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by

Howard J. Wall and Gylfi Zoega

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Regional Business Cycles and the Natural Rate of Unemployment*

Howard J. Wall[$]
Federal Reserve Bank of St. Louis

Gylfi Zoega[£]
University of Iceland
Birkbeck College, University of London
Central Bank of Iceland

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Abstract

Monetary policy is nearly always formulated on the basis of national-level macroeconomic data. This is in spite of the well-known observation that its impact typically differs across regions and industries. The paper shows how policy making might benefit from closer attention to regional developments. Our model is motivated by micro-econometric evidence that shows the response of wage inflation to vacancies to be non-linear: an increase in vacancies raises wage inflation at an increasing rate. Based on this observation, we use a model of the natural rate of unemployment to show that the greater is the dispersion of regional vacancy rates, the higher is the national inflation rate. Our empirical results show that changes in the distribution of regional unemployment in the United States in the 1990s is attributed, in part, to a falling natural rate.

JEL: J6, E2

Keywords: Regional unemployment, inflation, natural rate of unemployment.

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[$] Research Division, Federal Reserve Bank of St. Louis, 411 Locust St., St. Louis, Missouri 63166, United States. E-mail: wall@stls.frb.org

[£] Department of Economics, University of Iceland, 101 Reykjavik, Iceland. E-mail: gz@hi.is.

Milton Friedman and Edmund Phelps convinced the economics profession in the late 1960s of the absence of a long-run trade off between inflation and unemployment. A policy that pushes the unemployment rate below a certain threshold – dubbed the natural rate of unemployment by Friedman – would lead to rising inflation, while pushing it above the threshold would lead to ever-declining rates of inflation. The proposition of a long-run neutrality of inflation and money growth soon gained wide acceptance and recent work in this area has focused on making the natural rate of unemployment fully endogenous in general-equilibrium models (Pissarides, 2000; Layard, Nickell, and Jackman, 1991; and Phelps, 1994). This theory can be used to show how a variety of macroeconomic shocks – such as the rate of technical progress, real interest rates, and oil prices – affect the natural rate and social welfare.

Inflation-targeting central banks often monitor employment and wage changes in the hope of preventing wage inflation in the labor market from generating general price inflation.[1] The acceptance among policy makers of the notion of an equilibrium level of unemployment that is independent of current and past monetary variables has made the estimation of the natural rate important. This practice relies on models of the representative-agent type – the ones used to provide microeconomic foundations for the inflation-unemployment relationship – to assess the state of the economy on the basis of aggregate data. A central banker then uses data on aggregate employment, unemployment and average wage inflation across all sectors of the economy to assess the position of the economy in relation to the (directly un-measurable) natural rate of unemployment. Most often, this amounts to calculating the implied natural rate from estimates of aggregate Phillips curves.

The objective of this paper is to show that the sole reliance on representative-agent models and aggregate data may lead to incorrect inferences about the natural rate of unemployment. We show how regional business cycles might affect aggregate wage inflation, and how attention paid to regional labor-market trends can be useful for policy

[1] Such considerations have led to the appointment of a labor economist – Steve Nickell – to Britain's Monetary Policy Committee.

making. Moreover, we show how the natural rate of unemployment depends directly on the distribution of economic activity across regions.

Our regional approach has some parallel with the sectoral approach of Lilien (1982), Abraham and Katz (1986), and Brainard and Cutler (1993). Lilien (1982) found that a measure of sector-specific disturbances accounted for a significant portion of the variation in aggregate employment: When it takes less time for an industry to shed redundant labor than it does for the affected workers to find employment elsewhere, unemployment rises when the pace of sectoral reallocation of labor (and capital) increases. Abraham and Katz (1986) pointed out that Lilien's estimates might exaggerate the role of sectoral disturbances by failing to take into account differences in the sensitivity of different industries to macroeconomic shocks. More recently, Brainard and Cutler (1993) developed a data series to measure the intensity of reallocation shocks. They constructed a time series of the variance of sectoral stock market excess returns and found that they had a modest – though statistically significant – role in explaining aggregate employment fluctuations.

Our paper follows recent work illustrating the significant regional differences in economic conditions, business cycle dynamics, and reactions to monetary policy. Overman and Puga (2002) demonstrate the increased polarization of unemployment within Europe where unemployment increasingly appears in regional clusters that cross national borders. Crone (1998/1999) groups the U.S. states into regions based on common cyclical behavior, while Carlino and Sill (2001) find considerable state differences in the volatility of regional cycles (of GDP per capita). In particular, Crone and Carlino and Sill find considerable co-movement of the regional business cycles in New England, the Southeast, the Southwest and the Far West, but a weaker correlation between the national aggregates, on the one hand, and the Mideast and the Plains regions, on the other hand. Finally, the cyclical behavior of the

Great Lakes regions is much different from that of the other regions and the nation. It follows from the results that the national economy of the United States is a composite of significantly diverse regions.

In this paper, we show how the diversity in regional labor-market conditions can be used to enrich policy makers' understanding of the aggregate economy. In the section immediately following, we briefly lay out a state-level view of recent U.S. labor market trends. In section 2 we present a theoretical model in which differences in regional business cycles lead to changes in aggregate wage inflation, and discuss the implications of the model in section 3. In section 4 we test this model empirically using US data and demonstrate how region-level data can be used to estimate the aggregate natural rate of unemployment in the United States. In Section 5 we look at data from a much smaller and more ethnically and geographically homogenous country, Iceland, in order to test whether regional developments are also important for the smaller economies. Section 6 concludes.

1. A state-level view of U.S. unemployment

This paper relies on two suppositions about the distribution of regional labor market conditions: (i) that it is related to aggregate conditions, and (ii) that it changes over time. Both suppositions are supported by Figure 1, which illustrates that the movements in the aggregate unemployment rate over the last 25 years have largely been in synch with changes in the dispersion of state unemployment rates (as measured by the cross-state variance). The synchronization of the level and the variance are such that a simple OLS estimation indicates that, on average, 68 percent of the variation in the aggregate unemployment rate can be explained by the variation in the cross-state variance. Correspondingly, the 1990s saw steadily declining unemployment alongside a convergence of state unemployment rates. The only period during which aggregate unemployment was out of synch with the variance was in 1986-87, when a handful of states had sudden increases in unemployment following the crash of energy prices in 1986.[2] Along with the country as a whole, all other states saw falling unemployment during this period.

Figure 2 shows the analogous relationships for employment growth. It is less clear on the first supposition, but very clear on the second. Trend aggregate employment growth has tended to move independently of the variance of employment growth rates. On the other hand, the variance of employment growth has shown a steady downward trend since 1977.

Further evidence of the importance of regional variation for understanding the aggregate labor market is provided by Figure 3, which illustrates the distribution of changes in state unemployment during the three most recent recession episodes. Associated with the 1981-82 recession, the US unemployment rate rose by about 45 percent from the third quarter of 1981 to the fourth quarter of 1982. Over the same period, 30 states saw their unemployment rates rise by less than this, with 10 states seeing increases that were less than half as large (Nevada actually saw a small decrease). On the other hand, of the 20 states whose unemployment rates rose relatively more than the national average, six states saw them rise by more than twice as much.

The 1990-92 period is perhaps the most regionally distinct of the three. The aggregate unemployment rate rose by 43 percent from the second quarter of 1990 to the third quarter of 1992. The brunt of the increase was felt on the coasts where most states saw larger than average increases in their unemployment rates, particularly the large states of California, New York, North Carolina, and Washington. At the other end, a significant majority of states (34), mostly located in the vast middle of the country, saw a milder than average increase in

[2] These states were Alaska, Alabama, Colorado, Louisiana, Mississippi, Texas, and Wyoming.

unemployment. In fact, six states actually saw their unemployment rates fall during the period.

The most recent runup in unemployment began with the fourth quarter of 2000 and has continued up to the time that this paper was written. By the first quarter of 2002, though, the fact of a regionally diverse unemployment experience, and an increasing variance, had become clear. By that time, the aggregate unemployment rate had risen by 41 percent, although 34 states saw smaller percentage increases and six had seen declines. The states hit most severely were scattered across the country, with pockets in the Great Lakes region, along the Atlantic Seaboard, in the western Plains, and the Southwest.

2. A natural-rate model with heterogeneous agents

To understand how regional heterogeneity can be introduced into aggregate labor-market models, it is instructive return to the textbook discussion of the natural rate of unemployment, which can be traced back to Phelps (1968). We take Phelps's model and derive its implications for the effect of regional heterogeneity for wage inflation and unemployment. Following Oi (1962), workers are treated as quasi-fixed assets and hiring is inherently an investment decision and, hence, the stock of employees is an asset to the firm. To protect the stock of human capital, firms set wages with the aim of recruiting new workers and retaining existing ones. There are information frictions about jobs and workers so that unemployed workers have to search for vacancies and firms have to search for workers to fill these vacancies. Firms incur direct hiring costs, such as the cost of advertising, screening, and training new workers. Importantly, wages can also be used to attract new workers and high (relative) wages can be as effective as advertisements in newspapers. Quitting is costly to employers. When a worker decides to jump ship and join either the ranks of the unemployment – hoping to get a job offer – or to join the ranks of a rival firm, a loss is incurred in that his employer either has to reduce production or invest in finding and hiring a replacement worker. For this reason, the firm uses wages to retain existing workers.

