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Wage and Price Formation in a Small Open Economy: Evidence from Iceland

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Abstract

This paper uses an open economy version of a wage-price model with imperfect competition in goods and labour markets to analyse wage and price inflation in Iceland. The model identifies three main sources of wage and price inflation in Iceland: a *conflicting claims channel*, a *real exchange rate channel*, and an *excess demand channel*. The model explains a large proportion of wage and price inflation during the last three decades and is remarkably stable, considering the fundamental changes in the institutional setup in Iceland during this period. There is some evidence of an upward shift in the equilibrium mark-ups in the late 1980s. The results indicate that this was due to a substantial rise in the cost of capital that reflected the move towards market determined interest rates and a shift in policy priorities towards price stability, which cumulated in a path-breaking labour market agreement in early 1990. These changes led to a downward shift in steady state inflation and an upward shift in the natural rate of unemployment.

Keywords: Wage and price formation, mark-up pricing, wage bargaining, dynamic modelling.
JEL Classification: E31, J30, C32, C51.

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1. Introduction

During the last three decades dramatic changes have occurred in the development of price and wage inflation in Iceland. In the 1950s and 1960s average price inflation was close to 10% a year, but the 1970s witnessed a substantial rise in inflation following the two OPEC oil shocks, successive wage shocks and a very accommodative monetary policy stance. At the start of the decade inflation was around 13% but had reached almost 60% by the end of the decade. The early half of the 1980s saw a continuation of this development, with annual inflation peaking at 83% in 1983. In 1983 the first steps towards reducing inflation to a rate prevalent in other OECD countries were taken, with a stabilisation package that included, among other things, the abolishment of wage indexation, exchange rate stabilisation and various income policy measures. This first phase of the disinflation process succeeded in bringing inflation down to roughly 20% in the middle of the 1980s. The second phase of the disinflation process started in the late 1980s and involved much more radical changes in policy priorities. In this phase inflation was brought down to very low levels, with annual inflation ranging from 1.5% in 1994 to 3.5% in 1999, and for the most of the period being below 2%. The key ingredients in the second phase were the liberalisation of the domestic financial and labour markets, a shift from high-employment monetary policy to a policy more aimed to preserve price stability, and a ground-breaking labour market agreement in early 1990 that reflected the growing perception among the general public, labour unions and policymakers that economic prosperity was best secured by low and stable inflation.[1]

From this short description of the inflation dynamics in Iceland during the last three decades, it should be clear that the challenge of any empirical model of this process is enormous. However, a simple model that is constant throughout the estimation period and fits the data quite well exists. This model assumes imperfect competition in domestic goods and labour markets and identifies three main sources of wage and price inflation in Iceland. First there is a *conflicting claims channel*, where firms and workers attempt to maximise their share in total income. This channel works through the wage bargaining process with firms raising their prices and workers claiming higher nominal wages until a steady state is reached. Second, there is a *real exchange rate channel*. In this case a rise in domestic currency import prices increases demand for domestic goods, thereby pushing up domestic prices and profits of domestic firms. Workers claim their share of increased profits through the bargaining process, thus raising wages. Third, there is an *excess demand channel*. In this case, excess demand for domestic

[1] See Andersen and Gudmundsson (1998) and Gudmundsson, Pétursson and Sighvatsson (2000) for a detailed historical account of these two disinflation phases.

goods will push up domestic prices until demand falls back to capacity levels. A similar effect is at work in the labour market, where excess demand for labour pushes up wages through the bargaining process.

Finally, there is some evidence of an upward shift in the equilibrium mark-ups in the late 1980s. The results indicate that this was due to a substantial rise in the cost of capital that reflected the above mentioned financial market reforms and changes in policy priorities. These changes led to a downward shift in steady state inflation and an upward shift in the natural rate of unemployment.

The remainder of the paper is organised as follows. Section 2 discusses a theoretical model of the static steady state wage and price formation, which constitutes the long-run relations of the estimated dynamic wage-price model. Section 3 discusses the data. Section 4 estimates the long-run relations and Section 5 the dynamic wage-price model. Section 6 discusses the dynamic steady state properties of the model. Section 7 analysis the forecasting ability of the model and Section 8 concludes.

2. The theoretical model

2.1. Wage bargaining

It is assumed that wage formation is determined through Nash-bargaining between firms and labour unions over wages. This is the prevalent theory of wage bargaining in relatively unionised economies such as Iceland, cf. Carlin and Soskice (1990) and Lindbeck (1993), and the most popular framework for empirical wage modelling since Andrews and Nickell (1983).

The wage bargaining formulation can be derived directly from a model with profit maximising firms and utility maximising consumers, organised in labour unions, as in Pétursson and Sløk (2001). These type of models predict that the bargaining solution will depend on the real product wage and productivity from the firm side and the real consumption wage from the workers side.

A log-linear form of the bargaining solution can be written as (with lower case letters denoting logs)

$$w = \alpha p_r + (1-\alpha)p + \delta z - \theta u + \xi_w, \qquad 0 \leq \alpha, \delta \leq 1, \theta \geq 0, \tag{2.1}$$

where w is the target nominal wage rate, p_r is the producer price level, p is the consumer price level, z is labour productivity and u is the unemployment rate. ξ_w includes other terms that affect the bargaining outcome, such as the replacement ratio, tax rates, the degree of labour market skill mismatch and institutional factors such as the existence of centralised wage bargaining institutions (cf. Nickell, 1987). The term $p_r - p$ is often called the price wedge and plays an important role in wage bargaining models. If $\alpha = 0$, the price wedge has no long-run effect on $w - p$, i.e. the bargaining solution fully reflects the real consumption wage, whereas if $\alpha = 1$, the price wedge will have a proportional long-run effect on $w - p$, such that the bargaining solution fully reflects the real product wage, $w - p_r$.

The bargaining solution also implies that an increase in labour productivity will lead to higher wages, since higher productivity increases the profitability of firms, so they are more likely to accept higher wage claims from the unions. Note that if $\delta = 1$, the bargaining solution will be in terms of unit labour cost, $w - z$, i.e. all gains in labour productivity will be reflected in the wage rate in the long run, so that equilibrium prices are independent of productivity. Finally, the model contains the unemployment rate, which represents the degree of tightness in the labour market which influences the outcome of the bargaining process. It can therefore be interpreted as capturing the relative bargaining power of the labour unions.

2.2. Price formation

Assume a representative firm in an imperfectly competitive market, producing a single good for which imperfect substitutes are produced abroad. The planned price of the good is determined as a mark-up over marginal costs

$$p_r = \mu + mc, \tag{2.2}$$

where μ is the mark-up and mc are marginal costs. The mark-up is not necessarily constant and may be a function of relative prices. This allows for a pricing-to-market effect, with the mark-up inversely related to the elasticity of demand (see, for example, Krugman, 1987)

$$\mu = \kappa + \lambda(q - p_r) + \xi_p, \qquad \kappa, \lambda \geq 0, \tag{2.3}$$

where q is the domestic currency price of imperfect substitute tradeable goods produced abroad and λ reflects the exposure of domestic firms to foreign demand. Thus, the greater the pricing-to-market effect (smaller λ) the less is the pass-through from foreign price or exchange rate shocks to domestic prices. ξ_p includes other terms that affect the mark-up, such as indirect taxes, the marginal cost of capital and changes in the market power of firms that are not reflected in the pricing-to-market effect.

Production technology is given by a simple Cobb-Douglas production function, with constant returns to scale

$$y = \log \zeta + \gamma n + (1 - \gamma)k, \qquad 0 < \gamma < 1, \tag{2.4}$$

where y is value added output, ζ is total factor productivity, n is total hours of work and k is capital input. Assuming that firms maximise profits with respect to labour inputs gives marginal costs as

$$mc = w - z - \log \gamma, \tag{2.5}$$

where $z = (y - n)$. Substituting (2.3) and (2.5) into (2.2) gives the planned producer price level as a mark-up over unit labour cost and import prices, with prices homogenous in both these arguments

$$p_r = \left(\frac{\kappa - \log \gamma + \xi_p}{1+\lambda}\right) + \left(\frac{1}{1+\lambda}\right)(w - z) + \left(\frac{\lambda}{1+\lambda}\right) q. \tag{2.6}$$

In this paper the focus is on the consumer price level rather than the producer price level, since no data on producer prices is available for Iceland. These are related through the following equation

$$p = (1-\eta)p_r + \eta q, \qquad 0 < \eta < 1, \tag{2.7}$$

where η is the share of imported goods in the consumption basket. The long-run solution for consumer prices is therefore given as

$$p = \left(\frac{(1-\eta)(\kappa - \log \gamma + \xi_p)}{1+\lambda}\right) + \left(\frac{1-\eta}{1+\lambda}\right)(w - z) + \left(\frac{\eta+\lambda}{1+\lambda}\right) q. \tag{2.8}$$

Thus, there are two channels through which foreign price and exchange rate shocks effect domestic consumer prices. First, there is a direct channel through imported goods in the consumer price index, given by η. Second, a rise in import prices reduces the elasticity of demand for domestic imperfect substitutes, thus allowing domestic producers to increase their mark-up, μ, and the price of their products. Consumer prices rise subsequently through the definition of the consumer price index, the total amount given by $\lambda(1-\eta)/(1+\lambda)$. The greater the pricing-to-market effect the less is this pass-through effect.

