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June 2007

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Kiel Working Paper No. 1333

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Abstract

This paper examines the evolution of the Phillips Curve (PC) for the Spanish economy since 1980. In particular, we focus on what has happened since the late 1990s. Since 1999 the unemployment rate has fallen by almost 7 percentage points, while inflation has remained relatively subdued around a plateau of 2%-4%. Thus, the slope of the PC has become much flatter. We argue that this favorable evolution is largely due to the huge rise in the immigration rate, from 1% of the population in 1994 to 9.3% in 2006. We derive a New Keynesian Phillips curve accounting for the effects of immigration, a variable which is found to shift the curve if preferences and bargaining power of immigrants and natives differ. We then estimate this curve for Spain since 1980 and find that while the fall in unemployment over the last 8 years comes along with an increase in inflation of 2.2 percentage points per year, the increase of the relative unemployment rate of immigrants vis-à-vis natives accounts for an ofsetting 0.9 percentage points drop in the inflation rate per year.

Keywords: Phillips curve, immigration

JEL Codes: E31, J64.

1 Introduction

Over the period 1994-2006 Spanish unemployment has decreased by almost 15 percentage points, from 22% to 8%, while inflation remained subdued, falling from 4% to 2% in the run-up to EMU and then rising back to about 4% in the first half of the 2000s. Thus, there have been remarkable changes in the position and slope of the Spanish Phillips curve, which has shifted inwards and become flatter (see Figure 1). Although shared by other countries, the fall in the trend level and volatility of inflation has been specially intense in Spain and it has taken place simultaneously with a much larger reduction in unemployment than elsewhere.[1]

The causes of the reduction in Spanish unemployment over the last decade has been analyzed to some extent (see, for instance, Bentolila and Jimeno, 2006). However, the changes in the long-run level of inflation and in its trade-off with unemployment remain largely unexplained. Most of the theories proposed to explain the joint evolution of inflation and unemployment, both at low and high frequencies, do not seem to pass even a cursory check when applied to the Spanish economy. For instance, although it seems obvious that structural unemployment has fallen, it is difficult to identify the institutional reforms in the labor market that could explain such a reduction and, hence, sustain a lower level of long-run inflation at all levels of unemployment. A rise in the rate of productivity growth, which has been postulated to explain the improvement in the inflation-unemployment trade-off in the US (Ball and Moffitt, 2001), does not fit the Spanish story, as over the last decade, the productivity growth rate in Spain has been the lowest in the EU and, if anything, it has fallen. Models relying on long-run effects of monetary policy on real activity (Karanassou, Sala, and Snower, 2002, and Karanassou and Snower, 2007) fit the data satisfactorily only under extreme assumptions about both the sources and nature of the shocks hitting the economy and the way prices are adjusted. As for globalization, some authors show that the opening of both the trade and the capital account lead to a flattening of the Phillips curve (Razin and Loungani,

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[1] The decline in the volatility of inflation has happened in many other economies, simultaneously with a decline in the volatility of economic activity. Several authors refer to this phenomenom as "the Great Moderation".

2007). However, although foreign trade has noticeably increased since the early 1990s, it is doubtful that, on its own, it could sustain low inflation in the face of such a large reduction in unemployment. Moreover, if globalization increases competition and, hence, makes wages and prices more flexible, the Phillips curve ought to become steeper, not flatter as observed in several countries.[2] EMU could have contributed to explaining the flattening of the Phillips curve, as inflation expectations became better anchored. Still, why inflation did not surge with the large reduction in unemployment remains a puzzle.

Recent studies on the unemployment-inflation in Spain have taken three different approaches. First, there is the application of the NKPC paradigm for fitting the Spanish Phillips curve. Thus, for instance, Galí and López-Salido (2001) provide evidence on the fit of the NKPC during the disinflation period (1980-1998). Their results show that the NKPC fits the data well, although with a relatively high degree of inflation persistence, and that the price of imported intermediate goods and labor market frictions are key factors driving the dynamics of marginal costs, that together with inflation expectations determine inflation. Secondly, there exists an analysis of the unemployment-inflation trade-off in the long-run focusing on the interaction between money growth and nominal frictions (Karanassou, Sala, and Snower, 2002). Finally, interest has shifted to the analysis of the sources of inflation differentials within EMU. Several studies using two-country, two-sector dynamic stochastic general equilibrium models with nominal rigidities conclude that demand shocks biased towards non-tradable goods combined with real wage rigidities (López-Salido, Restoy, and Vallés, 2005) and fluctuations in productivity improvements in the tradable sector (Rabanal, 2006) are the most important sources of inflation differentials between Spain and the rest of EMU.