2.a. Homogeneous-agents model

The probability of a worker quitting is a function of the vacancy rate (the ratio of the number of vacancies to the labor force) and the unemployment rate. With a high vacancy rate a worker can expect to receive a job offer soon after leaving his current post. With a low unemployment rate the worker has few competitors when applying to fill one of these vacancies. On both counts, he can expect a new job in the near future. Hence, the incentive to quit is higher. But the danger that a previously trained, fully functional employee decides to quit will make firms attempt to protect their stock of human capital by attempting to pay higher wages relative to what the worker can expect elsewhere. A high vacancy rate also has the direct effect of making firms offer high wages in the hope of filling the vacancy.

Denote the desired relative wage differential of firm i – that is, the difference between wages paid at firm i and average wages in the economy – as follows;

$$\Delta_i^* \equiv \frac{w_i^* - w}{w}, \tag{1}$$

where w denotes average wages in the economy while w_i is the wage paid by firm i. With identical firms, the desired wage differential is a function of the unemployment rate u and the vacancy rate v;

$$\Delta^* = m(u, v), \tag{2}$$

with m_u<0 and m_v >0. Higher unemployment reduces the desired wage differential while a higher average vacancy rate raises the required wage differential. The rate of wage inflation is a function of the desired wage differential;

$$\frac{\dot{w}}{w} = \lambda\Delta^* = \lambda m(u, v). \tag{3}$$

When each firm has a positive desired wage differential, $\Delta^* > 0$, they all attempt to raise their relative wages. Each firm raises its wage assuming that others will not follow suit, but relative wages do not change because one firm's wage increase offsets that of another.[3]

From equation (3) it follows that there is a locus of unemployment-vacancy rate combinations that give zero wage inflation. A rise in the vacancy rate puts pressure on wage inflation because this induces workers to quit more frequently and, hence, firms to attempt to raise their wage differential to combat the increased quits and fill the unfilled vacancies. But a rise in the unemployment rate can offset the effect of vacancies on the wage inflation: Higher unemployment deters quits and makes it easier for firms to fill vacancies at unchanged wage differentials.

We now take into account the dynamics of employment. This will enable us to do away with the vacancy rate in equation (3) and replace it with the rate of growth of the labor force. Moreover, this will enable us to find the level of the natural rate of unemployment – still to be defined – which will turn out to be a function of the rate of growth of the labor force. Equation (4) is a differential equation for the growth of employment, which is equal to the difference between hires H, the number of retirements R, and the number of workers quitting Q;

$$\dot{N} = H - R - Q. \tag{4}$$

The number of workers retiring is independent of economic variables and is equal to a proportion r of the labor force. In contrast, the number of hires and the number of quitters depend on unemployment, vacancies and the size of the labor force;

[3] There is an implicit assumption that wages are not adjusted instantaneously. This may be due to the costs of setting wages, perhaps wage setting is staggered and inflation persists as long as the desired wage differential remains positive.

$$z = \frac{\dot{N}}{L} = H(u,v) - r(1-u) - Q(u,v) = z(u,v), \tag{5}$$

where $z_1>0$ and $z_2>0$. The function z describes employment growth as a function of both the rate of unemployment as well as the vacancy rate. The reason should be transparent by this stage. The higher is the unemployment (vacancy) rate, the more people (firms) are looking for a job and the more frequently is there a match between a vacancy and a suitable worker. Using equation (5), we can now write vacancies as a function of employment growth z and the unemployment rate u: $v = V(z,u)$, where $V_z>0$ and $V_u<0$. Combining the equations above gives equation (6):

$$\frac{\dot{w}}{w} = \lambda m[u, V(u,z)] = \pi(u,z) \tag{6}$$

This equation gives a convex Phillips curve: falling unemployment raises inflation but also requires rising vacancies to maintain employment growth at z, which then further reinforces the effect on inflation.

The final step in the derivation is to allow for anticipated inflation. Adding this to the effect of demand in equation (6) gives the following equation:

$$\frac{\dot{w}}{w} = \pi(u,z) + \frac{\dot{w}^e}{w}. \tag{7}$$

Now use γ to denote the rate of growth of the labor force.[4] The rate of employment growth is then equal to $(1\text{-}u)\gamma$ minus the change in the unemployment rate: $z = (1-u)\gamma - \dot{u}$. The *macroeconomic equilibrium path* is defined as the path taken by unemployment u^* – for

[4] Notice that higher employment growth, that is a higher value of z holding unemployment constant, causes increased inflation for a given level of expected inflation. A transitory rise in the rate of employment growth entails an increase in the vacancy rate, which then causes firms to reconsider and raise their desired wage differentials causing rising inflation. This inflation may then feed into anticipated inflation and acquire a life of its own once the employment growth is over.

a given rate of change of the labor force – that leaves actual inflation equal to expected inflation,

$$\frac{\dot{w}}{w} = \frac{\dot{w}^e}{w}. \tag{8}$$

This equilibrium unemployment path u^* can then be described by the following equation:

$$\pi[u^*, (1-u^*)\gamma - \dot{u}^*] = 0. \tag{9}$$

The economy follows such a non-inflationary equilibrium path towards steady state. Since actual and anticipated inflation are equal along the path, it follows that the equilibrium path can be defined in terms of correct expectations or perfect foresight. Since unemployment is changing continuously along the path it is useful to define the steady-state unemployment rate as the natural rate of unemployment u_n. The definition follows:

$$\pi[u_n, (1-u_n)\gamma] = 0. \tag{10}$$

Although mostly unnoticed in the literature, this equation gives the first model of a moving natural rate of unemployment. Rapid population and labor force growth requires a higher vacancy rate for a given unemployment rate, but the steady-state unemployment rate also has to increase to prevent inflation from rising. Hence, a higher labor-force growth rate raises the natural rate of unemployment.

Once we add the assumption of adaptive expectations to this model we have the familiar textbook implication that if monetary policy is used to maintain unemployment at a rate lower than the equilibrium rate u^* – or the natural rate u_n in steady state – wage inflation will be rising. There is some rate of unemployment that is compatible with stable wage inflation. If the economy is pushed – by intent or due to a business cycle – below this level, wage inflation will arise.

2.b. Asymmetric wage adjustment, heterogeneous agents and the natural rate

The original Phelps model – as outlined above – has now entered most macroeconomics textbooks in one form or another. These textbook models give little role to firm heterogeneity. However, numerous statistical studies of the distribution of wage changes point to a potential role for asymmetric wage adjustments and heterogeneity. These studies show that the distribution of wage changes is skewed away from small increases and absolute wage cuts and towards large increases. There is a thinning of the left-hand tail to the left of the zero-inflation point, which indicates nominal wage rigidity. But, as McLaughlin (1999) documents, the skewness of the distribution exists even in the absence of any nominal wage rigidity: If we truncate the distribution at zero wage increases we still get a skewed distribution. It follows that in an economy where some sectors and firms are declining and others expanding, the wage cuts occurring in the former are smaller than the wage increases offered in the latter. There is hence a need to modify the textbook model to take into account this heterogeneity.

Assume that there are *N* firms and also *N* types of labor, both distinguished by their location. Importantly, assume that each firm has a desired wage differential when it comes to its own wage relative to the average national wage.[5] Firm heterogeneity becomes important if the vacancy rate differs across regions. Differences in the vacancy rate are caused by regional business cycles, such as the ones documented by Carlino and Sill (2001) for the United States.

The desired wage differential is defined as follows:

$$\Delta_i^* = \frac{w_i^* - w^e}{w^e}. \tag{11}$$

[5] This excludes the possibility that each firm has a desired wage differential vis-à-vis every other firm.

where w^e is the expected average wage elsewhere in the economy. The expected wage differential follows, where w_i is the current own wage:

$$\Delta_i^e = \frac{w_i - w^e}{w^e}. \tag{12}$$

Importantly, the expected wage differential is also the actual wage differential at a given point in time.

We postulate that the firm's decision rule is such that the rate of change of the expected wage differential is proportional to the discrepancy between the desired differential and the present differential, where the coefficient λ denotes the speed of adjustment;

$$\dot{\Delta}_i^e = \lambda_i \left(\Delta_i^* - \Delta_i \right). \tag{13}$$

The speed of adjustment depends on such factors as the staggering of wage-setting decisions. There may also be a cost of changing wages that prevents complete and instantaneous adjustment.