2.3. The empirical long-run relations

Substituting (2.7) into (2.1) and using the price equation in (2.8) gives the empirical long-run wage and price relations used in this paper

$$\begin{aligned} w &= (1+\phi)\, p - \phi q + \delta z - \theta u + ec(w), && (2.9)\\ p &= \psi(w - z) + (1-\psi) q + ec(p), && (2.10) \end{aligned}$$

where $\phi = \alpha\eta/(1-\eta)$, $\psi = (1-\eta)/(1+\lambda)$ and $ec(w)$ and $ec(p)$ are the wage and price mark-ups from the static steady state analysis above.[2] Note that the estimate of ψ will in general be larger than the propensity to import, η, if $\lambda > 0$.

The wage bargaining solution implies that when wages are below the equilibrium target wage, i.e. when the wage mark-up $ec(w)$ is below its equilibrium value, labour unions will bid up the wage rate to restore the long-run equilibrium. This equilibrium relation can also be written in an alternative way that may facilitate further interpretation. Denote $s = w - z - p_r$ as the labour share in value added (or equivalently, real unit labour costs), which is proportional to real marginal costs, $mc - p_r = s - \log\gamma$ from (2.5), and $r = q - p_r$ as the real exchange rate (or price competitiveness).[3] In this case the wage bargaining solution can be written as

$$ec(w) = s - (1-\alpha)\eta r + (1-\delta)z + \theta u. \tag{2.11}$$

Thus, for a given wage mark-up, a rise in the wage share, or real marginal costs, imposes a downward pressure on wages to push s down again towards its original steady state. Furthermore, if $\alpha < 1$, an appreciation of the real exchange rate (a fall in r) will also put a downward pressure on wages. The reason is that an appreciation decreases the competitiveness of domestic firms, thus decreasing their ability to pay wages. If $\alpha = 1$, the wage share will be independent of real exchange rate shocks. If, however, $\alpha = 0$ (as found in the empirical part below), the long-run effect of a terms of trade shock will be larger than if $\alpha > 0$ (for a given p). The same applies the more open the economy is (larger η). Finally, a fall in the unemployment rate signals increased tightness in the labour market, thus pushing up wages and the wage share in the long run. This effect will be larger the more flexible wages are (larger θ).

Next, the long-run mark-up pricing rule implies that when prices are below the equilibrium target price, i.e. when the price mark-up $ec(p)$ is below its equilibrium value, firms will revise their pricing strategy and start raising prices towards the long-run equilibrium. This will raise consumer prices through (2.7). The ability of firms to respond to changes in marginal costs and foreign prices is determined by the elasticity of demand for their goods. The greater the substitutability of domestic and foreign goods, i.e. the less the market power of domestic firms (greater λ), the more are domestic prices determined by world prices. In the

[2] Strictly speaking $ec(p)$ and $ec(w)$ consist of the equilibrium mark-ups plus the deviations of actual wages and prices from their target values. In steady state these deviations are zero and $ec(p)$ and $ec(w)$ correspond to the equilibrium mark-ups. Note that ξ_w and ξ_p are included in the mark-ups, $ec(w)$ and $ec(p)$, and are therefore assumed to be stationary or form a cointegrating subset. They will therefore not affect the estimation of the long-run coefficients.

[3] Note that since there are no non-traded goods, this will also constitute the terms of trade.

limit where $\lambda \to \infty$, all goods are perfect substitutes and domestic prices are solely determined abroad, which represents the pure form of the PPP hypothesis. Hence, domestic firms have no scope to respond to domestic cost developments. If, however, $\lambda = 0$ all goods are imperfect substitutes and domestic producer prices are solely determined by domestic marginal costs and consumer prices simply by domestic costs and foreign prices according to their relative share in the consumer price index. Hence, the pass-through of foreign price and exchange rate shocks, $1 - \psi = (\eta + \lambda)/(1 + \lambda)$, is larger the larger the share of imported goods in the consumption basket (larger η) or the smaller the pricing-to-market effect (larger λ).

The price mark-up can also be written in terms of the wage share and the real exchange rate, similar to the wage bargaining solution in (2.11)

$$ec(p) = -\left(\frac{1-\eta}{1+\lambda}\right) s - \lambda \left(\frac{1-\eta}{1+\lambda}\right) r. \tag{2.12}$$

Thus, for a given price mark-up, a rise in the labour share will force firms to raise their prices in an attempt to retain their share in total value added $(1 - s)$. Furthermore, a real appreciation of the domestic currency will force firms to lower their prices through (2.3), which will lower consumer prices through the consumer price index. This real exchange rate effect will be larger, the more domestic firms are exposed to foreign demand, i.e. the weaker the pricing-to-market channel.

The above analysis is partial in nature, describing the behaviour of each decision variable conditional on the other. The steady state reflects the joint determination of both prices and wages and is obtained by solving (2.9) and (2.10) together

$$p^* = \varphi_p + q - \left(\frac{(1-\eta)(1-\delta)}{\lambda + (1-\alpha)\eta}\right) z - \left(\frac{(1-\eta)\theta}{\lambda + (1-\alpha)\eta}\right) u, \tag{2.13}$$

$$w^* = \varphi_w + q + \left(1 - \frac{(1+\lambda)(1-\delta)}{\lambda + (1-\alpha)\eta}\right) z - \left(\frac{(1+\lambda)\theta}{\lambda + (1-\alpha)\eta}\right) u, \tag{2.14}$$

where φ_p and φ_w are constants that are functions of the equilibrium mark-ups and the other parameters of the model. Prices and wages display long-run homogeneity with respect to import prices. δ determines how the productivity gain is distributed between firms and workers. If $\delta < 1$ a rise in productivity will lead to a fall in equilibrium prices and a rise in equilibrium wages. The rise in equilibrium real wages will be less than proportional, leading to a fall in the wage share. If, however, $\delta = 1$, equilibrium wages will completely absorb all the productivity gain and equilibrium prices will not be affected. The rise in real wages will be proportional to the productivity gain and the wage share will be unaffected.

The solution can also be written for the long-run equilibrium unemployment rate as a function of the real exchange rate and productivity

$$u^* = \varphi_u + \left(\frac{\lambda + (1-\alpha)\eta}{\theta}\right) r - \left(\frac{1-\delta}{\theta}\right) z, \tag{2.15}$$

where φ_u is a constant that is a function of the equilibrium mark-ups and the other parameters of the model. The long-run homogeneity of wages and prices in (2.13)-(2.14) ensures that the system displays long run nominal neutrality ensuring that the equilibrium unemployment rate is independent of nominal variables. The equilibrium unemployment rate will be negatively affected by productivity, for a given real exchange rate, if $\delta < 1$, but independent of productivity if $\delta = 1$. This is consistent with the lack of an obvious long-run downward trend in unemployment despite a significant long-run trend growth of productivity in most countries. Equilibrium unemployment will also fall when the equilibrium real exchange rate appreciates, i.e. when the economy is hit by a positive terms of trade shock. The equilibrium unemployment rate is more sensitive to real exchange rate shocks the more open the economy (larger η), the less responsive the real product wage is to real exchange rate shocks (larger α), the less the pricing-to-market effect (larger λ) and the less flexible the labour market (smaller θ).

2.4. Modelling the wage-price dynamics

The wage and price dynamics towards the long-run solutions are assumed to be given by the following error correction model (ECM)

$$\begin{aligned} \alpha_p(L)\Delta_k p_t &= \beta_p(L)\Delta_k w_t + \delta_p(L)\Delta_k z_t + \mu_p(L)\Delta_k q_t \\ &\quad + \phi_p(L) g_t + \lambda_p(L)\Delta_k u_t - \rho_p ec(p)_{t-k} + \epsilon_{pt}, \end{aligned} \tag{2.16}$$

$$\begin{aligned} \alpha_w(L)\Delta_k w_t &= \beta_w(L)\Delta_k p_t + \delta_w(L)\Delta_k z_t + \mu_w(L)\Delta_k q_t \\ &\quad + \lambda_w(L)\Delta_k u_t - \rho_w ec(w)_{t-k} + \epsilon_{wt}, \end{aligned} \tag{2.17}$$

where $\alpha_p(L)$, etc., are polynomials in the lag operator, $L^k x_t = x_{t-k}$, $\Delta_k x_t = (1 - L^k) x_t$, $ec(p)_{t-k}$ and $ec(w)_{t-k}$ are the lagged mark-ups from the static long-run analysis above (the error corrections) and ϵ_{pt} and ϵ_{wt} are i.i.d. error processes.

The dynamic price equation allows the output gap (g_t) to have short-run effects on the price mark-up since in the short run the marginal cost curve is upward sloping (as the capital stock is fixed). Hence, any increases in output above potential will exert an upward pressure on inflation. On the other hand, a negative output gap implies the existence of non-utilised resources that can be activated without generating inflationary pressures.

The ECM above can be interpreted as generalised version of Phillips-curves for wages and prices, derived from New-Keynesian theories of sticky wages and prices. The model can also be viewed as a generalised version of the "triangle" model of inflation, a formulation of the Phillips-curve suggested by Gordon (1997).