There is, however, a fundamental change affecting the Spanish labor market over the last decade whose impact on the Phillips curve has not been addressed so far: the immigration boom. In 1995 the proportion of foreigners in the Spanish population and in the Spanish labor force were, respectively, below 1% and below 0.5%. In 2006 these rates were around 9,3% and 14%, respectively.[3] Over this period, there have been large

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[2] For a skeptical view of the impact of globalization on inflation, see Ball (2006). Futher discussion can be found in Rogoff (2003) and Bean (2006).

[3] Counting only foreigners with less than six years of residence in Spain, these rates were, respectively,

waves of immigrants coming from Latin America, North Africa, and Eastern Europe.[4]

In this paper we look at the consequences of immigration for the joint behavior of unemployment and inflation. This is a topic that has been little addressed so far. Razin and Binyamini (2007) show that in- and out-migration raise the elasticities of labor supply and labor demand and that this flattens the Phillips curve. Engler (2007) finds the same result via temporary outmigration of natives. In our model, immigration can affect inflation determination through several channels. First, to the extent that wages are differently determined for natives and immigrants or insofar as the marginal rate of substitution between consumption and leisure is different for both groups, expected marginal costs could fall as immigration rises. Secondly, by easing the sectoral realloca-tion of labor, as immigrants are more mobile and willing to take low-paid jobs, higher immigration also moderates expected marginal costs. Thus, we embed immigration into an otherwise standard New Keynesian Phillips Curve (NKPC, henceforth) with real wage sluggishness, as proposed by Blanchard and Galí (2006), to derive micro-founded inflation equations. We use these equations to account for the impact of immigration in the Spanish recent evolution of unemployment and inflation.

The rest of the paper is structured as follows. In Section 2, we review in more detail several hypotheses regarding the changes in the Phillips curve and provide descriptive evidence for Spain. In Section 3 we document the changes in the Spanish labor market since the mid-1990s, with regard to institutional changes and the impact of immigration. In Section 4 we derive a NKPC when the labor market is composed of different segments, in our case natives and immigrants. In Section 5 we discuss results from estimating the NKPC with immigration. Finally, Section 6 concludes. Two Appendices (A and B) gather some analytical derivations and a description of the data.

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6.3% and 8.9%. Excluding foreigners from the EU and those with more than six years of residence in Spain, these rates are, respectively, 5.7% and 8.2%. (Data are from the Labour Force Survey in 2005).

  [4]For a more detailed account of the stylised facts of immigration to Spain, see Carrasco, Jimeno and Ortega (2007), and Dolado and Vazquez (2007).

2 The joint fall of inflation and unemployment

The recent evolution of inflation and unemployment suggests a reduction in inflationary expectations, in the trade-off between unemployment and inflation, and in the NAIRU. While the source of the fall in inflationary expectations is clearly related to the change in the monetary policy regime in the late 1990s, the factors behind the change in the slope and in the NAIRU are less evident.

According to some estimates (see Izquierdo and Regil, 2006), the NAIRU has fallen from about 15% in 1996 to 9% in 2006. This is truly remarkable, as structural policy indicators commonly used to explain this rate have not shown important changes. Thus, according to the "reform intensity indicator", elaborated by Brandt *et al.* (2005) to measure changes in labor market institutions during the period 1994-2004, Spain is ranked in the 24th position (out of 30 OECD countries). In fact, among all institutional dimensions considered relevant in explaining structural unemployment (tax wedge, Employment Protection Legislation (EPL), unemployment benefits entitlements, wage setting and industrial relations, working-time flexibility, incentives for labor market participation, and product market regulation), Spain only shows some changes in the strictness of EPL for permanent employment (which according to the OECD indicator has been significantly relaxed between 1994 and 2003, a too benign judgment, in our view, of a labor reform in 1997) and in product market regulation (an improvement shared by most of the other OECD countries).[5]