We can now take the time derivative of the desired wage differential in equation (11) to get:

$$\dot{\Delta}_i^e = \frac{\dot{w}_i}{w^e} - \frac{\dot{w}^e}{w^e} - \frac{\dot{w}^e}{w^e w^e} \left(w_i - w^e \right). \tag{14}$$

This simplifies to equation (15):

$$\dot{\Delta}_i^e = \frac{\dot{w}_i}{w^e} - \frac{\dot{w}^e}{w^e} \frac{w_i}{w^e}. \tag{15}$$

One can now combine equations (13) and (15) to get:

$$\frac{\dot{w}_i}{w_i} = \lambda_i \left(\Delta_i^* - \Delta_i \right) \frac{w}{w_i} + \frac{\dot{w}^e}{w}. \tag{16}$$

Equation (16) becomes a standard augmented Phillips curve in a symmetric equilibrium where all wages are equalized; $w = w_i$. But at this point our interests lie in extending the model to analyze a non-symmetric equilibrium.

Actual wage differentials equal expected wage differentials in steady state: $\Delta_i = \Delta_i^e = \Delta_i^*$, $i = 1, 2, 3, ... N$. It follows that the rate of wage increases in every firm equals actual and expected inflation in steady state:

$$\frac{\dot{w}_i}{w_i} = \frac{\dot{w}}{w} = \frac{\dot{w}^e}{w}, \qquad \text{i = 1, 2, 3 …..}N.$$

There can be wage differentials between the *N* regions in steady state, but they are maintained over time. Nominal wages in each of the regions rise in line with expected wage inflation, generating actual inflation that equals its expected value. However, actual and desired wage differentials are only equalized in the stationary state. More often, some firms may want to increase their differentials while others may want to reduce them:

Regions wanting to increase their wage differentials: $\Delta_i^* > \Delta_i \quad \rightarrow \quad \dot{\Delta}_i^e > 0$

Regions wanting to decrease their wage differentials: $\Delta_i^* < \Delta_i \quad \rightarrow \quad \dot{\Delta}_i^e < 0$

Average wage inflation is then equal to the weighted average of wage inflation in each of the *N* regions;

$$\frac{\dot{w}}{w} = \sum_{i=1}^{N} n_i \frac{\dot{w}_i}{w_i}. \tag{17}$$

where n_i denotes region *i*'s share of total employment. Combining equations (16) and (17) gives:

$$\frac{\dot{w}}{w} = \sum_{i=1}^{N} n_i \lambda_i \left(\Delta_i^* - \Delta_i\right) \frac{w}{w_i} + \frac{\dot{w}^e}{w}. \tag{18}$$

Using equation (2) we get:

$$\frac{\dot{w}}{w} = \sum_{i=1}^{N} n_i \lambda_i \left(k^i(u,v,v_i) - \Delta_i\right)\frac{w}{w_i} + \frac{\dot{w}^e}{w}. \tag{19}$$

The desired wage differential is an increasing function of both the average vacancy rate in the economy and a negative function of the unemployment rate. This is because the higher the vacancy rate is and the lower the unemployment rate is, the more tempted workers are to search for a new job. Moreover, the desired wage differential at firm i is a positive function of the vacancy rate in the i^{th} region, v_i. The higher the vacancy rate, the more the representative firm is willing to spend to fill these vacancies. Hence the desired wage differential is greater.

At each moment of time, wages are going to be rising in some sectors – relative to anticipated inflation – and falling in others – also relative to anticipated inflation. Figure 4 gives the regional-level wage inflation as a function of the regional vacancy rate. There is a threshold vacancy rate $\bar{v}_i$ such that for lower vacancy rates regional firms would like to reduce their wage differentials and hence raise their wages at a rate lower than the rate of anticipated national wage inflation. Also below the threshold $\tilde{v}_i$, regional firms actually are so eager to reduce wage differentials that they would want to lower their nominal wages. The position of the upward-sloping locus depends on the unemployment rate and the average vacancy rate. When unemployment falls and/or the average vacancy rate rises, the locus shifts upward giving higher wage inflation.

The slope of the locus depends on the speed of adjustment λ for a given level of Δ_i. The higher is this parameter the steeper is the locus. Moreover, the slope will change over time because wage differentials are eventually brought to their desired level. The term Δ_i is falling for firms wanting to lower wage differentials and rising for those wanting to raise them. As a result the term $k^i(u,v,v_i)$-Δ_i gradually falls over time and the slope of the line diminishes until it becomes perfectly horizontal at $\dot{w}/w$. It follows that we can have relative wage adjustments – firms in some regions raise wages faster than anticipated national wage inflation while firms in other regions raise it at a slower pace – in a macroeconomic equilibrium where average wage inflation equals anticipated wage inflation.

So far, the sectoral demand pressures, manifested in the distribution of vacancies across the *N* regions, have played no role in the wage-inflation dynamics. However, slight modifications in the analysis will open the door for distribution effects. Based on the empirical evidence of the distribution of wage changes we can assume that the speed of adjustment is higher for regions wanting to raise their wage differential than for those who would like to reduce it. This is easily justified. It may be more tempting for managers to please their workers with wage increase than it is to disappoint them with wage increases that do not keep up with inflation. This small change in our setup will make the figure look as in Figure 5.

In this case sectoral imbalances and the distribution of vacancies clearly do matter. The larger is the variance of the distribution, the higher is the average rate of wage inflation. Think of there being only two regions in the economy ($N = 2$), one wanting to reduce its wage differential – located along *A* in the figure – and the other wanting to increase it – located along *B*. The further they are apart, the higher will be the average rate of wage inflation – indicated by the two broken horizontal lines. A mean-preserving spread of the distribution of vacancies will hence act to raise average wage inflation. Note that the total number of vacancies stays the same but the variance goes up. There is the interesting possibility that an increase in the regional dispersion of vacancies at an unchanged unemployment rate will cause rising wage inflation: increased dispersion causes reported indices of average wage inflation to rise, which then affects expectations. To the extent that reported wage inflation affects expectations, we find that further wage increases are affected and persistent wage inflation may arise.

It follows from our analysis that in order to prevent such wage-inflation acceleration, average national unemployment has to be higher and/or the average vacancy rate lower. This translates into an increase in equilibrium unemployment. Higher unemployment shifts the locus downwards which then reduces average wage inflation to the level of anticipated wage inflation.

Over time, the flatter segment of the locus will shift upwards while the steeper segment shifts downwards, as in Figure 6. This causes average wage inflation to fall allowing the unemployment rate to fall without wage inflation taking off. Hence, the emergence of sectoral imbalances – at time t_0 in Figure 7 – causes equilibrium unemployment to jump to a higher level from which it then gradually recovers.

There is a related reason why the distribution of vacancies may be of importance. Go back to the symmetric case but rule out absolute money wage reductions. Card and Hyslop (1997) find that there is less thinning of the distribution of wage changes below zero in high-inflation periods for hourly workers. McLaughlin (1999) uses data from the PSID and finds that the left side of the distribution below zero is thinner than the right side.[6] It follows that reductions in money wages are likely to meet even greater resistance than the failure of wage increases to meet general inflation. Moreover, survey results by Truman Bewley (1999) indicate that managers are hesitant to cut wages because of considerations about worker morale. Wage cuts are likely to introduce personnel and incentive problems beyond the intended effect on turnover. This can change the picture dramatically when the expected rate of wage inflation is low. The segment below the horizontal axis is then discontinued and the

[6] In addition, he finds that wage changes are skewed to the right and that there is a spike at zero in the distribution of wage changes.

size of this segment is increasing in the rate of expected inflation (Figure 8). When expected inflation is very high, almost no firm would like to reduce its nominal wages. Allowing wages to rise at a rate lower than the expected rate of nominal wage inflation is usually sufficient to reduce wage differentials. Once again, the variance of the regional distribution of vacancies will be important. The larger the variance, the greater the proportion of regional firms that would like to lower their money wages for a given rate of anticipated national wage inflation.[7]

3. Implications

Asymmetric wage adjustment has several clear implications for the conduct of monetary policy. This relates to the origins and persistence of wage inflation as well as to the optimal response of monetary authorities. The analysis suggests that regional business cycles can play an important role in generating and sustaining wage inflation. This dimension may be no less important than changes in national aggregates over time. An economy experiencing low unemployment and a high level of vacancies may see rising wage inflation, especially if unemployment falls rapidly. But an increase in the dispersion of vacancies can also affect wage inflation and expectations.

The importance of regional factors in this context is unrelated to the well-documented idea of a mismatch between jobs and vacancies. In the literature on mismatch – based on

[7] There is a second, no less important, implication of this extension of the basic model. This involves the long-run Phillips curve that now acquires non-vertical segments. Assume we start with zero expected inflation. In this case a large proportion of firms will desire absolute money wage reductions. Inflation will be positive – due to the asymmetry of the wage response – unless unemployment is sufficiently high to curb inflation at all firms. We can now experiment by raising the level of anticipated inflation. Imagine the central bank announcing a higher inflation target! In this case steady state requires lower unemployment – hence higher quit rates – which make some firms desire a higher wage differential. Now raise expected inflation further. Some of the firms will then decide to raise wages at a faster rate but many will be content to passively observe falling wage differentials. For steady state we then need to reduce the unemployment rate even further. It follows that the natural rate of unemployment is a decreasing function of expected inflation until no firm would like to (absolutely) reduce money wages in order to accomplish a reduction in its wage differential.

regions or skills – vacancies are distributed differently from unemployment, causing the two to co-exist in equilibrium. Vacancies may be found in one part of the country, in certain industries, or for jobs requiring certain skills, while the unemployed are somewhere else or have different skills. The unemployment may be placed in the "wrong" area, trained to work in the "wrong" industry, or not sufficiently skilled for the demands of those wanting to hire new labor. In contrast, regional effects do not require any such mismatch. Imagine that vacancies and unemployment have the same distribution across regions or industries, the analysis above shows that the dispersion of vacancies across sectors still matters. The greater the dispersion, the greater is average wage inflation and the higher is the level of unemployment needed to prevent inflation from rising. This leads to the first policy implications:

- Wage inflation may arise in the absence of any changes in unemployment – hence output – and the total number of vacancies in the economy.