Hence, domestic prices respond to demand pressures in the goods market, as measured by the output gap, and wages respond to demand pressures in the labour market, as measured by the unemployment rate. The formulation of the Phillips-curves adopted here also includes lagged wage and price inflation, capturing price and wage inertia effects, and the lagged $ec(p)_t$ and $ec(w)_t$, capturing the effects of deviations of the price and wage mark-ups from their long-run equilibrium targets on price and wage inflation, respectively. The formulation also includes productivity and import price effects, which can be thought of as proxying supply shocks. Traditional Phillips-curves of price determination do typically not include unit labour costs and import prices as explanatory variables. They are, however considered very important for price formation in small open economies that are regularly hit by supply shocks and have a relatively centralised wage bargaining system, such as Iceland (cf. Gudmundsson, 1990, Andersen and Gudmundsson, 1998 and Pétursson, 1998) and Norway (cf. Bårdsen, Fisher and Nymoen, 1998).[4]

It is also standard to include expected future values of inflation and wage growth in these type of models. In the formulation of the Phillips-curve models above these do not enter explicitly. One interpretation is that expectations are purely backward-looking. Hence, augmenting the standard Phillips-curves with lag dynamics can simply be viewed as capturing the information set used by firms and wage setters when forecasting inflation and wage growth. An alternative view is to assume that firms and wage setters are forward-looking and that (2.16)-(2.17) represents the reduced form, where future forecasts of prices and wages based on its data generating process (DGP) have been substituted in the underlying structural Phillips-curve equations. In this case, the coefficients in (2.16)-(2.17) are an amalgamation of the underlying structural parameters of the Phillips-curves and the parameters of the DGP of prices and wages whose relation is ignored when estimating the reduced form in (2.16)-(2.17), thus being subject to the Lucas critique.[5]

[4]These supply shocks may also be important for larger countries that are more closed and have more decentralised labour markets. For example, Lown and Rich (1997) argue that moderate growth of unit labour costs was an important factor behind the low inflation rate experienced in the US in the first half of the 1990s, despite strong growth and output above potential. Similarly, Rich and Rissmiller (2000) argue that a significant decline in import prices played a major role in the latter half of the 1990s.

[5]Pétursson (1998) estimates a forward looking price equation similar to (2.16), where firms are assumed to set prices based on expected future marginal costs, similar to the theoretical "new" Phillips curves suggested by Galí and Gertler (1999). The cross-equation restrictions

3. The data

To estimate the wage-price model, this paper uses semi-annual data for the period 1973 to 1999. The reason for choosing semi-annual rather than quarterly data has to do with the irregular behaviour of quarterly wages due to the centralised wage bargaining process which often caused large increases in wages at discrete intervals, especially in the early part of the period. The quarterly wage growth series therefore deviates markedly from the underlying Gaussian-distributional assumption. Using semi-annual data smooths over this irregular behaviour. An additional argument for using semi-annual rather than quarterly data is that other studies have often found it difficult to obtain significant effects of output gaps on inflation at quarterly frequency, but have had more success using semi-annual or annual data, cf. Roberts (1997).

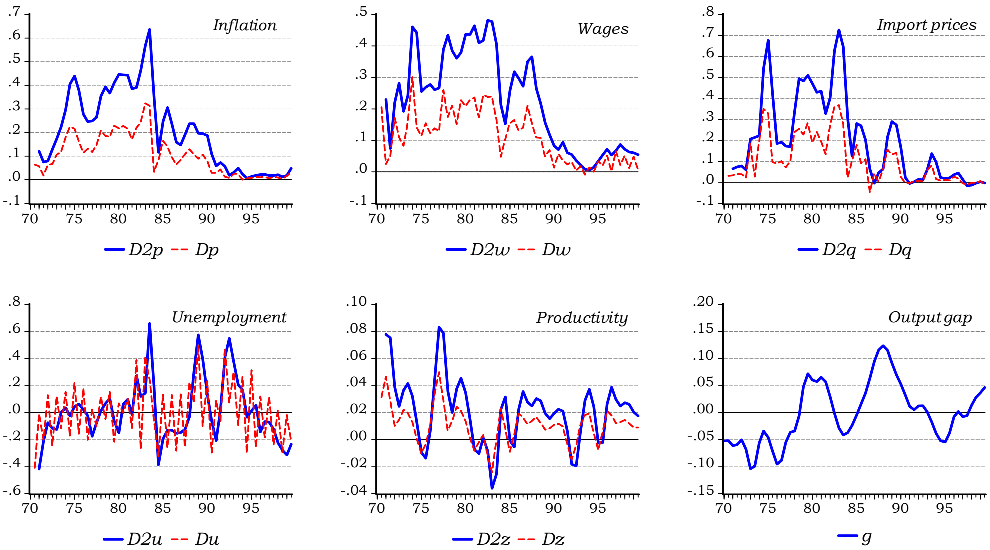

Figure 1. Annual ($\Delta_2 x_t$) and semi-annual (Δx_t) growth rates and the output gap

The price series used is the consumer price index. The wage series is the index of hourly earnings for production workers. The import price level is an index of the average of world export prices and oil prices, weighted according to relative weights in Iceland's previous years imports, measured in domestic currency. The unemployment rate is the rate of registered unemployment as a percentage of the labour force. All these series are measured as logarithms of semi-annual averages

between the structural taste parameters of firms and the parameters of the DGP for marginal costs are not rejected. The data is, however, unable to distinguish between this forward-looking specification and a corresponding backward-looking one, implying that the Lucas critique may not be of practical importance in this data set.

of monthly data.

As quarterly national accounts are not available for Iceland, output and employment are only available at an annual frequency. Annual labour productivity and output gap measures were thus generated from annual data and semi-annual data obtained by minimising the squared first derivative of an integrated continuous flow compatible with the annual series, see Gudmundsson (1999).[6] Figure 1 shows the data.

4. The cointegrating vectors

4.1. The unrestricted VAR

This paper uses a partial vector autoregressive (VAR) model to estimate the long-run relations given in (2.9)-(2.10). Thus, the wage-price system is estimated conditional on import price, productivity, unemployment and output gap developments. Conditioning wage and price dynamics on these variables is an obvious shortcoming of this paper. This especially applies to the exchange rate part of import prices, which should be endogenous to price and wage behaviour. The demand pressure measures, the output gap and the unemployment rate, should also respond to price and wage determination, although this is less of a problem in the final specification of the wage-price model as both enter lagged, whereas the contemporaneous value of import prices is allowed to affect prices. In addition, one would like to model the joint determination of the output gap and the unemployment rate, e.g. via Okun's law. These arguments all suggest a joint modelling of all the variables, as in Jacobsson *et al.* (2001). However, given the relatively small data set available, such an approach would be difficult to implement. Therefore, the partial approach adopted here, although not without problems, seems a logical first step to analyse the core determination of prices and wages in Iceland. This paper is not alone in adopting such a partial strategy. In fact most papers condition their wage and price analysis on variables such as import prices, cf. Bårdsen *et al.* (1998).

The VAR model includes a seasonal dummy and an impulse dummy, that equals unity in the latter half of 1983 and zero elsewhere ($d_{83:2t}$), capturing the abolishment of wage indexation and the introduction of a stabilisation package in May 1983 which aimed to moderate inflation.

[6] The output gap is estimated using a structural vector autoregressive approach, with long-run identifying restrictions (cf. Blanchard and Quah, 1989). Potential output was thus identified as a linear combination of stochastic trends in fish catch, the terms of trade and domestic productivity. See Jacobsson, Jansson, Vredin and Warne (2001) for similar ideas and Gudmundsson *et al.* (2000) for details.

Table 1. Analysis of the partial VAR

A. *Cointegration rank analysis*

Rank order	Eigenvalues	λ_{trace}	λ_{trace} (df. adj)	95% critical values
$r = 0$	0.57	56.44	50.05	35.30
$r \leq 1$	0.20	11.68	10.36	9.90

Standardised cointegrating vectors

p_t	w_t	q_t	u_t	z_t
1.000	0.310	−1.213	0.263	−1.041
−0.623	1.000	−0.302	0.014	−1.457

B. *Misspecification tests*

Equation	$F_{ar1-2}(2, 27)$	$F_{ar1-5}(5, 24)$	$F_{arch1}(1, 27)$	$\chi^2_n(2)$
Prices	0.42	0.18	0.84	0.97
Wages	0.06	0.19	0.91	0.43
	$F_{ar1-2}(8, 48)$	$F_{ar1-5}(20, 36)$		$\chi^2_n(4)$
System	0.08	0.47	–	0.94

The test statistic λ_{trace} is the trace eigenvalue statistic for testing the number of cointegrating vector as in Johansen and Juselius (1990). The critical values are obtained from Tables 6 and 7 in Harbo *et al.* (1995), using their suggested nuisance parameter weight approximation. F_{ar1-k} is a F-test for kth-order autocorrelation in a given equation. F_{arch1} is a F-test for first order ARCH effects in a given equation. χ^2_n is a residual normality test for a given equation. The table also shows corresponding system residual tests. The numbers given are p-values.