As for the unemployment-inflation trade-off, it has been argued that higher productivity growth could reduce the level of inflation at given wages. The basic idea is that misalignment between wage aspirations and productivity shift the Phillips curve. This explanation has been used to rationalize the inward shift of the Phillips curve observed in the US since 1995 (see, for instance, Ball and Moffitt, 2001). However, since the mid-1990s, when unemployment began to fall in Spain, the productivity growth rate has also been significantly lower. As seen in Figure 2, both labor productivity and Total Factor Productivity (TFP) showed a noticeable deceleration, with labor productivity growth

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[5]For a discussion of EPL reforms in Spain, see Dolado *et al.* (2002).

being barely positive and TFP growth negative since the beginning of this decade.[6]

Finally, another possible factor driving the fall of inflation is globalization, by operating through two basic mechanisms: changes in import prices, and increasing trade integration and global competition (e.g. International Monetary Fund, 2006). Figures 3 and 4 report the aggregate indicators for Spain in this regard. Admittedly, although import prices have decelerated during the period 1980-90, with inflation closely following this decreasing trend, since the early 1990s the rate of growth of import prices fluctuates around a constant mean, while inflation shows first a decreasing trend up to 1998 and an increasing trend afterwards.

As for trade integration, the degree of openness of the Spanish economy shows an increasing trend which clearly tilts upwards since 1992, when the second disinflation episode of the recent three decades started. However, the evolution of inflation during the 1992-98 period, as in other EMU countries, seems to be mostly determined by the nominal convergence process in the run-up to EMU.

3 The immigration boom

In 1991 there were about 350.000 foreigners living in Spain (1% of total population). This figure has risen to about 4.1 million (9.3% of total population) in 2006. The average annual immigrant flow during the 2000-2005 period is approximately 575 thousand (1.2 and 1.0 millions, respectively, in the US and in the EU) which is one of the largest among developed countries. The geographical distribution of immigrants is roughly 24% from the EU and 76% from the rest of the world (34% from South America, 20% from Africa, 13% from Eastern Europe, and 5% from Asia). Immigrants are over-represented in the services (58%) and construction (13%) sectors and 53% of them have a low educational attaintment. As seen in Figures 5 and 6, respectively, in the first half of the 2000s immigration flows have accelerated and the unemployment rate of immigrants has remained above that of native workers, as the inflation rate increased from 2% to 4%.

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[6]Data on productivity are from the EU KLEMS Database, March 2007, www.euklems.net.

As a very rough, first-pass, indication of the potential impact of immigration on the Spanish labor market, Figure 7 shows a negative correlation between real wage growth and the difference between the unemployment rate of immigrants and the overall unemployment rate. It is also noticeable that real wage growth turns negative precisely during the latter period, when that unemployment rate differential is positive and higher.

Much has been written about the impact of immigration on the labor market of the receiving country. The bulk of studies focus on the impact of immigrant on the employment rates and wages of native workers.[7] Less attention has been paid, however, to immigration in the macroeconomic analysis of the labor market and, more concretely, to the impact of immigration on the NAIRU and on the unemployment-inflation trade-off. Plausibly, this neglect is due to the long-run neutrality of labor supply in standard macroeconomic models of unemployment. However, assuming some differences between immigrants and natives, there are several channels through which immigration may affect the NAIRU and the unemployment-inflation trade-off. First, there is a well-documented evidence on the existence of complementarities in production between immigrants and natives (Ottaviano and Peri, 2006). Secondly, the employment patterns of immigrants and, in particular, their sectoral composition and geographical mobility, suggest that they have different preferences between consumption and leisure than native workers. Finally, it is also plausible that, in monopolistic markets, immigrants' bargaining power is lower. Hence, a rise of the immigration flow increases the labor intensity of production, changes the elasticity of labor supply, and decreases the markup of wages over the marginal rate of substitution between consumption and leisure. In the next section, we explicitly model how these three effects interact to change the intercept and the slope of the Phillips curve.