Firms may rely on aggregate indices of wage inflation when setting wages. When wage setting is asymmetric – as in Figure 5 – the consequence is an upward bias in wage inflation. Inflationary pressures are over-estimated because the downward pressure on wages in contracting sectors is not fully reflected in the index. This gives the second implication:

- The use of aggregate wage indices to capture general wage inflation creates an upward bias in realized wage inflation under asymmetric wage adjustment.

This is a very basic but also an important implication. We have shown that averaging across heterogeneous firms in the presence of regional business cycles can create an upward bias in measured wage inflation. This creates a further upward bias in wage inflation if firms base their expectations of future inflation on these reported indices. Of course, the same calculus can affect workers' judgment. To the extent that workers base their decisions whether to quit on a comparison of own wages and average reported wages they may face a greater temptation to quit during times of significant regional cycles, which then can lead to further wage inflation.

Finally, the effect of monetary policy depends on which transmission mechanism is operative at each moment, in particular where in the economy its impacts are to be found. If inflation is the problem, monetary policy would be effective if it manages to reduce vacancies in the booming regions or sectors. In contrast, policy that only reduces vacancies in regions where relative wages – not to mention nominal wages – are falling is going to have a limited effect on overall wage inflation.

- The effect of monetary policy on inflation depends on which transmission mechanism is operative; in particular whether it is the booming or non-booming regions and sectors that are affected by the policy.

It follows that monetary policy makers need to have some idea whether policy affects the real economy through the interest rate/investment channel, the interest rate/wealth/consumption channel, or the exchange rate channel, and also some idea about which sectors are most affected by the different channels.

4. Convexity and the natural rate in the United States

The theoretical model implies a convex upward-sloping relationship between vacancies and wage inflation. When the vacancy rate in one region rises relative to that of another, the rate of wage inflation should rise at an increasing rate. Ideally, we would like to estimate the following equation to test for the convexity of this relationship:

$$\frac{\dot{w}_{it}}{w_{it}} = \alpha_0^i + \alpha_1 v_{it} + \alpha_2 v_{it}^2 + \alpha_3 \frac{\dot{w}_t^e}{w_t} + \varepsilon_{it}. \tag{21}$$

Due to our lack of state-level vacancy data, however, we appeal to equation (5) and substitute two variables for vacancies at the state level, the state unemployment rate and the rate of growth of employment at the state level, $v_i = V(z_i, u_i)$.

This gives rise to the following equation, which can be estimated with state-level panel data:

$$\frac{\dot{w}_{it}}{w_{it}} = \alpha_0^i + \alpha_1 \frac{\dot{N}_{it}}{N_{it}} + \alpha_1 \left(\frac{\dot{N}_{it}}{N_{it}}\right)^2 + \alpha_2 u_{it} + \alpha_2 u_{it}^2 + \alpha_3 \frac{\dot{w}_t^e}{w_t} + \varepsilon_{it}, \tag{22}$$

where α_0^i are state fixed effects. In (22), the subscript i indicates the state and t the time period. We use quarterly data from 1977.3 to 2002.1, hourly earnings in manufacturing as our wage measure, the payroll survey for employment, and the household survey for unemployment rates. Expected wage inflation at the national level is measured by actual CPI inflation lagged one quarter.[8] We estimate (22) with Feasible Generalized Least Squares (FGLS) so as to correct for state-specific autocorrelation and heteroscedasticity that is correlated across states.[9]

As reported in Table 1, the coefficients for employment growth (in levels and squared) imply a convex relationship between wage inflation and employment growth. As illustrated by Figure 9, the convexity of the estimated relationship supports the asymmetry of the theoretical relationship shown in Figure 5. However, the coefficient on the squared term is not statistically significant at traditional levels, so the relationship is not statistically different from linearity. On the other hand, the convexity of the relationship between our

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[8] This is consistent with the assumptions of rational as well as adaptive expectations due to the random walk property of wage inflation.

[9] We are able to correct for this most-general form of heteroskedasticity because our time-series is relatively long for a cross-state panel. A useful rule of thumb is that this is possible if there are twice as many time periods as cross-sectional units (Beck and Katz, 1995), which our panel just satisfies.

other proxy for vacancies, the unemployment rate, is statistically significant and is consistent with our theoretical model (see Figure 10).

The weight of this empirical evidence indicates that the relationship between vacancies and wage inflation is convex, meaning that changes in the dispersion of vacancies across states will have repercussions at the aggregate level. In particular, divergent regional business cycles cause measured wage inflation to rise for a given aggregate unemployment rate. In other words, the aggregate unemployment rate at which wage inflation is unchanged will be higher.

These results suggest one possible reason for the non-inflationary boom that took place in the United States in the 1990s. As shown Figures 1 and 2, the cross-state variance of state unemployment rates and employment growth rates fell throughout the period, indicating a convergence of economic activity. Consistent with our model, the decreased variance in activity was accompanied by a falling aggregate unemployment rate and no increase in inflation.

In order to explore this possibility further we estimate a relatively simple Phillips curve for the United States, using the basic features common to Phillips curve models:[10]

$$\frac{\dot{w}_t}{w_t} - \theta_t^e = \alpha_0 + \alpha_1 \frac{\dot{N}_t}{N_t} - \alpha_2 \ln u_t + \mathbf{A\Omega} + \mathbf{B\Phi} + \pi_t^e + \varepsilon_{it} . \qquad (23)$$

In (23), the dependent variable is nominal hourly wage growth averaged over years t and t+1 net of expected productivity growth, θ_t^e, measured by the trend growth of output per worker in the non-farm business sector. To control for differences across the business cycle, the independent variables include the employment growth rate. They also include a vector of

[10] The variety of Phillips curve specifications is vast; Staiger, Stock, and Watson (2002) alone has dozens of different Phillips curve specifications and estimates. As Phelps (1968) noted thirty-five years ago, and which is no less true today, "(t)he numerous Phillips curve studies of the past ten years have … (offered) countless independent variables in numerous combinations to explain wage movements. But it is difficult to choose among these econometric models, and rarely is there a clear rational for the model used" (p.678).

demographic variables **Φ** to control for changes in the composition of the labor force (Phelps and Zoega, 1997; Shimer, 1998; Francesconi, et al, 2000; and Staiger, Stock, and Watson, 2002). Following Staiger, Stock, and Watson, these variables are the percentages of the adult population that are: high school dropouts, college graduates, white, female, and aged 25-54. Expected wage inflation, π_t^e, is measured by average CPI inflation for years *t*-1 and *t*-2.

Our innovation is to include **Ω,** a vector of the cross-state variances of unemployment rates and employment growth rates. According to our theoretical model, each of these variances should be positively related to wage inflation: even if the aggregate unemployment rate is unchanged, an increase in the dispersion of labor market conditions will raise the aggregate rate of wage inflation.

In choosing the time frame for estimating (23), we are hampered by the unavailability of state-level data before 1977 and demographic variables after 2000. In addition, to eliminate the estimation problems associated with the Monetarist experiment period, we include only 1982 and later. Despite these data restrictions, we are able to obtain the fairly reasonable results reported by Table 2.

Results for our most general specification – which includes demographic variables and the cross-state variances – indicate that the education, gender, and age variables have all been important in determining the rate of wage inflation. This contrasts with Staiger, Stock, and Watson (2002), who find that none of these variables were statistically significant. More importantly for our present purposes, because the coefficients on both of the cross-state variance variables are positive and significant, the results are consistent with our hypothesis that the regional dispersion of economic activity has been important.

Table 2 also reports the results when (23) is estimated without, in turn, the cross-state variances and the demographic variables. From these results it is clear that these sets of variables are related. When the cross-state variances are excluded the coefficient on only one of the demographic variables – the share of college graduates – is any where near to being statistically significant. When the demographic variables are excluded, the coefficients on the cross-state variances are much smaller and are statistically no different from zero – although that for the variance of unemployment rates has a p-value of 10.2 percent. We conclude, therefore, that the demographic and regional trends are complementary in explaining wage inflation.