Panel A of Table 1 contains the rank analysis for the partial VAR for the period 1973:2-1999:2 with three lags, which, as shown in Panel B, was found sufficient to obtain normally distributed, homoscedastic innovation errors. The table shows the eigenvalues and the associated trace statistics, λ_{trace}, which test the hypothesis of $r - 1$ against r cointegrating vectors. As a partial system is analysed, the conventional critical values of the rank analysis are not appropriate. To generate appropriate critical values the nuisance parameter weight approximation suggested by Harbo, Johansen, Nielsen and Rahbek, (1995) is used. The rank analysis suggests two cointegrating vectors, as suggested by the static steady state analysis above.[7]

[7]Recursive analysis indicates no problem of instability in the VAR, with high and stable eigenvalues in Table 1 over the whole sample, supporting the finding of two long-run relations. These recursive estimates need, however, to be interpreted with caution since the data set used is relatively small. This also applies to the other recursive results reported below.

4.2. The restricted long-run relations

The over-identifying restrictions on the cointegrating space are those implied by the wage bargaining solution (2.9) and the mark-up price relation (2.10) in the static steady state analysis above.

First, the model is estimated imposing only a zero restriction on unemployment and a unit labour cost restriction in the price mark-up. The test value is $\chi^2(1) = 0.8$ ($p = 0.36$). Adding the restriction that the coefficient on productivity in the wage equation, δ, equals unity gives $\chi^2(2) = 3.3$ ($p = 0.20$). Furthermore, the coefficient on import prices in the wage equation, ϕ, is found to be very close to zero and adding this restriction gives $\chi^2(3) = 4.4$ ($p = 0.22$). The final restriction involves the unit labour cost coefficient in the price equation, ψ. Imposing the value of 0.6 gives the fully restricted over-identified cointegrating vectors as

$$\begin{aligned} ec(p) &= p - 0.6(w - z) - 0.4q, && (4.1) \\ ec(w) &= w - p - z + \underset{(0.03)}{0.222}\, u, && (4.2) \end{aligned}$$

with a over-identifying test value of $\chi^2_{or}(5) = 9.4$ ($p = 0.10$). The price mark-up relation indicates that the static steady state price level is given as a mark-up over unit labour costs and import prices, with the weight on domestic costs, ψ, equal to 0.6. This matches earlier findings, such as Gudmundsson (1990) and Pétursson (1998), although both these papers rejected static long-run homogeneity, which is accepted in this data set. The most likely explanation is that these papers use quarterly data with a simple linear trend proxying productivity. Pétursson (1998) also reports results for annual data with actual labour productivity, where homogeneity is not rejected.

Obtaining an estimate of $\psi = 0.6$ is also close to what has been found for Norway (cf. Bårdsen *et al.*, 1998) but smaller than what is usually found for larger countries, such as the UK where ψ close to 0.8 is usually found (cf. Bårdsen *et al.*, 1998 and Martin, 1997). This should not come as a surprise since $1 - \psi$ is a measure of the openness of the economy. It reflects the share of imported goods in the overall price level, η, and the exposure of domestic firms to foreign competition, λ. Thus, a smaller ψ should reflect a more open economy, as borne out by the empirical results.

The static steady state wage relation indicates that $\delta = 1$, so that productivity gains are fully reflected in the wage rate in the long run, which is consistent with the lack of a long-run downward trend in the wage share and unemployment despite the apparent long-run trend growth of productivity. The empirical results also suggest that $\alpha = 0$, so that the bargaining solution reflects the real consumption wage. This also implies, as shown above, that the wage share will reflect the terms of trade in the bargaining solution. Acceptance of $\alpha = 0$ and $\delta = 1$ can also be found in many other studies, such as Bårdsen *et al.* (1998), for Norway and the UK, and Clements and Mizon (1991), for the UK, see also Layard, Nickell and Jackman (1991). Pétursson and Sløk (2001) also find $\delta = 1$ for Denmark but $\alpha = 1$. Note, however, from (2.13)-(2.14) that the steady state real wage will be independent of import prices in the long run. This is consistent with Layard *et al.* (1991) who argue that import prices should not have permanent effects on real wages.

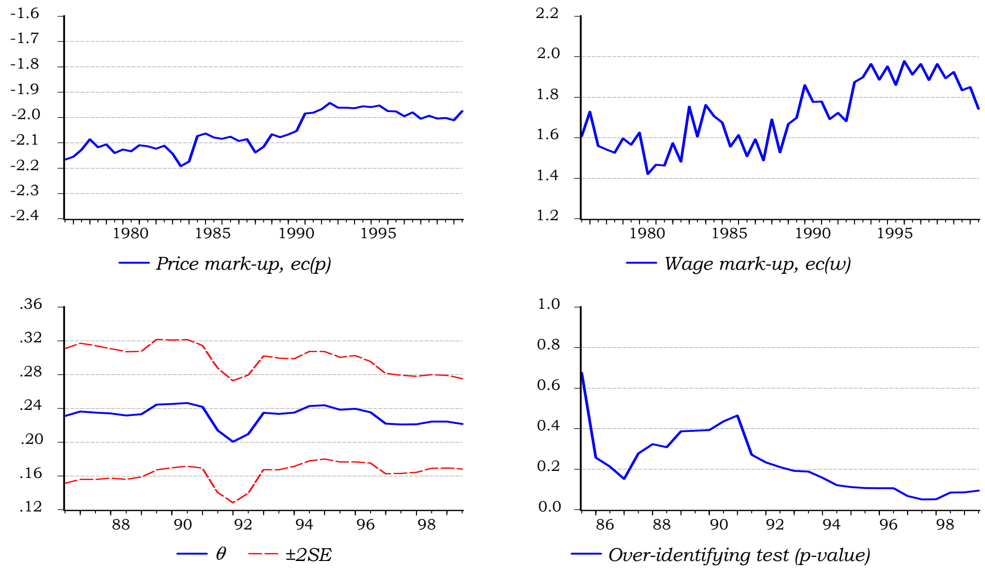

Figure 2. The restricted static equilibrium mark-ups

Finally, the results indicate that the unemployment coefficient in the wage equation, θ, equals 0.2.[8] This matches the results from Andersen and Gudmundsson (1998), who find $\theta = 0.17$ for Iceland in a single-equation framework. This is also very close to what has been found for other countries. For example, Bårdsen *et al.* (1998), for Norway and the UK, and Clements and Mizon (1991), for the UK, find $\theta = 0.1$. However, Pétursson and Sløk (2001) find a somewhat larger response for Danish data, or $\theta = 0.3$. The estimate of θ in these and many other

[8]It should be noted that the exact identification of the temporal properties of u_t, r_t and s_t does not affect the interpretation of the wage-price dynamics, although it effects the interpretation of the cointegrating vectors. If u_t is stationary, the real consumption wage per production units, $w_t - z_t - p_t$, should also be stationary (see (4.2)). Note also from (2.12) that s_t and r_t cointegrate. If, however, r_t is stationary (a long-run PPP property), stationarity of s_t would also follow. Wage inflation would therefore react to three separate stationary disequilibria components: r_t, s_t and u_t while price inflation would react to r_t, s_t and the output gap.

countries usually ranges between 0.1 and 0.2. The fact that the estimate of θ for Iceland is found to be in the higher range may indicate that real wages are quite responsive to labour market pressures in the long run, compared to many other countries. This is consistent with the widely held view that Nordic real wages are very responsive to changes in unemployment, cf. Layard *et al.* (1991).

Figure 2 plots the mark-ups from (4.1) and (4.2). It is interesting to note that there seems to be an upward shift in the static equilibrium mark-ups in the late 1980s. The most plausible explanation is an upward shift in the cost of capital at that time, following the liberalisation of domestic financial markets and a shift in monetary policy priorities towards maintaining price stability. This is discussed in detail below. The figure also presents the recursive estimate of θ and the recursive test value of the over-identifying test. The recursive estimates suggest that the restricted cointegrating vectors belong to the cointegrating space at every sample size.

5. The dynamic wage–price model

The final step in modelling wage and price interaction in Iceland is to obtain a parsimonious representation of the dynamic properties of the wage-price system. This follows Hendry and Mizon (1993) in starting with the stationary representation of the unrestricted VAR, i.e. the vector ECM (VECM) in (2.16)-(2.17) and deleting insignificant terms. The model is formulated in annual differences, since modelling the semi-annual differences proved less successful. The estimation period is 1974:2-1999:2 and the estimation procedure is full information maximum likelihood (FIML).

The unrestricted VECM includes two lags of each of the endogenous variables $(\Delta_2 p_t, \Delta_2 w_t)$ and the conditional variables $(\Delta_2 q_t, \Delta_2 z_t, \Delta_2 u_t)$. In addition, the original specification includes the output gap, g_t, lagged for one and two periods and the static steady state mark-ups in (4.1) and (4.2) lagged two periods. Finally, the model includes the dummy variable $d_{83:2t}$. Thus, each equation includes 19 variables.[9] Table 2 reports the final, parsimonious representation of the wage-price dynamics. The insignificance of the over-identifying test implies that the data does not reject the restrictions imposed, suggesting that the final model encompasses the underlying unrestricted VECM, cf. Hendry and Mizon (1993). The remaining parameters all have t-values greater than three. Furthermore, there is no evidence of system misspecification.

Looking first at the price equation, there are significant positive impact effects from wage and import price changes. The short-run effects are found to be smaller

[9] As the data set used is relatively small, this obviously puts a strain on the information content of the data. The results should be interpreted accordingly.