4   A New Keynesian Phillips curve with immigration

As is standard in the literature on the New Keynesian Phillips curve, let us assume an economy with a continuum of monopolistically competitive firms, each producing a dif-

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[7]For a survey, see Borjas (1999), and for an example of this type of studies, see Card (2001).

ferentiated product (Y) and facing an isoelastic demand with price elasticity $\epsilon > 1$. The production function is Cobb-Douglas with two inputs, labor (N) and raw materials (M), where the labor input consists of two components: native workers (N_1) and immigrants (N_2), which are aggregated through a CES function. Hence,

$$Y_t = N_t^{1-\alpha} M_t^{\alpha} \tag{1}$$

$$N_t^{\rho} = \alpha_1 N_{1t}^{\rho} + \alpha_2 N_{2t}^{\rho} \tag{2}$$

so that $\sigma = (1 - \rho)^{-1}$ is the elasticity of substitution between native workers and immigrants.[8]

By means of the envelope theorem, marginal costs plus the markup (both in logs) can be expressed as a function of the aggregate index of labor input, N, as follows (throughout, lowercase letters denote logs of variables in levels):

$$mc + \mu^p = \omega - (y - n) - \ln(1 - \alpha) + \mu^p, \tag{3}$$

where ω is the average (logged) real wage and $\mu^p \ (= log(\epsilon/\epsilon - 1))$ is a (logged) constant price markup.

We assume that immigrants and native workers are not only different in production, but also in their marginal rate of substitution between consumption and leisure, as given by the following utility functions

$$U_i = \ln C_i - e^{\xi} \frac{N^{1+\phi_i}}{1 + \phi_i}, \ (i = 1, 2)$$

where C_i is composite consumption (with elasticity of substitution equal to ϵ) and ξ is a preference parameter. Hence, the marginal rate of substitution, mrs, between consumption and labor is given by

$$mrs_i = c_i + \phi_i n_i + \xi \tag{4}$$

Following the discussion in section 3, it is assumed that the slope of the labor supply of immigrant workers in the $\omega - N$ space is larger than that of native workers, i.e.,

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[8]The assumption of CRS in (1) can be relaxed to short-run decreasing returns $(\alpha_m + \alpha_n < 1)$, considering that we ignore capital. BG (2006) discuss this case and show that the specification of the NKPC later derived in (20) below only changes by having the change in the unemployment rate as an additional regressor.

$\phi_2 > \phi_1$. This means that the labor supply of the former is less elastic than that of the latter.[9]

Then, taking a log-approximation of equation (2) around the steady state, we have that the average labor and wages (in deviations from steady state) are given by (see Appendix A.1 for a derivation)

$$
\begin{aligned}
n &= \lambda n_1 + (1 - \lambda)n_2 \\
\omega &= \lambda \omega_1 + (1 - \lambda)\omega_2,
\end{aligned} \tag{5}
$$

with $\lambda \simeq \alpha_1(\frac{\overline{N_1}}{\overline{N}})^{\frac{\sigma-1}{\sigma}} = 1 - \alpha_2(\overline{MR})^{\frac{\sigma-1}{\sigma}}$, where $\overline{MR}\ (= \overline{N_2}/\overline{N})$ denotes the immigration rate (defined in terms of employment) in steady state.

4.1   Sluggish wages and markups

As in Blanchard and Galí (BG) (2006), we consider the case where real wages respond sluggishly to labor market conditions, due to some (unmodeled) imperfection in the labor market. Further, it is assumed that there are gross wage markups (possibly time varying) denoted (in logs) by μ_i^ω $(i = 1, 2)$, reflecting workers having some monopoly power in the labor market, distorsionary taxes on labor income, etc., which can differ across both types of worker. Specifically, it is assumed that real wages of both native and immigrant workers follow a partial adjustment model of the form:

$$
\omega_i = \gamma \omega_{i,-1} + (1 - \gamma)(mrs_i + \mu_i^\omega); \ (i = 1, 2). \tag{6}
$$

Thus, replacing (4) in (6) yields

$$
\omega_i = \gamma \omega_{i,-1} + (1 - \gamma)(c_i + \phi_i n_i + \xi + \mu_i^\omega),
$$

where $\gamma \in [0, 1)$ is the sluggishness parameter. In order to compute the average wage, ω, notice that

$$
\lambda \phi_1 n_1 + (1 - \lambda)\phi_2 n_2 = \psi n + \phi_{21} mr, \tag{7}
$$

---

[9]This implies that, in the presence of a negative demand shock, immigrants are more ready than natives to reduce their wages in order to remain employed. However, by the same token, if a positive demand shock takes place, immigrants' wages would increase by a larger amount, given our linear assumption. In order to check whether the labour supply curve of immigrant workers is concave, we will later allow for a quadratic term in their relative unemployment when estimating equation (20) in section 5 below.