Further insight into the importance of the cross-state variances can be gained by examining the natural rates of unemployment implied by our Phillips curve estimation. Specifically, solving equation (23) for when unexpected wage inflation is zero, it can be rewritten as:

$$\Delta\left(\frac{\dot{w}_t}{w_t}\right) = \alpha_1 \frac{\dot{N}_t}{N_t} - \alpha_2\left(\log(u_t) - \log(u_t^n)\right) + \varepsilon_{it}; \quad (24)$$

where $u_t^n = \exp[(\alpha_0 + \mathbf{A\Omega} + \mathbf{B\Phi})/\alpha_2]$ is the time-variant natural rate of unemployment.

The three trend natural rates from our estimation, along with the trend unemployment rate, are illustrated by Figure 11. Our most general model indicates that the natural rate fell steadily between 1982 and 2000, from about 6.7 percent to about 5.2 percent, with the steepest declines coming prior to 1993. In contrast, the two less-general models both suggest that the natural rate fell by only 0.8 percentage points over the same period, just more than one-half the decline implied by the general model. Keep in mind, though, that due to the large standard errors, the confidence intervals on these latter two natural rates are wide.

5. Regional business cycles in a small, homogenous economy

The question arises whether regional developments matter primarily in the larger, more heterogeneous countries. We now look at data from Iceland, which is one of the smallest and most homogeneous of the OECD countries.

It turns out that regional business cycles are pronounced in Iceland. A modern service-based economy is found in the capital city Reykjavik while the rest of the country has small fishing villages and agriculture. Until quite recently, the business cycle was driven by changes in the value of the fish catch. Changes in the terms of trade and the volume of the catch caused earnings and employment to rise in rural areas. The effects were then transmitted to the capital region where services are predominant. The traditional transmission channel was the government's exchange rate policy. When the value of the catch increased, the exchange rate was allowed to appreciate, which caused a real exchange rate appreciation and an increase in real wages in both urban and rural areas. Higher real wages then made consumption spending go up, which benefited the urban service sector. These cycles were closely correlated with factors that were external to the economy and, as a result, the cycle was out of synch with that of neighboring countries. The top panel of Figure 12 shows the rate of growth of real GDP and the rate of growth of the real value of the domestic fish catch. Note the close correspondence between the two series. The bottom panel shows the correspondence between changes in the value of the catch and changes in average real earnings, which is similarly quite impressive.

The last decade or so has seen a reversal of the earlier pattern of resource-driven business cycles. The recession that took place between 1990 and 1996, the subsequent recovery, and the most recent recession all originated in the service sector in the urban part of the country. The expansion coincided with capital market liberalization, a domestic credit expansion, and an investment boom. Figure 13 shows vacancies (as a ratio to the labor force) in Reykjavik and in the rural parts of the country during this most recent period. While rural vacancies exhibit fluctuations around a fixed mean, vacancies in Reykjavik fell in the late 1980s, early 1990s, and during the recovery until 2000, when the current recession commenced. This trough precedes the year of peak unemployment, which was 1996. The behavior of unemployment also reveals a significant cycle in Reykjavik as seen in Figure 14.

We now turn to Icelandic regional data and estimate equation (23) using panel data for Icelandic regions.[11] Inflation turns out to be a positive function of employment growth and a negative function of unemployment. The relationship between wage inflation and employment growth – shown in Figure 15 – is convex as predicted by the theory. Finally, we estimate a Phillips curve that includes the higher moments of the distribution of unemployment and employment growth across regions. We use seemingly unrelated regression. The results are reported in Table 4.

The standard deviation of the distribution of employment growth has a positive effect on inflation for a given unemployment rate and a given employment growth rate at the national level. This indicates that the higher the standard deviation, the higher is the value of the natural rate of unemployment. Note that the variance of employment growth rates affects inflation much more so than the variance of the rates of unemployment.

5. Conclusions

We have shown how regional developments affect the path of the natural rate of unemployment. Asymmetric wage adjustments imply that inflationary pressures are an

[11] The regions are: Reykjavik, Reykjanes, Vesturland, Vestfirdir, Nordurland Vestra, Nordurland Eystra, Austfirdir, Sudurland.

increasing function of the regional dispersion of vacancies. Our empirical results for the United States support this hypothesis.

For the United States, we used unemployment and employment growth to proxy for vacancies at the state level and showed that the relationship between unexpected wage inflation, on the one hand, and unemployment and employment growth, on the other hand, is convex. The higher the cross-state dispersion of unemployment and employment growth, the higher is the level of national wage inflation. Finally, we included the variance of state unemployment and employment growth rates in a Phillips curve estimation and found both to be statistically significant.

We conclude that when examining changes in the natural rate of unemployment in the United States over the past two decades, it is important to consider the convergence of state labor-market conditions. Further, such regional developments are complementary to other proposed explanations discussed by Ball and Mankiw (2002), who find that the primary sources were the acceleration of productivity growth (Pissarides, 2000; Hoon and Phelps, 1997) and the changing composition of the labor force (Phelps and Zoega, 1997; Shimer, 1998; Francesconi, et al, 2000).

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Table 1. Wage inflation and vacancies in a state panel

	Coeff.	*s.e.*	*t*
Employment growth	0.0365*	0.0146	2.50
Employment growth	0.0047	0.0036	1.31
Unemployment rate	-0.0679*	0.0207	3.28
Unemployment rate	0.0021*	0.0012	1.66
Expected wage inflation	0.5907*	0.0293	20.14
State fixed effects (48)		Yes	
Observations		4752	
Estimated covariances		1176	
Estimated Autocorrelations		48	
Log-likelihood		-4587.42	

A '*' indicates statistical significance at the 10 percent level. The estimator is FGLS and corrects for state-specific autocorrelation and heteroskedasticity with cross-state correlations. Quarterly state-level data, 1977.3-2002.1. Indiana and Kansas are excluded because of missing earnings data in early years of the sample. For space considerations, we do not report the estimates of the state fixed effects.

Table 2. U.S. Phillips curve estimation

	Variances and Demographics	Demographics Only	Variances Only
Constant	-183.522* (53.457)	-105.417 (82.721)	6.497* (0.847)
Employment growth rate	-0.007 (0.100)	0.193* (0.068)	0.136 (0.092)
Log unemployment rate	-3.816* (0.628)	-3.182* (0.981)	-4.180* (0.548)
Variance of state unemployment rates	0.491* (0.120)		0.173 (0.098)
Variance of state employment growth rates	0.078* (0.033)		-0.027 (0.030)
Share high school dropout	1.157* (0.471)	0.896 (0.763)	
Share college graduate	0.747* (0.172)	0.483* (0.249)	
Share white	-0.190 (0.847)	-0.033 (1.278)	
Share female	2.905* (1.143)	1.651 (2.189)	
Share aged 25-54	0.426* (0.138)	0.125 (0.160)	
Expected wage inflation	0.472* (0.077)	0.474* (0.117)	0.533* (0.051)
Observations	19	19	19
R^2	0.969	0.923	0.894

White-corrected standard errors are in parentheses. A '*' indicates significance at the 10 percent level. Yearly aggregate data, 1982-2000.

Table 3. Regional wage inflation, unemployment, and employment growth in Iceland

	Coefficient	t-statistic
Unemployment	0.851	1.88
Unemployment squared	0.047	0.77
Employment growth	-0.044	1.01
Employment growth squared	1.860	2.83
Lagged inflation	0.279	3.95
Observations	104	
Period	1988-2000	

White heteroscedasticity-consistent standard errors and covariance.

	R^2	DW
Reykjavik	0.26	1.96
Reykjanes	0.47	2.13
Vesturland	0.44	1.86
Vestfirdir	0.67	1.86
Nordurland Vestra	0.46	1.91
Nordurland Eystra	0.39	2.22
Austurland	0.51	1.99
Sudurland	0.45	1.70

Table 4. Icelandic Phillips curve estimation

		(1)	(2)	(3)	(4)
Constant		0.04 (0.73)	0.06 (0.56)	-0.06 (0.79)	0.02 (0.34)
Lagged inflation		0.70 (3.43)	0.71 (3.37)	0.70 (3.78)	0.70 (3.84)
Unemployment rate		-0.01 (0.86)	-0.01 (0.74)	0.00 (0.29)	-0.01 (0.68)
Employment growth		1.82 (5.34)	1.76 (2.73)	1.83 (5.18)	1.95 (5.51)
Unemp.	St. dev.		-0.02 (0.20)		
	Skewness		-0.03 (0.32)		
	Kurtosis		0.01 (0.14)		
Employm. Growth	St. dev.			1.04 (1.61)	0.65 (1.52)
	Skewness			-0.03 (1.18)	
	Kurtosis			0.03 (0.71)	
Observations		20	20	20	20
R-squared		0.86	0.87	0.89	0.87
R-squared adjusted		0.84	0.80	0.83	0.83
Durbin Watson		2.64	2.68	2.55	2.60

