. A. (1982). Aggregate demand management in search equilibrium. *Journal of political Economy*, **90** (5), 881–894.

Drèze, J. H. and Bean, C. R. (eds.) (1991). *Europe's Unemployment Problem*. Cambridge, Mass: The MIT Press.

Eichhorst, W., Feil, M. and Braun, C. (2008). *What have we learned? Assessing labor market institutions and indicators*. No. 22/2008 in IAB Discussion Paper: Beiträge zum wissenschaftlichen Dialog aus dem Institut für Arbeitsmarkt- und Berufsforschung, Nürnberg.

Engle, R. F. (1974). Band Spectrum Regression. *International Economic Review*, **15** (1), 1–11.

Farmer, R. E. A. (2012). Confidence, Crashes and Animal Spirits. *The Economic Journal*, **122** (559), 155–172.

— and Nicolò, G. (2018). Keynesian economics without the Phillips curve. *Journal of Economic Dynamics and Control*, **89**, 137–150.

Flaig, G. and Rottmann, H. (2013). Labour market institutions and unemployment: an international panel data analysis. *Empirica*, **40** (4), 635.

Galenson, W. and Zellner, A. (1957). International Comparison of Unemployment Rates. *NBER*, pp. 439–584.

Galí, J. (2015). *Hysteresis and the European unemployment problem revisited*. Tech. rep., National Bureau of Economic Research.

Galí, J. (2016). Insider-outsider labor markets, hysteresis and monetary policy. *Universitat Pompeu Fabra, Department of Economics Working Papers*, (1506).

Gallegati, M., Gallegati, M., Ramsey, J. B. and Semmler, W. (2011). The US Wage Phillips Curve across Frequencies and over Time*. *Oxford Bulletin of Economics and Statistics*, **73** (4), 489–508.

—, —, — and — (2014). Does Productivity Affect Unemployment? A Time-Frequency Analysis for the US. In M. Gallegati and W. Semmler (eds.), *Wavelet Applications in Economics and Finance*, Dynamic Modeling and Econometrics in Economics and Finance, Cham: Springer International Publishing, pp. 23–46.

—, —, — and — (2015). Productivity and unemployment: a scale-by-scale panel data analysis for the G7 countries. *Studies in Nonlinear Dynamics & Econometrics*, **20** (4), 477–493.

Groote, P., Albers, R. and Jong, H. d. (1996). *A standardised time series of the stock of fixed capital in the Netherlands, 1900-1995*. Tech. Rep. 199625, Groningen Growth and Development Centre, University of Groningen.

Hatton, T. J. (2007). Can Productivity Growth Explain the NAIRU? Long-Run Evidence from Britain, 1871–1999. *Economica*, **74** (295), 475–491.

Herbertsson, T. T. and Zoega, G. (2002). The Modigliani 'puzzle'. *Economics Letters*, **76** (3), 437–442.

Jordà, Ò., Schularick, M. and Taylor, A. M. (2016). Macrofinancial History and the New Business Cycle Facts. *NBER Macroeconomics Annual 2016, Volume 31*, pp. 213–263.

Kapadia, S. (2005). The Capital Stock and Equilibrium Unemployment: A New Theoretical Perspective. *http://economics.ouls.ox.ac.uk/13450*, **181**.

Karanassou, M., Sala, H. and Salvador, P. F. (2008). Capital accumulation and unemployment: new insights on the Nordic experience. *Cambridge Journal of Economics*, **32** (6), 977–1001.

Keynes, J. M. (1937). The General Theory of Employment. *The Quarterly Journal of Economics*, **51** (2), 209–223.

Layard, P. R. G., Nickell, S. J. and Jackman, R. (2005). *Unemployment: Macroeconomic Performance and the Labour Market*. Oxford University Press.

Layard, R., Nickell, S. and Jackman, R. (1991). *Unemployment: Macroeconomic Performance and the Labour Market*. Oxford, New York: Oxford University Press.

Lebergott, S. (1957). Annual Estimates of Unemployment in the United States, 1900-1954. *The Measurement and Behavior of Unemployment*, pp. 211–242.

Maddison, A. (1959). Economic Growth in Western Europe 1870-1957. *Banca Nazionale Del Lavoro Quarterly Review*, **XII**.

— (1964). *Economic growth in the West : comparative experience in Europe and North America*. A Twentieth Century Fund study, 99-0112347-X, New York: The Twentieth Century Fund.

Manning, A. (1990). Imperfect Competition, Multiple Equilibria and Unemployment Policy. *The Economic Journal*, **100** (400), 151–162.

— (1992). Multiple equilibria in the British labour market: Some empirical evidence. *European Economic Review*, **36** (7), 1333–1365.

Modigliani, F. (2000). *Europe's economic problems : prepared for the 3rd Monetary & Finance Lecture 2000 at Albrecht-Ludwigs-University Freiburg i. Br.* Freiburg.

Mortensen, D. T. (1989). The Persistence and Indeterminacy of Unemployment in Search Equilibrium. *The Scandinavian Journal of Economics*, **91** (2), 347–370.

Ogilvie, S. and Carus, A. W. (2014). Chapter 8 - Institutions and Economic Growth in Historical Perspective. In P. Aghion and S. N. Durlauf (eds.), *Handbook of Economic Growth*, *Handbook of Economic Growth*, vol. 2, Elsevier, pp. 403–513.

Oi, W. Y. (1962). Labor as a Quasi-Fixed Factor. *Journal of Political Economy*, **70** (6), 538–555.

Okun, A. M. (1962). Potential GNP, its measurement and significance. *Proceedings of the Business and Economic Statistics Section*, pp. 98–104.

Percival, D. B. and Walden, A. T. (2006). *Wavelet methods for time series analysis*, vol. 4. Cambridge University Press.