where $\psi = \lambda\phi_1 + (1-\lambda)\phi_2$, i.e., the average of the inverse labor supply elasticities, $\phi_{21} = (1-\lambda)(\phi_2 - \phi_1) > 0$, and $mr = n_2 - n$, i.e. approximately the (log of) the immigration rate in the employment stock. Then, denoting the lag operator by L, (6) can be rewritten as $\omega_i = \frac{(1-\gamma)(mrs_i + \mu_i^\omega)}{1-\gamma L} = mrs_i + \mu_i^\omega - \frac{\gamma\Delta(mrs_i + \mu_i^\omega)}{1-\gamma L}$, so that using (4) the average wage in (5) is given by

$$\omega = y + \psi n + \phi_{21}mr + \xi + \mu^\omega - \frac{\gamma\Delta(y + \psi n + \phi_{21}mr + \xi + \mu^\omega)}{1-\gamma L} \tag{8}$$

where, in our economy of just consumption goods, average consumption equals is equal to output, that is, $\lambda c_1 + (1-\lambda)c_2 = y$, and μ^ω is the average markup given by $\mu^\omega = \lambda\mu_1^\omega + (1-\lambda)\mu_2^\omega$.

From (1), the MRS between labor and raw materials implies that

$$y - n = \alpha(m - n) = \alpha(\omega - p_m) + \alpha\ln\frac{\alpha}{1-\alpha}$$

Thereby, substituting this expression in (9) yields an equation describing the evolution of real wages from the workers' side:

$$\omega = \Gamma\omega_{-1} + \frac{1-\Gamma}{1-\alpha}\left(\alpha\ln\frac{\alpha}{1-\alpha} + (1+\psi)n + \phi_{21}mr + \xi - \alpha p_m + \mu^\omega\right) \tag{9}$$

with $\Gamma = \frac{\gamma}{1-\alpha+\gamma\alpha} < 1$.

4.2 First-best equilibrium

The next step consists of deriving the (first-best) flexible price equilibrium, under flexible prices and wages and where labor and goods markets are perfectly competitive, i.e., $\mu^\omega = \mu^p \equiv 0$.

From the firms' side, the real aggregate wage will be equal to the marginal product of labor (mpn), that is $\omega = mpn = y - n + \ln(1-\alpha)$. Similarly, from the workers' side, the real wage will be equal to the marginal rate of substitution, that is, $\omega = y + \psi n + (1-\lambda)\phi_{21}mr + \xi$. Therefore, equating both expressions and denoting the equilibrium value of a given variable x by $\overline{x}$, we have that the equilibrium values of the employment of natives and immigrants is defined by

$$(1+\psi)\overline{n} + \phi_{21}\overline{mr} = \ln(1-\alpha) - \xi. \tag{10}$$

9

4.3 Equilibrium with real wage rigidities and monopoly power

Going back to our economy with labor market frictions and monopolistic power in the goods market, replacing (11) in (10) yields the evolution of the wage-setting from the workers' side,

$$\omega = \Gamma\omega_{-1} + \frac{1-\Gamma}{1-\alpha}\left(\alpha\ln\alpha + (1-\alpha)\ln(1-\alpha) - \alpha p_m + \mu^\omega + (1+\psi)\widetilde{n} + \phi_{21}\widetilde{mr}\right), \quad (11)$$

where $\widetilde{n}(= n - \overline{n})$ and $\widetilde{mr}(= mr - \overline{mr})$ are the deviations of n and mr from their first-best values.

From the firms' side, we have that $mc + \mu^p = \omega - mpn + \mu^p$. Then inserting (12) into this expression and using (1), yields the following equation describing the dynamic evolution of $mc + \mu^p$

$$(1 - \Gamma L)(mc + \mu^p) = \frac{(1-\Gamma)(1+\psi)}{1-\alpha}\widetilde{y} + (1-\Gamma)\phi_{21}\widetilde{mr} + \alpha\Gamma\Delta p_m + (1-\Gamma)(\mu^\omega + \mu^p) \quad (12)$$

where $\widetilde{y} = y - \overline{y}$.