Figure 1. U.S. unemployment and its cross-state variance, 1977.Q3 - 2002.Q1

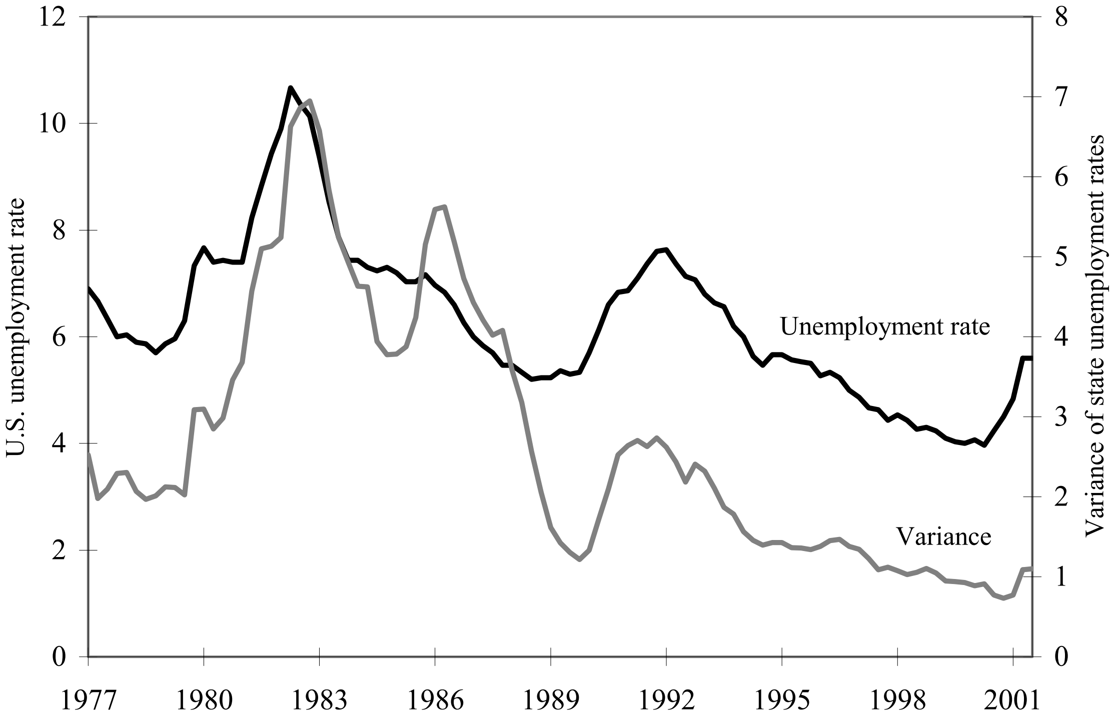


Figure 2. U.S. employment growth and its cross-state variance, 1977.Q3 - 2002.Q1

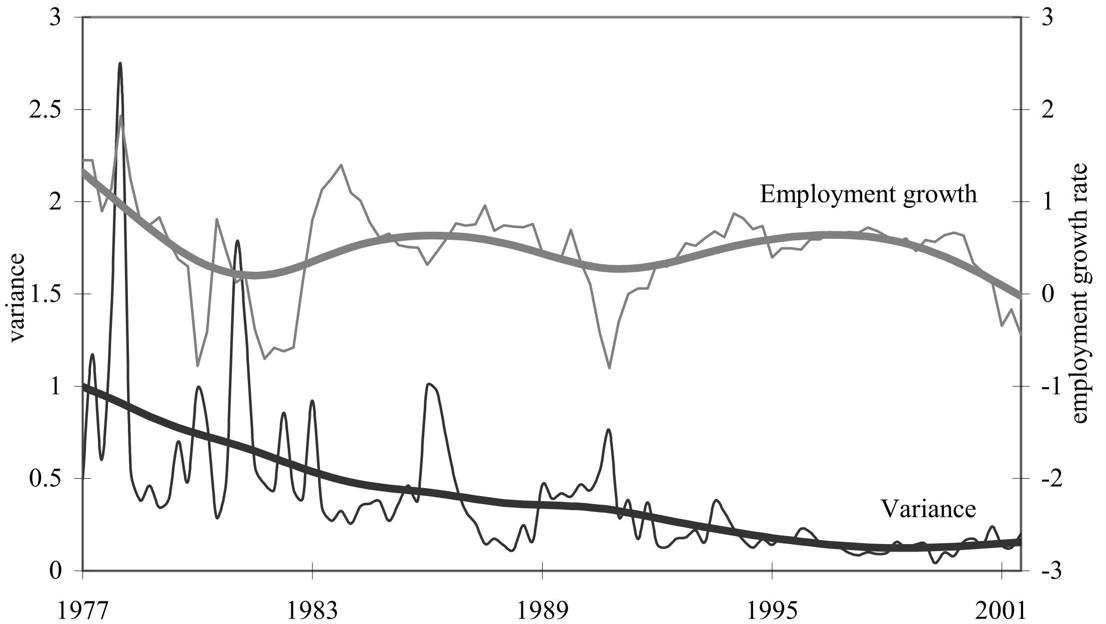
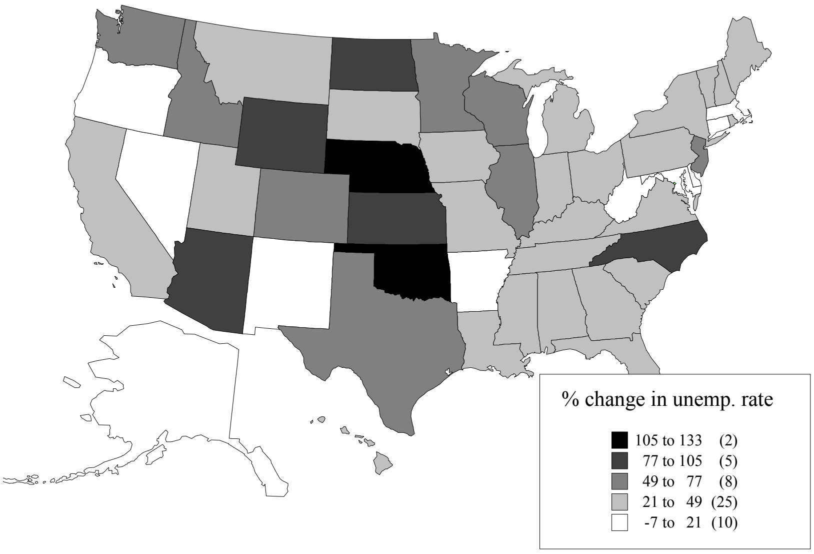
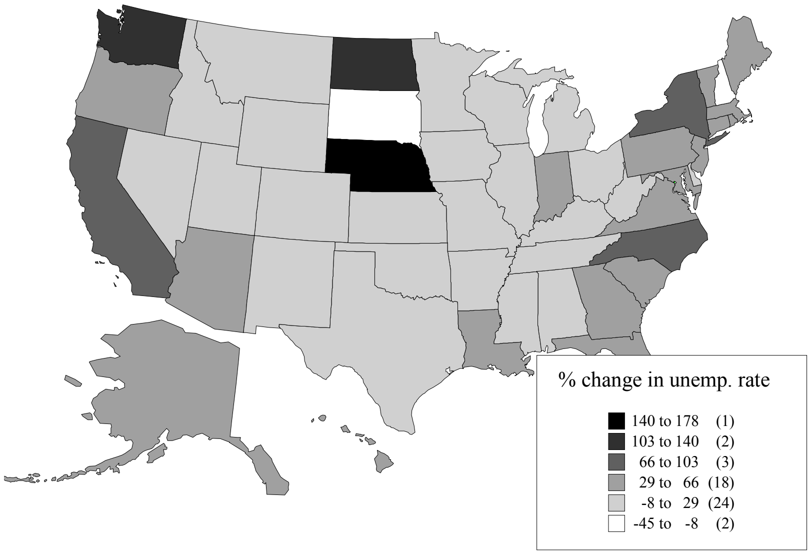