Table 2. The dynamic wage-price model

The price equation

$$\widehat{\Delta_2 p_t} = -\underset{(0.15)}{0.708} + \underset{(0.05)}{0.326}\,\Delta_2 p_{t-1} + \underset{(0.04)}{0.321}\,\Delta_2 w_t - \underset{(0.05)}{0.206}\,\Delta_2 w_{t-2} + \underset{(0.02)}{0.372}\,\Delta_2 q_t$$
$$-\underset{(0.008)}{0.023}\,\Delta_2 u_{t-1} + \underset{(0.05)}{0.233}\,g_{t-2} + \underset{(0.02)}{0.098}\,d_{83:2t} - \underset{(0.08)}{0.361}\,ec(p)_{t-2}$$
$$\sigma_p = 1.77\%$$

The wage equation

$$\widehat{\Delta_2 w_t} = \underset{(0.10)}{0.451} + \underset{(0.12)}{0.877}\,\Delta_2 w_{t-1} + \underset{(0.11)}{0.354}\,\Delta_2 p_t - \underset{(0.13)}{0.698}\,\Delta_2 p_{t-1}$$
$$+\underset{(0.06)}{0.221}\,\Delta_2 q_{t-2} - \underset{(0.05)}{0.236}\,ec(w)_{t-2}$$
$$\sigma_w = 3.75\%$$

The steady state mark-ups

$$ec(p)_t = p_t - 0.6(w_t - z_t) - 0.4q_t$$
$$ec(w)_t = w_t - p_t - z_t + 0.2u_t$$

Diagnostic tests

Over-identifying restrictions:	$\chi^2_{or}(23)$:	$p = 0.13$
Autocorrelation:	$F_{ar1-2}(8, 76)$:	$p = 0.26$
	$F_{ar1-5}(20, 64)$:	$p = 0.34$
Normality:	$\chi^2_n(4)$:	$p = 0.70$

Estimation period: 1974:2-1999:2. χ^2_{or} is a χ^2-test for over-identifying restrictions on the unrestricted VECM. F_{ar1-k} is a F-test for kth-order autocorrelation in the system. χ^2_n is a residual normality test for the system.

than the long-run effects, as should be expected, although the import price effects are quite similar suggesting a relatively quick pass-through of exchange rate shocks to inflation. The lack of a significant short-run effect of productivity growth implies that short-run price formation is not neutral to wage shocks that are offset by productivity shocks of equal size, even though neutrality holds in the long run.[10] There are also significant effects from lagged unemployment growth and the price mark-up with the expected sign. Finally, the model implies that if the economy is operating above capacity, inflation will start to increase after one year. The coefficient on the output gap is found to be 0.23 but due to the simultaneous wage-price dynamics of the model, the impact on inflation will be somewhat larger. Thus, from (2.16) and (2.17), the impact on inflation will be $0.23/(1 - \beta_{p0}\beta_{w0}) = 0.26$. An output gap of 1% will therefore lead to a nearly 0.3% rise in annual inflation after one year.[11]

[10] These results should be interpreted with caution, given potentially huge measurement problems in productivity.

[11] The significance of the lagged effect of the output gap is quite robust to the particular way the gap is estimated. For example using the Hodrick-Prescott filter or the production-function approach also gave a significant output gap, although the coefficients were larger, due to the smaller amplitude of the output gap measured by these alternative approaches.

The size of this effect is close to that found in other studies, although the transmission mechanism from the output gap to inflation seems to start off somewhat later according to the results found in Table 2.[12] For example, Bårdsen *et al.* (1998) find a significant effect from the output gap lagged one quarter in Norway, with a 1% output gap raising inflation by 0.08% in the subsequent quarter and by 0.33% after one year, after working through the wage-price dynamics of their model. Other studies often find somewhat larger multipliers. For example, using aggregate EC data, Gerlach and Smets (1999) find that a 1% output gap raises the rate of inflation by 0.2% in the subsequent quarter. Taking account of the inflation dynamics in their model, their results imply that inflation will rise by approximately 0.4% after one year. Even larger multipliers have been reported. Working through the dynamics of UK inflation in Bårdsen *et al.* (1998) suggests that inflation increases by 0.6% in the subsequent quarter and by 1.4% after one year. The somewhat smaller and delayed effects of demand pressure on inflation found here could imply that prices react more sluggishly to demand pressures in Iceland than in other countries. Note, however, that lagged changes in the unemployment rate also have significantly negative effects on inflation. Given the close link between the output gap and the unemployment rate, this effect could capture an additional effect of demand pressures on inflation that starts off somewhat earlier.

Turning next to the wage equation, there is a significant positive impact effect from inflation on wage growth. The short-run effect is again found to be smaller than the long-run effect.[13] The wage response to unemployment shocks is also smaller in the short run than in the long run. The model therefore does not display wage-hysteresis effects, cf. Nickell (1987). Finally, there are also significant effects from the wage mark-up and lagged imported inflation with the expected sign. The significance of imported inflation in the wage equation suggests short-run effects of the price wedge, $p_r - p$, since imported inflation can be written as a linear combination of the growth rate of the price wedge and consumer price inflation.

The actual and fitted values of the dynamic wage-price model are given in Figure 3. As can be seen from the figure, the fit is quite good in both cases, with the model explaining the high and volatile wage and price inflation in the 1970s to 1980s and the subsequent fall in the 1990s.

The steady state properties of the model, identify three main channels of wage and price inflation in Iceland. First there is a *conflicting claims channel*,

[12] See, for example, the studies contained in the BIS conference volume: *Monetary Policy and the Inflation Process*, volume 4, July 1997.

[13] Note also that the wage equation can be written in terms of the real wage growth. The less than proportional short-run effect of inflation on wage growth implies that inflation has a negative short-run effect on real wage growth.

where firms and workers attempt to maximise their share in total profits, $1 - s_t$ and s_t, respectively. This channel works through the wage bargaining process with firms raising their prices and workers claiming higher nominal wages until the Nash-bargaining equilibrium is reached. Second, there is a *real exchange rate channel*. In this case a rise in foreign prices or a nominal depreciation of the króna increases demand for domestic goods, thereby pushing up domestic prices and profits of domestic firms. Workers claim their share of increased profits through the bargaining process, thus raising wages. Finally, there is an *excess demand channel*. In this case, excess demand for domestic goods pushes up domestic prices until demand falls back to capacity levels. The excess demand effect on inflation works through the output gap. A similar effect works through the unemployment rate in the labour market, where excess demand for labour pushes up wages in the bargaining process.

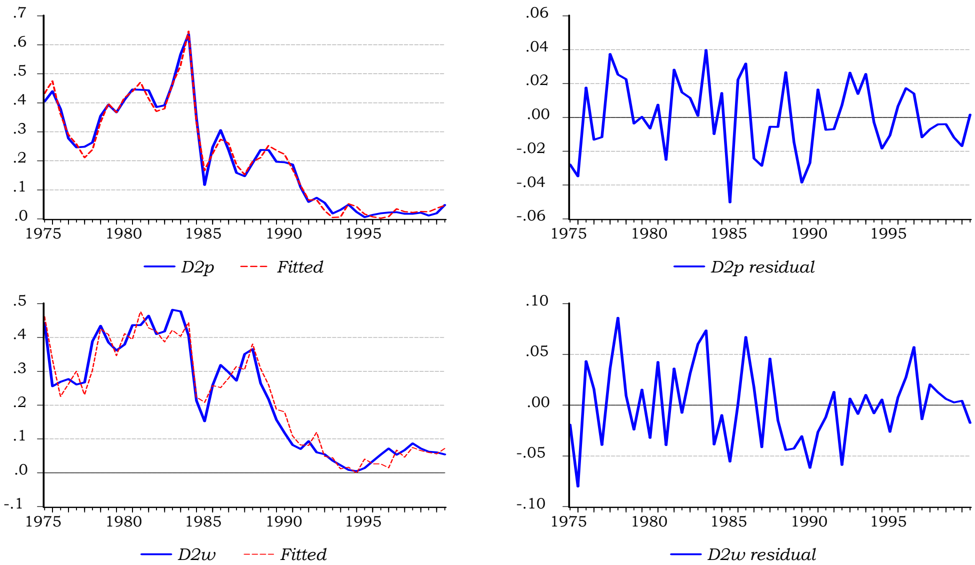

Figure 3. Fit of the dynamic wage-price model

Figure 4 reports recursive diagnostics for the model. The figure reports the recursive one-step residuals along with their $\pm 2\sigma$ bands, the recursive p-values of the over-identifying test in Table 2 and three recursive Chow tests. The first is a recursive one-step test, the two others are N-step tests with increasing and decreasing horizons, respectively. These tests find no evidence of in-sample instability and suggest that the dynamic wage-price model encompasses the unrestricted system at every sample size. Hence, the model constitutes a valid parsimonious representation of the system.