4.4 Unemployment and immigration

In order to express (13) in terms of observables, namely, the unemployment (u) and migration rates (mr), we follow again BG (2006) by assuming that the (logged) labor supplies (ℓ_i) and relative labor supply of immigrants vis-à-vis natives ($mrl = \ell_2 - \ell_1$) are implicitly defined by (cfr. (9)):

$$\omega = y + \psi\ell + \phi_{21}mrl + \xi + \overline{\mu}^\omega, \quad (13)$$

that is, ℓ and mrl measure the notional quantities of labor that native and immigrant workers would like to supply given their current wages, marginal utility of income, and a steady-state wage markup, $\overline{\mu}^\omega$. Hence, from the firms' side, substitution of (14) into (3), yields

$$mc + \mu^p = (1+\psi)\ell - (\ell - n) + \xi - \ln(1-\alpha) + \phi_{21}mrl + \overline{\mu}^\omega + \mu^p \quad (14)$$

Then, making use of the definition $u \simeq \ell - n$, noticing that $mrl = (mrl - \overline{mr}) + \overline{mr}$, and recalling the first-best equilibrium condition in (11), implies that (15) can be

rewritten as

$$mc + \mu^p = \frac{1+\psi}{1-\alpha}\widetilde{y} + \psi u + \phi_{21}(mrl - \overline{mr}) + \overline{\mu}^\omega + \mu^p \tag{15}$$

Hence, solving for $\frac{(1+\psi)}{1-\alpha}\widetilde{y}$ in (16) and replacing it in (13), yields the following equation describing the evolution of $mc + \mu^p$ in terms of observables

$$\Delta(mc + \mu^p) = -\frac{1-\Gamma}{\Gamma}\left(\psi u + \phi_{21}(u_2 - u) - \widetilde{\mu}^\omega\right) + \alpha\Delta p_m \tag{16}$$

where $\widetilde{\mu}^w = \mu^\omega - \overline{\mu}^\omega$, and use has been made of the result that $mrl - mr = (\ell_2 - \ell) - (n_2 - n) \simeq u_2 - u$, i.e., the difference between the unemployment rate of immigrants and the aggregate unemployment rate. This is the new variable our model brings out with respect to the BG specification of a similar equation without migration. As long as immigrants have a higher unemployment rate than natives due to adverse labor demand shocks, this induces a lower marginal cost via a higher fall in wages through their less elastic labor supply. Further, insofar as it is assumed that there could be deviations of the wage markup from its steady-state value, they would also alter the marginal cost (see Galí *et al.*, 2001 for a detailed discussion of this issue). As explained in Appendix A.2, we assume that $\widetilde{\mu}^w$ is a decreasing function of $u_2 - u$, so that $\widetilde{\mu}^w = -\delta(u_2 - u)$.

An important feature of (17) is that the optimal price set by firms ($p^* = mc + \mu^p$) has a unit root insofar as $0 < \Gamma < 1$, i.e. $0 < \gamma < 1$. As will be shown below, this implies that the PC has the property that, in the long run, inflation is independent of real factors, which only influence the change in inflation. The reason for this property, as explained in Appendix A.3, is the presence of rigidities, either in real wages, as in the present model, or in the price-setting rule.

4.5 Alternative New Keynesian Phillips curves

Finally, in order to obtain a New Keynesian Phillips curve (NKPC), we use the two well-known alternatives proposed by Galí and Gertler (1999): the forward-looking specification (FNPC) and the hybrid (i.e., a combination of forward and backward-looking price-setters) specification (HNPC). These two specifications are given (introducing time subscripts), respectively, by

$$\pi_t = \beta E_t \pi_{t+1} + \kappa_f(mc_t + \mu^p), \tag{17}$$

11

$$\pi_t = \frac{\beta\theta}{\tau}E_t\pi_{t+1} + \frac{\varsigma}{\tau}\pi_{t-1} + \kappa_h(mc_t + \mu^p), \tag{18}$$

where $\pi_t(\equiv p_t - p_{t-1})$ is the inflation rate in period t, $E_t\pi_{t+1}$ is the (rational) expectation of inflation in $t+1$ conditional on all information available up to t, $\kappa_f = (1-\beta\theta)(1-\theta)/\theta$, $\kappa_h = (1-\varsigma)(1-\beta\theta)(1-\theta)$, and $\tau = \theta + \varsigma - \theta\varsigma(1-\beta)$. In these expressions, β is the discount rate, $1-\theta$ is the probability that firms are allowed to optimally reset prices in period t according to Calvo's model, and ς is the proportion of firms which use the simple backward-looking rule of thumb proposed by Galí and Gertler (1999).[10]