Figure 3. Percentage changes in state unemployment rates during recessions

1981.3 to 1982.4



1990.2 to 1992.3



2000.4 to 2002.1

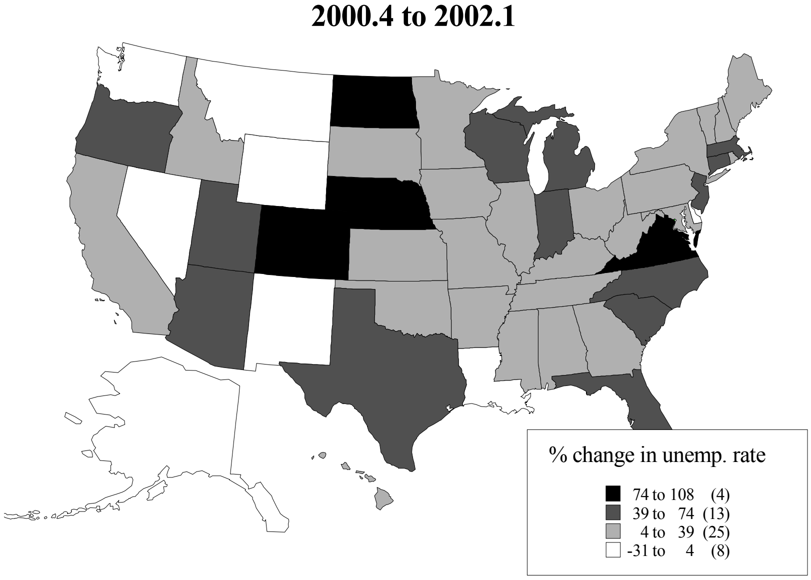


Figure 4. Symmetric wage pressure

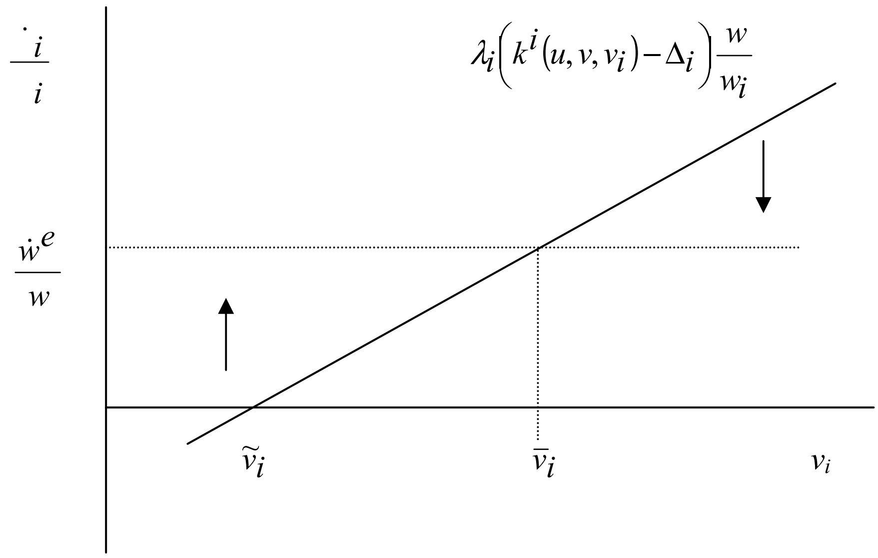


Figure 5. The dispersion of vacancies and asymmetric wage pressure

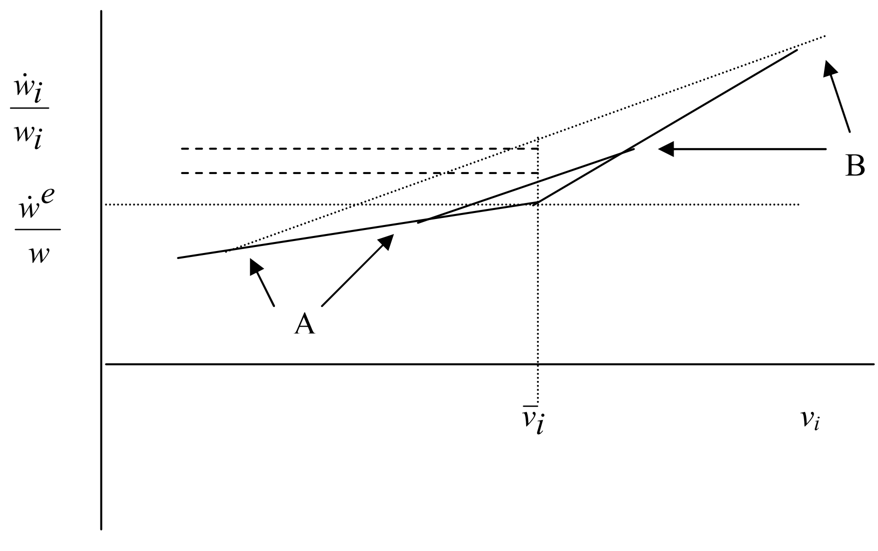


Figure 6. Dynamic adjustment under asymmetric wage pressure

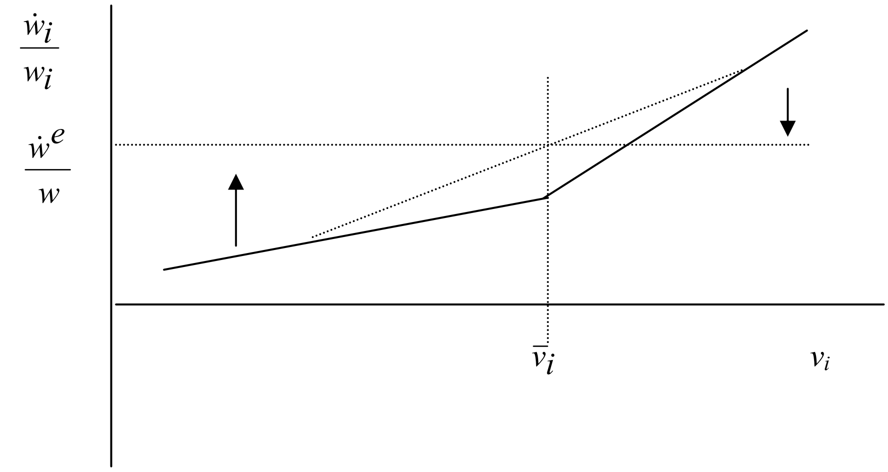


Figure 7. Sectoral imbalances and the natural rate of unemployment

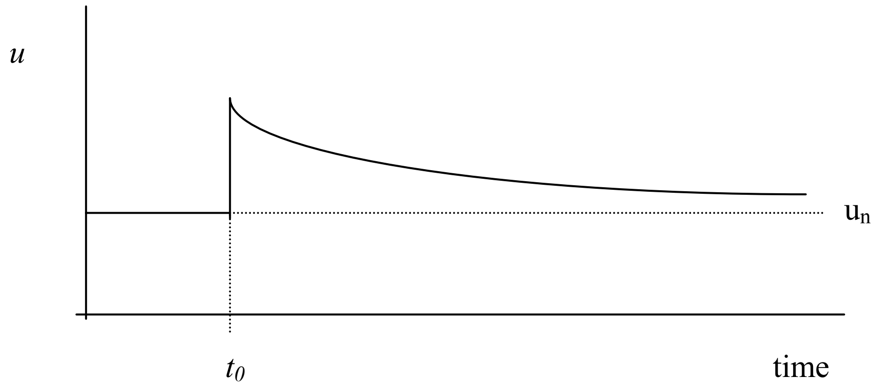


Figure 8. Dispersion of vacancies and wage pressure with no wage reductions

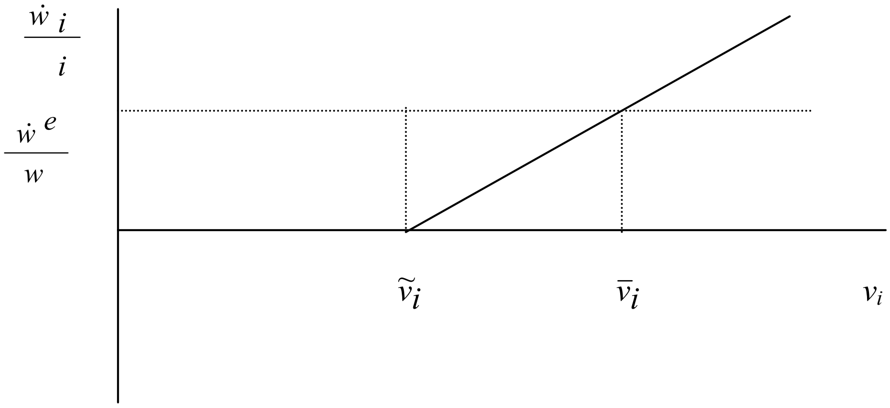


Figure 9. Wage inflation and vacancies (Employment growth)

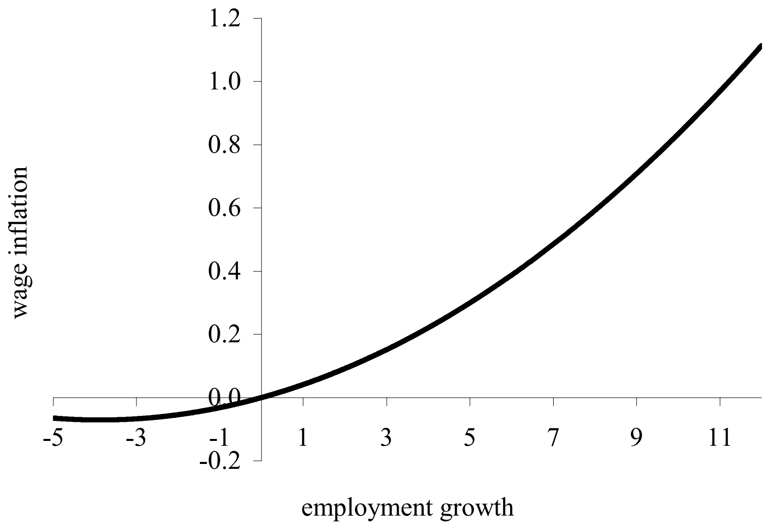


Figure 10. Wage inflation and vacancies (Unemployment rate)