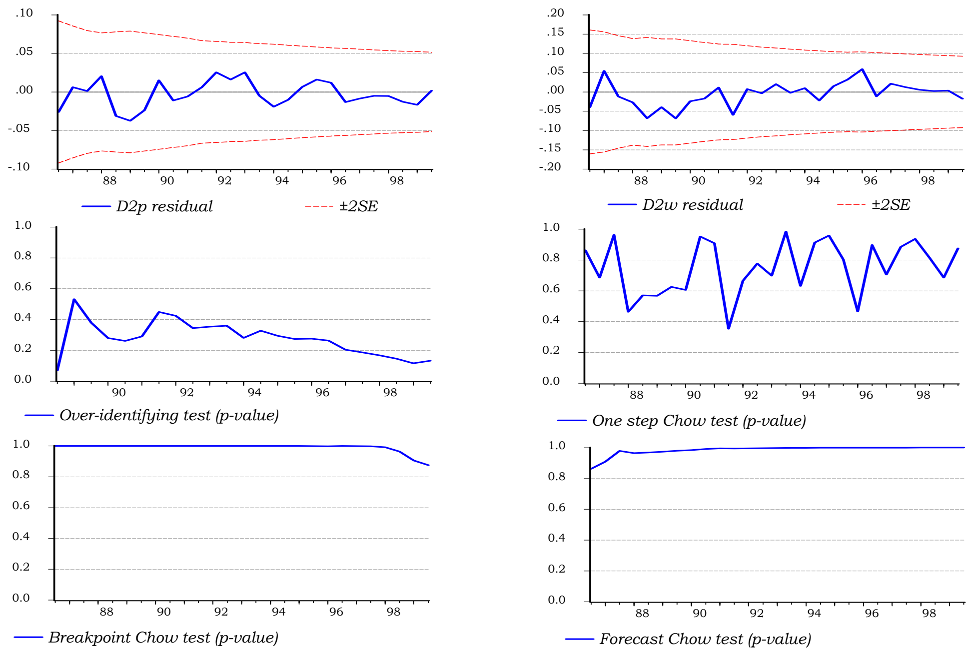

Figure 4. Recursive diagnostics of the dynamic wage-price model

6. The dynamic steady state

The steady state values of $ec(p)$ and $ec(w)$ in (4.1)-(4.2) reflect the static steady state, i.e. the steady state assuming zero steady state growth rates. More generally, the steady state can reflect constant, but not zero, growth rates. This formulation of the steady state is usually called the dynamic steady state. In this case $\Delta p_t = \Delta q_t = \pi$ and $\Delta w_t = \pi + \Delta z_t = \pi + \tau$, where π is the steady state inflation rate and τ is the steady state productivity growth rate. Hence from (2.16)-(2.17), the dynamic steady state mark-ups can be written as

$$ec(p)^d = \frac{1}{\rho_p}\left\{(\beta_p(1) + \mu_p(1) - \alpha_p(1))\,\pi + (\beta_p(1) + \delta_p(1))\,\tau\right\}, \quad (6.1)$$

$$ec(w)^d = \frac{1}{\rho_w}\left\{(\beta_w(1) + \mu_w(1) - \alpha_w(1))\,\pi + (\delta_w(1) - \alpha_w(1))\,\tau\right\}. \quad (6.2)$$

If $\beta_p(1) + \mu_p(1) - \alpha_p(1) = \beta_w(1) + \mu_w(1) - \alpha_w(1) = 0$ the mark-ups are dynamically homogenous with respect to inflation. These restrictions are, however, strongly rejected by the data, $\chi^2(2) = 46.1$ ($p = 0.00$). Dynamic homogeneity of the mark-ups with respect to productivity is ensured if $\beta_p(1) + \delta_p(1) = \delta_w(1) - \alpha_w(1) = 0$. These restrictions are not rejected by the data, $\chi^2(2) = 4.7$

($p = 0.10$). Thus, although static long-run homogeneity of wages and prices is accepted by the data in (4.1)-(4.2), dynamic homogeneity with respect to inflation is rejected. Similar results have been found for some other countries, cf. Bårdsen *et al.* (1998) for Norway and de Brouwer and Ericsson (1998) and Banerjee, Cockerell and Russell (2001) for Australia.

Solving for the static steady state mark-ups gives

$$ec(p) = ec(p)^d - \chi_p \pi, \quad (6.3)$$
$$ec(w) = ec(w)^d - \chi_w \pi, \quad (6.4)$$

where χ_p and χ_w are functions of the parameters in (6.1)-(6.2). The static steady state mark-ups depend negatively on the steady state rate of inflation. Thus, a decline in steady state inflation in Iceland in the late 1980s could explain the upward shift of the static mark-ups in Figure 2.

This type of a negative relationship between the steady state mark-ups and steady state inflation can be found in models of price-taking firms where higher inflation leads to greater competition and hence to lower mark-ups, as suggested by Bénabou (1992). Alternatively, in Russell, Evans and Preston (1997) and Athey, Bagwell and Sanichiro (1998) firms face costs in adjusting prices, due to missing information. As this information cost rises with increasing inflation, the firms' mark-ups get squeezed.

An important implication of the failure of dynamic homogeneity of the mark-ups with respect to inflation is that the natural rate of unemployment (or the NAIRU) will not be inflation neutral. From (6.3)-(6.4) the NAIRU can be written as

$$u^{nairu} = u^* + \frac{ec(p)^d + \psi ec(w)^d}{\theta \psi} = u^* - \chi_u \pi, \quad (6.5)$$

where u^* is the long-run equilibrium unemployment rate from (2.15). Thus, a downward shift in π will also correspond to an upward shift in the NAIRU.

Banerjee *et al.* (2001) argue that prices are $I(2)$ series, thus estimating a cointegrating relation between inflation and the price mark-up. In this case (6.3), (6.4) and (6.5) are cointegrating relationships and the long-run Phillips-curve will not be vertical. An alternative interpretation is that inflation and the mark-ups are stationary and the relationships above are merely short-run relationships that reflect a one-time discrete shift in the underlying steady state values, that make the series appear as being nonstationary and cointegrated, cf. Campos, Ericsson and Hendry (1996).[14]

[14] Pétursson (1998) tests for additional $I(2)$ trends in the data and rejects against the null of a single unit root.

The most plausible explanation for such a discrete shift are the structural reforms undertaken in the late 1980s and the reformulation of monetary policy priorities and labour unions bargaining strategy in the beginning of the 1990s. Until the mid-1980s the Icelandic economy was highly regulated. This especially applied to the financial markets where interest rates were determined centrally by the government, which also owned most of the financial institutions. By maintaining real interest rates very low or even negative for a prolonged period and securing cheap capital for firms through a largely state owned banking system and a vast system of production subsidies, the government made it possible for inefficient firms to stay in business, thus keeping measured unemployment artificially low for long periods. This very low real interest rate also kept the economy permanently fixed in a state of excess demand, thus maintaining persistent inflationary pressures.

All this changed in the mid to late 1980s when interest rates became market determined and the government started liberalising the financial system and the economy in general. At the same time there was a shift in policy priorities from high-employment monetary policy to policy more aimed to preserve price stability. These reforms and the shift in policy priorities were the key ingredients for the ground-breaking labour market agreement in February 1990 were wage settlements reflected forward-looking inflation targets that were much lower than the inflation at that time.[15]

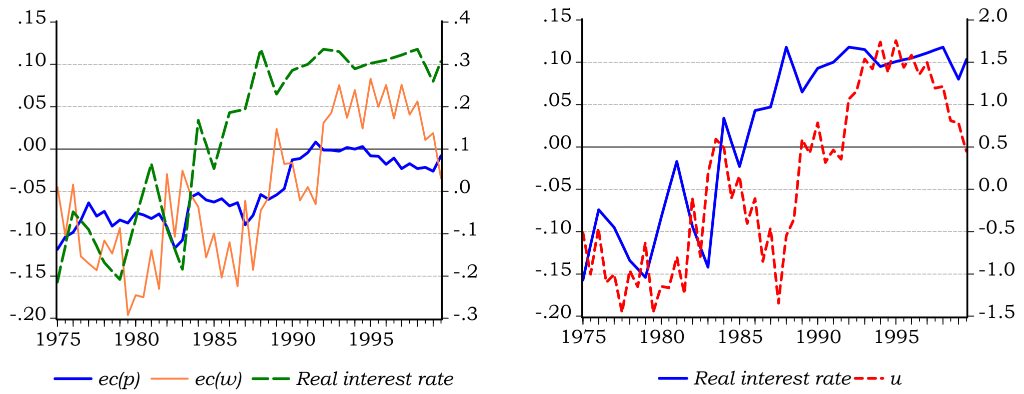

Figure 5. Real interest rate (left scale), mark-ups and unemployment (right scale)

The resulting upward shift in the cost of capital can be seen in Figure 5,[16] which

[15] Andersen and Gudmundsson (1998) also argue that the policy changes and market reforms created the necessary conditions for the realisation of the February 1990 wage settlement.

[16] The real interest rate is only available on annual frequency, so semi-annual data was constructed by linear interpolation.

Table 3. Equilibrium mark-ups, unemployment and structural shifts

	Equation					
	$ec(p)_t$		$ec(w)_t$		u_t	
Constant	− 2.070 (0.009)	− 1.961 (0.010)	1.694 (0.027)	1.902 (0.028)	− 0.021 (0.150)	1.355 (0.159)
Real interest rate	0.658 (0.088)		1.063 (0.246)		7.589 (1.414)	
Steady state inflation		− 0.463 (0.043)		− 0.894 (0.119)		− 5.857 (0.756)
R^2	0.733	0.805	0.412	0.648	0.541	0.717

The steady state inflation rate is given as $\pi_t = \pi_1 + \omega_t(\pi_2 - \pi_1)$. The numbers in parenthesis are Newey-West adjusted standard errors.

shows the *ex post* real interest rate on non-indexed bank loans together with the two static equilibrium mark-ups and the unemployment rate.[17] The real interest rate remains negative for most of the period until the mid 1980s when it starts rising substantially. The shift towards high positive real rates roughly corresponds to the upward shift in the equilibrium mark-ups and the unemployment rate. It is also interesting to note that Zoëga (2002) finds a sharp rise in bankruptcies at the same time.