Substituting (16) into (17) and (18) yields the two specifications of the NKPC allowing for immigration. The forward-looking (FNPCI) one is:

$$\begin{aligned}
\pi_t &= \psi_1^f E_t\pi_{t+1} + \psi_2^f \pi_{t-1} - \frac{\kappa_f(1-\Gamma)\psi}{\Gamma(1+\beta)}u_t \\
&\quad - \frac{\kappa_f(1-\Gamma)}{\Gamma(1+\beta)}(\phi_{21}+\delta)(u_{2t}-u_t) + \frac{\kappa_f\alpha}{1+\beta}\Delta pm_t,
\end{aligned} \tag{19}$$

with $\psi_1^f = \frac{\beta}{1+\beta}$ and $\psi_2^f = \frac{1}{1+\beta}$. In our empirical application below, we first estimate ψ_1^f and ψ_2^f, check that their sum adds up to 1, and then impose the restriction. Following our argument above, we are assuming that the wage markup depends on the relative immigrant unemployment rate. Note that in this new specification, both the intercept and the slope of the PC are shifted by the presence of immigrants.

The hybrid curve (HNPCI) is:

$$\begin{aligned}
\pi_t &= \psi_1^h E_t\pi_{t+1} + \psi_2^h \pi_{t-1} + \psi_3^h \pi_{t-2} - \frac{\kappa_h(1-\Gamma)\psi\tau}{\tau+\beta\theta}u_t \\
&\quad - \frac{\kappa_h(1-\Gamma)\tau(\phi_{21}+\delta)}{\tau+\beta\theta}(u_{2t}-u_t) + \frac{\kappa_h\alpha\tau}{\tau+\beta\theta}\Delta p_{mt},
\end{aligned} \tag{20}$$

with $\psi_1^h = \frac{\beta\theta}{\tau+\beta\theta}$, $\psi_2^h = \frac{\tau+\varsigma}{\tau+\beta\theta}$, and $\psi_3^h = -\frac{\varsigma}{\tau+\beta\theta}$. Notice that (19) gives rise to forward ($E_t\pi_{+1}$) and backward (π_{t-1}) components of inflation without having to rely on the existence of firms using a simple backward-looking rule of thumb to set prices. When these firms are considered, like in (20), then the backward component of inflation has two lags.

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[10] As discussed in Appendix A.3 a similar NKPC can be derived using Rotemberg's (1982) quadratic adjustment cost model of changing prices.

In estimating (20), we will also wish to impose the restriction that $\psi_1^h + \psi_2^h + \psi_3^h = 1$. Then:

$$\pi_t = \psi_1^h E_t \pi_{t+1} + (1 - \psi_1^h - \psi_3^h)\pi_{t-1} + \psi_3^h \pi_{t-2} + ...$$

so that:

$$\Delta \pi_t = \frac{\psi_1^h}{1 - \psi_1^h}(E_t \pi_{t+1} - \pi_t) - \frac{\psi_3^h}{1 - \psi_1^h}(\pi_{t-1} - \pi_{t-2}) + ... \tag{21}$$

where $\frac{\psi_1^h}{1-\psi_1^h} = \frac{\beta\theta}{\tau} > 0$ and $\frac{\psi_3^h}{1-\psi_1^h} = -\frac{\varsigma}{\tau} < 0$.

Both (19) and (20) satisfy the property that there is no long-run trade-off between inflation and unemployment. In other words, the FNPCI is indeed vertical.[11] Given this property, we can define the concept of fundamental change of inflation, $\Delta\pi_t^*$, along the lines of Galí and Gertler (1999) and Galí et $al.$ (2001), to then integrate this variable in order to get the fundamental level of inflation, π_t^*. Thus, iterating (19) forward we obtain:

$$\Delta \pi_t^* = (1 + \beta)\sum_{j=0}^{\infty} \beta^j E_t\{\widehat{x}_{t+j} \mid z_t\}, \tag{22}$$

where in our empirical application, $z_t = [\widehat{x}_t, \widehat{x}_{t-1}, \widehat{x}_{t-2}, \pi_t, \pi_{t-1}, \pi_{t-2}]$ and:

$$\widehat{x}_t = -\frac{\kappa_f(1-\Gamma)}{\Gamma(1+\beta)}[\psi u_t + (\phi_{21} + \delta)(u_{2t} - u_t) - \frac{\Gamma\alpha}{(1-\Gamma)}\Delta pm_t].$$