Pesaran, M. H. (2004). *General Diagnostic Tests for Cross Section Dependence in Panels*. Working Paper, Faculty of Economics.

Pissarides, C. A. (1992). Loss of skill during unemployment and the persistence of employment shocks. *The Quarterly Journal of Economics*, **107** (4), 1371–1391.

— (2000). *Equilibrium Unemployment Theory - 2nd Edition*. Cambridge, Mass: The MIT Press, second edition edition edn.

Reserve Bank of Australia (2001). *Australian Economic Statistics 1949-1950 to 1996-1997*. Tech. rep.

Roed, K. (1997). Hysteresis in Unemployment. *Journal of Economic Surveys*, **11** (4), 389–418.

Romer, C. (1986). Spurious volatility in historical unemployment data. *Journal of Political Economy*, **94** (1), 1–37.

Rowthorn, R. (1977). Conflict, inflation and money. *Cambridge Journal of Economics*, pp. 215–239.

— (1995). Capital formation and unemployment. *Oxford Review of Economic Policy*, pp. 26–39.

— (1999). Unemployment, wage bargaining and capital-labour substitution. *Cambridge journal of Economics*, **23** (4), 413–425.

SIGURDSSON, J. (2013). *Capital Investment and Equilibrium Unemployment*. Tech. Rep. wp61, Department of Economics, Central bank of Iceland.

SMITH, R. and ZOEGA, G. (2009). Keynes, investment, unemployment and expectations. *International Review of Applied Economics*, **23** (4), 427–444.

STAIGER, D. O., STOCK, J. H. and WATSON, M. W. (1997). How Precise Are Estimates of the Natural Rate of Unemployment? *Reducing Inflation: Motivation and Strategy*, pp. 195–246.

STATISTICS CANADA (2014). *Historical statistics of Canada: Section D: The Labour Force*. Tech. rep.

STATISTICS NETHERLANDS (2014). *Labour force; since 1800 by personal characteristics (12-hours threshold)*. Tech. rep.

STOCKHAMMER, E. and KLÄR, E. (2011). Capital accumulation, labour market institutions and unemployment in the medium run. *Cambridge Journal of Economics*, **35** (2), 437–457.

TIAINEN, P. (1994). *Taloudellisen kasvun tekijät suomessa : työvoman, pääpman ja kokonaistuottavuuden osuus vuosina 1900-90*. Kansantaloudellisia tutkimuksia, 0355-7847, Helsiniki: Univ.

VISSER, J. (2016). ICTWSS Data base. version 5.1.

WEITZMAN, M. L. (1982). Increasing Returns and the Foundations of Unemployment Theory. *The Economic Journal*, **92** (368), 787–804.

Appendix

A Data

Table 3: Data summary

Variable		Mean	Std. dev.	Min	Max	Observations
Unemployment	overall	5.32	3.65	0.20	21.80	N = 1040
	between		1.00	3.73	6.90	Countries = 10
	within		3.52	-0.43	20.22	Time-periods: 104
Inflation	overall	4.64	11.37	-37.68	241.41	N = 1040
	between		1.93	3.13	9.40	Countries = 10
	within		11.22	-39.52	236.65	Time-periods: 104
GDP growth	overall	2.93	5.57	-33.17	70.07	N = 1040
	between		0.45	1.99	3.38	Countries = 10
	within		5.55	-33.43	69.81	Time-periods: 104
Investment, percent of GDP	overall	19.83	5.78	1.73	38.89	N = 1040
	between		3.07	15.09	27.08	Countries = 10
	within		4.99	4.18	31.64	Time-periods: 104
Total factor productivity growth	overall	6.68	3.46	1.06	15.50	N = 1040
	between		0.76	4.89	7.48	Countries = 10
	within		3.38	1.09	14.70	Time-periods: 104
Long-term real interest rate	overall	1.92	7.4	-69.2	69.4	N = 1040
	between		1.05	-0.72	2.9	Countries = 10
	within		7.33	-66.6	69.8	Time-periods: 104

Source: see text.

Table 4: Sources for our unemployment data

Australia		1913-1940 (Butlin, 1984)	1941-1949 (Galenson and Zellner, 1957)	1950-1955 (Reserve Bank of Australia, 2001)	1956-2016 (OECD)
Belgium			1921-1939, 1945-1949 (Galenson and Zellner, 1957)	1913, 1950-1955 (Maddison, 1964)	1956-2016 (OECD)
Canada		1913 (Maddison, 1964)	1916-1920 (Galenson and Zellner, 1957)	1921-1955 (Statistics Canada, 2014)	1956-2016 (OECD)
Denmark				1913-1955 (Abildgren, 2010)	1956-2016 (OECD)
Finland				1913-1955 (Tiainen, 1994)	1956-2016 (OECD)
Netherlands				1913-1955 (Statistics Netherlands, 2014)	1956-2016 (OECD)
Norway			1913-1941, 1946-1949 (Galenson and Zellner, 1957*)	1950-1955 (Maddison, 1959)	1956-2016 (OECD)
Sweden			1913-1919, 1938-1949 (Galenson and Zellner, 1957*)	1920-1937, 1950-1955 (Maddison, 1964)	1956-2016 (OECD)
UK			1913-1919, 1939-1945 (Denham and McDonald, 1996)	1920-1938, 1946-1955 (Boyer and Hatton, 2002)	1956-2016 (OECD)
USA	1913-1930 (Romer, 1986)	1931-1940 (Coen, 1973)	1941-1946 (Lebergott, 1957)	1947-1955 (DataMarket, 2014)	1956-2016 (OECD)

* Levels adjusted downward from trade union data. See text.

Figure 3: Graphs for main variables

Source: see text.