Table 3 shows the results of regressing the static equilibrium mark-ups and unemployment on the real interest rate and a measure of the steady state inflation rate, calculated as

$$\pi_t = \pi_1 + \omega_t(\pi_2 - \pi_1), \tag{6.6}$$

where π_1 is the estimated steady state inflation in the high inflation state, π_2 is the estimated steady state inflation in the low inflation state and $0 \leq \omega_t \leq 1$ is a weighting function given as the following logistic function

$$\omega_t = [1 + \exp(a - bt)]^{-1}, \tag{6.7}$$

where t is a linear time trend, which equals zero in 1988:1, the first full year of an organised secondary market for financial assets in Iceland (see Pétursson, 2000 for similar ideas for estimating money demand in Iceland). The coefficient a determines the timing of the start of the adjustment process, i.e. the higher a is the later the process starts. The coefficient b determines the speed of adjustment, i.e. the lower b is the more prolonged the adjustment process becomes. The

[17]Phelps and Winter (1970) provide a formal model relating the cost of capital to the mark-up. In this model, the firm can raise current profits at the expense of lower future market share by raising its mark-up. Higher real interest rates will thus lead to a higher mark-up as investment in future market share decreases. See Zoëga (2002) for further discussion.

values of $a = 5$ and $b = 1.2$ are chosen so as w_t is zero until 1988:1, when it starts gradually rising to about a half in 1990:1, 3/4 in 1990:2 and unity in 1992:1. These values were also used by Pétursson (2000), with other choices of a and b giving more or less identical results.

Estimating (6.6) gave

$$\widehat{\Delta_2 p_t} = \underset{(0.023)}{0.330} + \omega_t(\underset{(0.004)}{0.025} - \underset{(0.023)}{0.330}), \tag{6.8}$$

with $R^2 = 0.70$ (Newey-West standard errors in parenthesis). Steady state inflation is therefore given as $\pi_1 = 33\%$ until 1988, when it starts gradually moving towards the lower steady state of $\pi_2 = 2.5\%$ (see Figure 6).[18]

The regression results indicate that the upward shift in the equilibrium mark-ups and unemployment in the late 1980s can equally be explained by the upward shift in the cost of capital and the downward shift in steady state inflation.

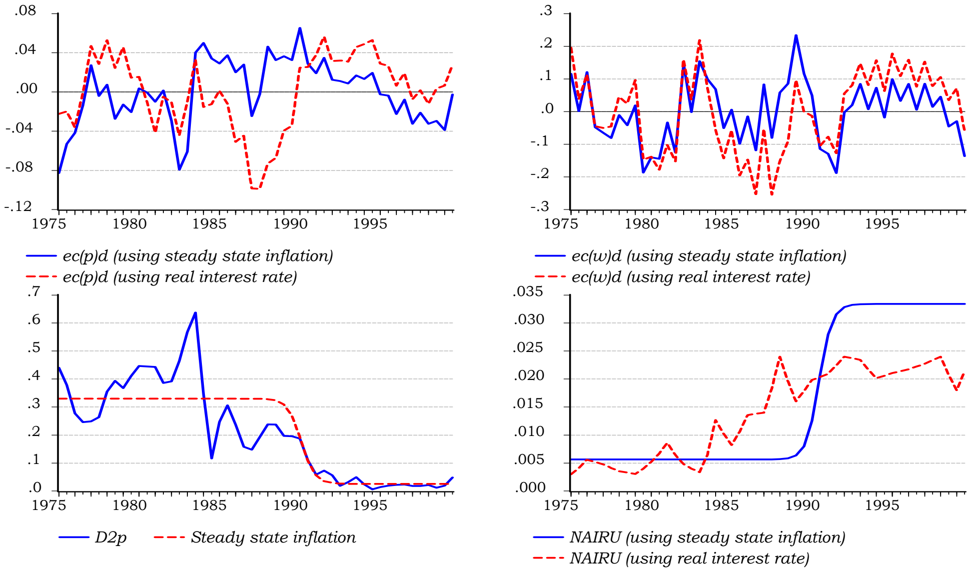

Figure 6. Dynamic steady state mark-ups, steady state inflation and the NAIRU

Figure 6 shows two measures of the dynamic steady state mark-ups and the NAIRU using the estimation results in Table 3 (the figure shows the exponential

[18]Steady state inflation was also estimated by using a Hodrick-Prescott filter on actual inflation, a step dummy that switches from zero to one at 1990:2 and by estimating a Markov-switching model that allowed an endogenous shift in mean inflation. All these alternatives gave almost identical results.

of the NAIRU estimate from Table 3).[19] The estimated dynamic steady state mark-ups show no evidence of an upward shift in the late 1980s or the beginning of the 1990s. Thus, the apparent upward shift in the static steady state mark-ups in Figure 2 can be explained by the structural reform that occurred in the late 1980s, which resulted in a substantial rise in the cost of capital, leading to a downward shift in the steady state inflation rate and an upward shift in the NAIRU.[20] The results from Table 3 give an estimate of NAIRU roughly between 2%-3.5%.[21]

7. Forecasting

Finally, it is important to evaluate the out-of-sample forecasting ability of the dynamic wage-price model in Table 2. For this purpose the model is estimated up to period T_1 and rolling window, one-step-ahead forecasts for inflation and wage growth generated for the period $T_1 + 1$ to T. Table 4 reports tests of out-of-sample stability and forecasting accuracy, using two alternative estimates of the asymptotic covariance matrix of the forecast errors. The first simply uses the sample estimate of the innovation covariance matrix, Ω. This can therefore be interpreted as a test of numerical parameter constancy. The second test uses an estimate of the forecast error covariance matrix that allows for parameter uncertainty and innovation variance, see Doornik and Hendry (1995) for details.

As can be seen from the table, out-of-sample parameter constancy cannot be rejected for one, two and four year forecast horizon. This can also be seen from Figure 7 which shows the one-step-ahead forecasts from 1994:1 to 1999:2. Note that these are *ex post* forecasts (or projections), since they are conditional on the actual values of the non-modelled variables.

The figure also reports dynamic forecasts of inflation and wage growth for a two year horizon. The forecasts follow the actual development of prices and wages quite closely and are well within the 95% confidence bands. These results suggest that the forecast performance of the dynamic wage-price model is quite good over short and long horizons, although the standard errors are quite large.

[19] From the figure and the discussion above, one could argue that there were in fact two shifts in steady state inflation: from high to moderate levels in the middle of the 1980s, to low levels in the beginning of the 1990s, see also the discussion in Andersen and Gudmundsson (1998). For the purposes of this paper it is, however, sufficient to allow for one shift in steady state inflation. In fact, adding a third stage (using a Markov-switching model) did not change the main results in any way.

[20] Gudmundsson and Zoëga (1997) also find evidence of structural break around 1988, using an expectations-augmented Phillips-curve model.

[21] The relatively wide margin reflects the different estimation methods used here, but can also be interpreted as reflecting the uncertainty in NAIRU estimates usually found in the literature.

Table 4. Forecast stability

	Forecast horizon		
Covariance matrix of forecast errors	1 year	2 years	4 years
Sample covariance matrix, Ω	0.821	0.951	0.796
Ω and parameter uncertainty	0.843	0.962	0.869

Under the null of parameter constancy the test statistics are distributed as $\chi^2_{for}(h)$, where h is the forecast horizon. The table reports p-values.

The standard errors of the dynamic model are approximately 1.8% and 3.8% at an annual rate for prices and wages, respectively. The forecast uncertainty in the one-step-ahead forecasts is 2.5% and 4.4% for prices and wages, respectively. The multistep standard errors are very similar, even when forecasting two years ahead. These are sizable figures, but close to findings in other countries, which typically report standard errors for dynamic forecasts of inflation in the 2% region (at best) for a 95% confidence interval (cf. de Brouwer and Ericsson, 1998).