Figure 11. The falling U.S. natural rate, 1982-2000

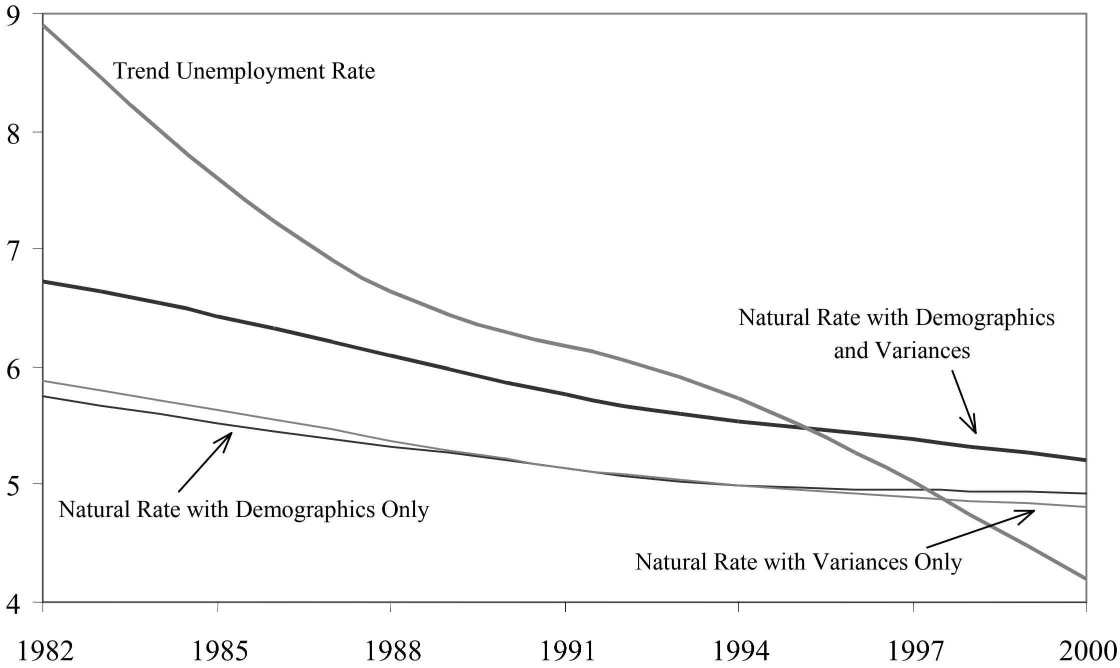
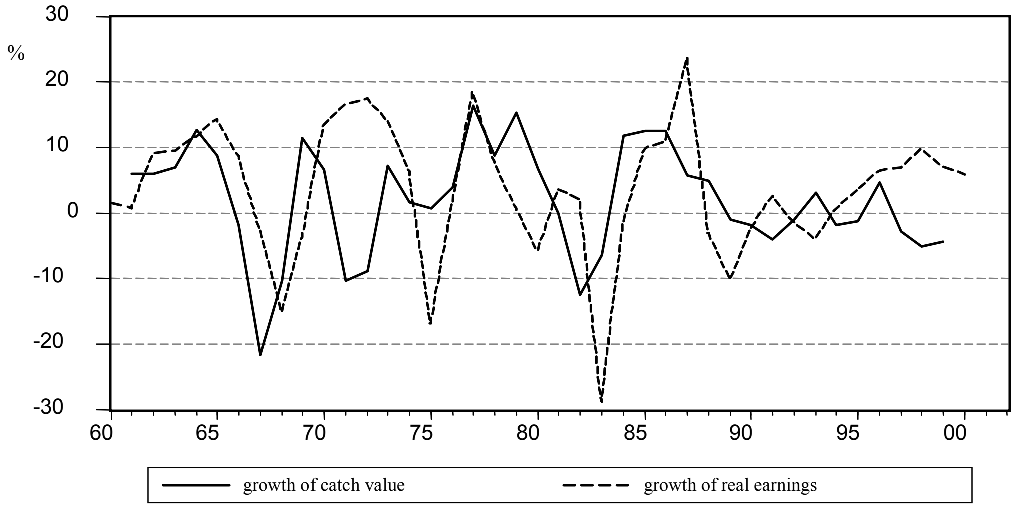


Figure 12. The fish catch, average earnings, and GDP in Iceland (annual growth rates).



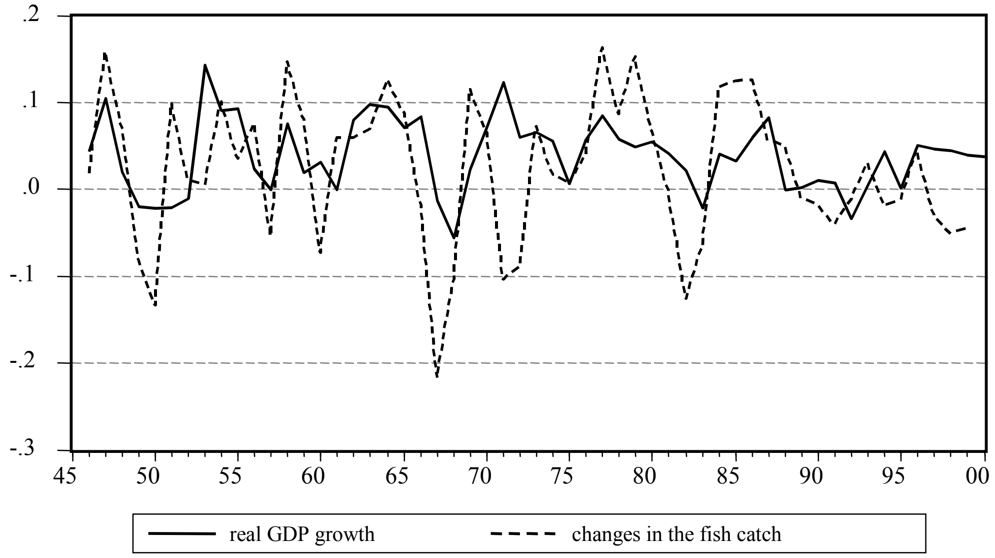


Figure 13. Vacancies (percentage of labor force) in Reykjavik and rural areas

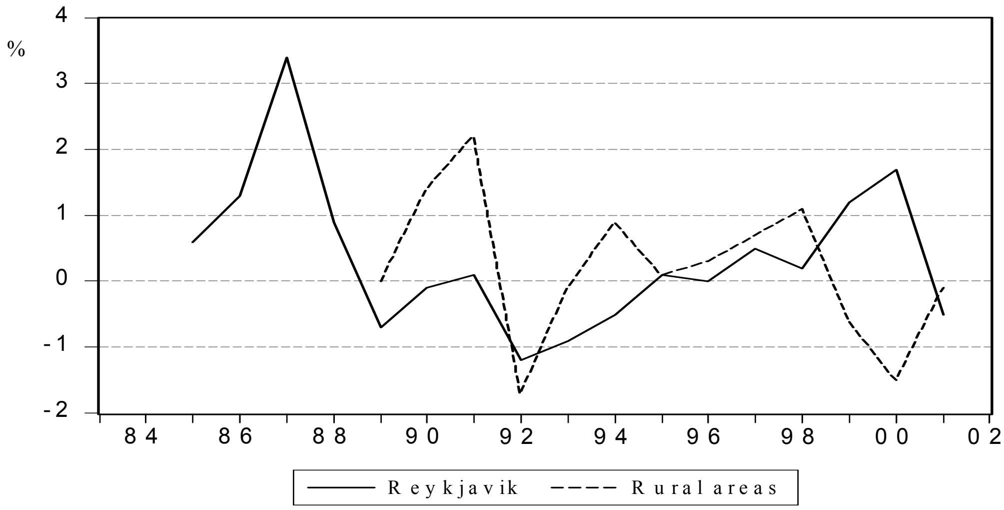
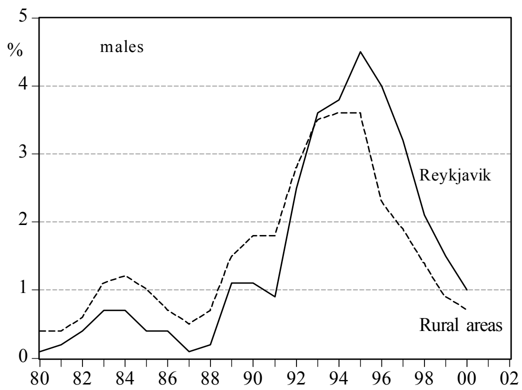


Figure 14. Male and female unemployment in Reykjavik and rural areas



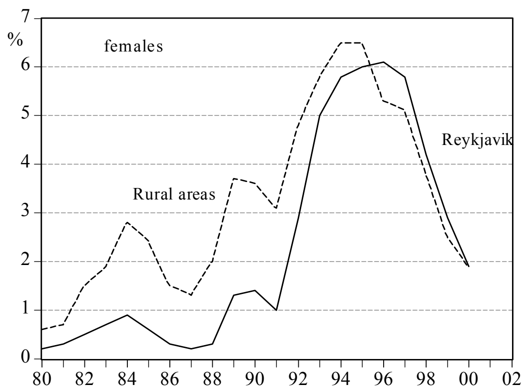


Figure 15. The convexity of wage adjustment in Iceland