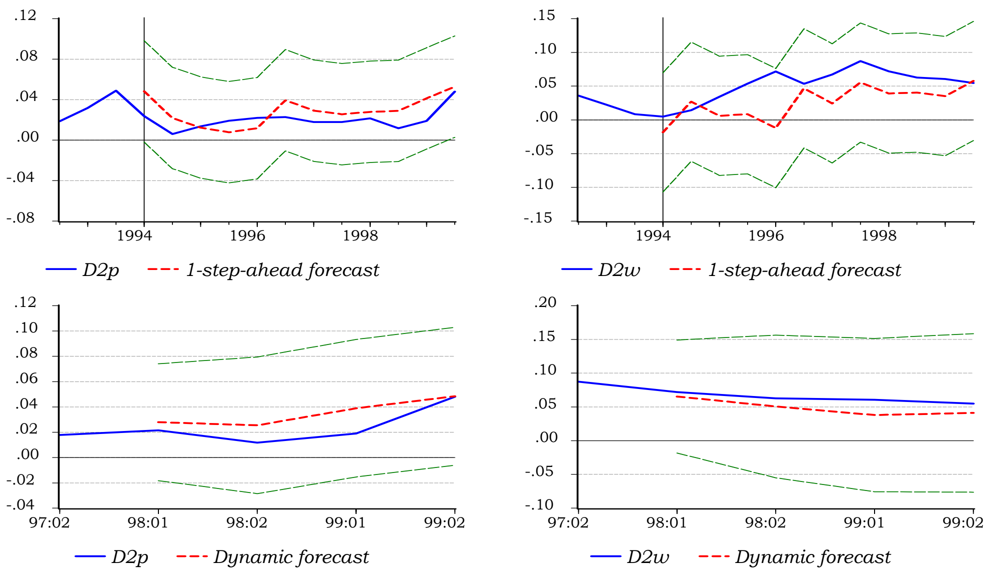

Figure 7. Forecast analysis with 95% confidence bands

8. Conclusions

This paper uses an open economy version of a wage-price model with imperfect competition in goods and labour markets to analyse wage and consumer price inflation in Iceland for the period 1973 to 1999. Price formation is modelled as a mark-up pricing over marginal costs, where the mark-up can vary due to pricing-to-market effects. The empirical steady state relation obtained gives consumer prices as a homogenous function of unit labour costs and import prices. Wage formation is modelled as a wage bargaining process between labour unions and firms. The steady state outcome of the Nash-bargaining process gives real consumption wages per unit of production as an inverse function of the unemployment rate, or, equivalently, the wage share in value added as a function of the real exchange rate and the unemployment rate.

The model developed in this paper identifies three main sources of wage and price inflation in Iceland. First there is a *conflicting claims channel*, where firms and workers attempt to maximise their share in total profits. This channel works through the wage bargaining process with firms raising their prices and workers claiming higher nominal wages until a steady state is reached. Second, there is a *real exchange rate channel*. In this case a rise in domestic currency import prices increases demand for domestic goods, thereby pushing up domestic prices and profits of domestic firms. Workers claim their share of increased profits through the bargaining process, thus raising wages. Third, there is an *excess demand channel*. In this case, excess demand for domestic goods will push up domestic prices until demand falls back to capacity levels. A similar effect is at work in the labour market, where excess demand for labour pushes up wages in the bargaining process.

There is also some evidence of an upward shift in the equilibrium mark-ups in the late 1980s. The results indicate that this was due to a substantial rise in the cost of capital that reflected the move towards market determined interest rates and a shift in policy priorities towards price stability, which cumulated in a path-breaking labour market agreement in early 1990 which further secured the durability of the new regime. These changes led to a downward shift in steady state inflation and an upward shift in the natural rate of unemployment.

The dynamic wage-price model explains a large proportion of wage and price inflation during the last three decades. It is remarkably stable, considering the fundamental changes in wage and price dynamics and the institutional setup in Iceland during this period. The model is able to explain the fall in wage and price inflation from high to moderate levels during the middle of the 1980s and the further fall from moderate to low levels in the 1990s. It suggests that the main source of the recent rise in inflation since 1999 is the strong growth in domestic goods and labour demand, reflected in a widening output gap and falling unemployment below its natural rate, which has pushed up the wage share and inflation.

References

[1] Andersen, P. S., and M. Gudmundsson (1998). Inflation and disinflation in Iceland. *Central Bank of Iceland Working Papers*, no. 1.

[2] Andrews, M., and S. J. Nickell (1983). Unions, real wages and employment in Britain 1951-79. *Oxford Economic Papers*, 35, 183-206.

[3] Athey, S., K. Bagwell and C. Sanichiro (1998). Collusion and price rigidity. MIT Department of Economics, *Working Papers*, no. 98-23.

[4] Banerjee, A., L. Cockerell and B. Russell (2001). An I(2) analysis of inflation and the markup. *Journal of Applied Econometrics*, 16, 221-40.

[5] Bårdsen, G., P. G. Fisher and R. Nymoen (1998). Business cycles: Real facts or fallacies? In S. Strøm (ed.), *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium*. Econometric Society Monograph Series no 32. Cambridge: Cambridge University Press.

[6] Bénabou, R., (1992). Inflation and markups: Theories and evidence from the retail trade sector. *European Economic Review*, 36, 566-74.

[7] Blanchard, O. J., and D. Quah (1989). The dynamic effects of aggregate demand and supply disturbances. *American Economic Review*, 79, 655-73.

[8] Campos, J., N. R. Ericsson and D. F. Hendry (1996). Cointegration tests in the presence of structural breaks. *Journal of Econometrics*, 70, 187-220.

[9] Carlin, W., and D. Soskice (1990). *Macroeconomics and the Wage Bargain.* Oxford: Oxford University Press.

[10] Clements, M. P., and G. E. Mizon (1991). Empirical analysis of macroeconomic time series. *European Economic Review*, 35, 887-932.

[11] de Brouwer, G., and N. R. Ericsson (1998). Modeling inflation in Australia. *Journal of Business and Economic Statistics*, 16, 433-49.

[12] Doornik, J. A., and D. F. Hendry (1995). *Pc-Fiml 8.0. Interactive Econometric Modelling of Dynamic Systems.* London: Chapman and Hall.

[13] Galí, J., and M. Gertler (1999). Inflation dynamics: A structural econometric analysis. *Journal of Monetary Economics*, 44, 195-222.

[14] Gerlach, S., and F. Smets (1999). Output gaps and monetary policy in the EMU area. *European Economic Review*, 43, 801-12.

[15] Gordon, R. J., (1997). The time-varying NAIRU and its implications for economic policy. *Journal of Economic Perspectives*, 11, 11-32.

[16] Gudmundsson, B. R., and G. Zoëga (1997). Unemployment in Iceland: Is there a natural rate? *Fjármálatídindi*, 44, 18-39. (In Icelandic).

[17] Gudmundsson, G., (1990). Statistical analysis of inflation in Iceland 1962-1989. *Fjármálatídindi*, 37, 43-53. (In Icelandic).

[18] Gudmundsson, G., (1999). Estimation of continous flows from observed aggregates. *Bulletin of the International Statistical Institute*. 52nd Session, Helsinki 1999.

[19] Gudmundsson, M., T. G. Pétursson and A. Sighvatsson (2000). Optimal exchange rate policy: The case of Iceland. In M. Gudmundsson, T. T. Herbertsson and G. Zoëga (eds.), *Macroeconomic Policy: Small Open Economies in an Era of Global Integration*. Reykjavík: University of Iceland Press.

[20] Harbo, I., S. Johansen, B. G. Nielsen and A. C. Rahbek (1995). Test for cointegrating rank in partial systems. Institute of Mathematical Statistics, University of Copenhagen. *Preprints*, no. 1995/1.

[21] Hendry, D. F., and G. E. Mizon (1993). Evaluating dynamic econometric models by encompassing the VAR. In P. C. B. Phillips (ed.), *Models, Methods and Applications of Econometrics*. Oxford: Basil Blackwell.

[22] Jacobsson, T., P. Jansson, A. Vredin and A. Warne (2001). Monetary policy analysis and inflation targeting in a small open economy. *Journal of Applied Econometrics*, 16, 487-520.

[23] Johansen, S., (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control,* 12, 231-54.

[24] Johansen, S., and K. Juselius (1990). Maximum likelihood estimation and inference on cointegration - With applications to the demand for money. *Oxford Bulletin of Economics and Statistics*, 52, 169-210.

[25] Krugman, P., (1987). Pricing to market when the exchange rate changes. In S. Arndt and J. Richardson (eds.), *Real-Financial Linkages Among Open Economies*. Cambridge: MIT Press.

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

[27] Lindbeck, A., (1993). *Unemployment and Macroeconomics.* Cambridge: MIT Press.

[28] Lown, C. S., and R. W. Rich (1997). A look at the US inflation puzzle. Monetary Policy and the Inflation Process. *BIS Conference Papers*, vol. 4.

[29] Martin, C., (1997). Price formation in an open economy: Theory and evidence for the United Kingdom, 1951-1991. *Economic Journal*, 107, 1391-1404.

[30] Nickell, S., (1987). Why is wage inflation in Britain so high? *Oxford Bulletin of Economics and Statistics*, 49, 103-28.

[31] Pétursson, T. G., (1998). Price determination and rational expectations. *International Journal of Finance and Economics*, 3, 157-67.

[32] Pétursson, T. G., (2000). The representative household's demand for money in a cointegrated VAR model. *Econometrics Journal*, 3, 162-76.

[33] Pétursson, T. G., and T. Sløk (2001). Wage formation and employment in a cointegrated VAR model. *Econometrics Journal*, 4, 192-210.

[34] Phelps, E. S., and S. G. Winter (1970). Optimal price policy under atomistic competition. In E. S. Phelps *et al.*, *Microeconomic Foundations of Employment and Inflation Theory.* New York: W.W. Norton.

[35] Rich, R. W., and D. Rissmiller (2000). Understanding the recent behaviour of US inflation. Federal Reserve Bank of New York, *Current Issues in Economics and Finance*, vol. 6, no. 8.

[36] Roberts, J. M., (1997). Is inflation sticky? *Journal of Monetary Economics*, 39, 173-96.

[37] Russell, B., J. Evans and B. Preston (1997). The impact of inflation and uncertainty on the optimum price set by firms. University of Dundee, Department of Economics. *Discussion Papers*, no. 84.

[38] Zoëga, G., (2002). Inflation and unemployment in Iceland in the light of Natural-rate theory. *Central Bank of Iceland Working Papers*, no. 17.