We construct $\widehat{x}_t$ using the coefficients estimated in our Phillips curve and, to compute forecasts of its future values, we run a second-order vector autoregression of π_t and $\widehat{x}_t$. Letting A denote the companion matrix of the VAR(1) representation of z_t, we have that $E_t\{\widehat{x}_{t+j} \mid z_t\} = e_1' A^k z_t$, where e_1 is a vector with a 1 in its first position and zeros elsewhere. Hence:

$$\Delta \pi_t^* = (1 + \beta)e_1'(I - \beta A)^{-1} z_t. \tag{23}$$

5 Estimation results

In this section we present our estimates of the model. We estimate the forward-looking specification in equation (19):

$$E_t\left\{(\pi_t - \alpha_1 \pi_{t+1} - \alpha_2 \pi_{t-1} + \alpha_3 u_t + \alpha_4(u_{2t} - u_t) - \alpha_5 \Delta pm_t)\, Z_t\right\} \tag{24}$$

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[11]Likewise, from (21), since $(1 - \psi_1^h - \psi_2^h - \psi_3^h) = 0$, the same result holds for the HNPCI specification. Obviously, ignoring the role of immigration, the NPC derived by Blanchard and Galí (2006), verifies the same result.

by the Generalized Method of Moments (GMM), using a set of instruments, Z_t, consisting of a constant plus four lags of the following variables: the inflation rate (π_t), the differential unemployment rate of immigrants ($u_{2t} - u_t$), the inflation rate of imported inputs (Δpm_t), the labor share, and cyclical output (with the trend estimated with the Hodrick-Prescott filter with a parameter of $1,600$). See the definitions of all variables in Appendix B. The data start in 1980:1 but given the lead and lags involved, our estimation period is 1982:1-2006:3. There is no data on the split of the labor force between natives and immigrants before 1987:2, which forces us to assume that they had the same unemployment rate through that date. This is not an important limitation, since during that period immigration only represented 0.3% of the labor force on average.

Column (1) in Table 1 presents the estimated coefficients in the unrestricted specification. All coefficients are statistically significant and have the expected signs. In particular, relative immigrant unemployment has a negative effect on inflation. We test for whether the response of immigrant labor supply is asymmetric upwards and downwards, by introducing in column (2) a quadratic term in relative immigrant unemployment, but we cannot find any asymmetry.[12] The value of the discount rate β implied by the coefficient on future inflation is 0.86. This is low but in line with those found in much of the literature; for instance, Galí *et al.* (2003) find values between 0.84 and 0.92 for the Euro area, and Galí and López-Salido (2001) between 0.75 and 0.85 for Spain over the period 1990-1998.

In column (1) the coefficients on future and lagged inflation are very close to adding up to 1, as implied by the model. A Wald test of this null hypothesis yields a *p*-value of 0.58. Thus, to gain efficiency, we impose this restriction, which implies a value of 0.852 for β. Column (3) shows the restricted estimates, which are similar to those in column (1).

The estimation of equation (24) yields 4 estimated coefficients (imposing that $\alpha_1 +$

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[12]Fernández and Ortega (2007) examine the labour market assimilation of immigrant workers in Spain, concluding that they tend to achive similar unemployment rates as natives five years after arrival. Thus, lack of concavity in the relative unemployment may mean higher inflation pressure in the future. However, even after this assimilation period, immigrants tend to be over-represented in temporary and low-skilled jobs for which they are over-qualified. This may reduce inflationary pressure.

$\alpha_2 = 1$), while from (19) we have the following 8 free parameters: β, γ, α, θ, λ, ϕ_2, ϕ_1, and δ. To check how sensible our estimation is, we calibrate α, λ, and ϕ_2/ϕ_1, and identify β, γ, θ, and δ (see Appendix A.4 for details). We obtain a value for θ, the fraction of firms that keep their prices unchanged per quarter, of 0.825. This is again in line with the estimates of Galí *et al.* (2003) for the Euro area (from 0.78 to 0.87) and of Galí and López-Salido (2001) for Spain (from 0.84 to 0.91). For the other two parameters, namely γ (real wage inertia) and δ (the effect of immigrants on the wage markup) the estimates are 0.848 and 0.762, respectively, but we have no counterparts in the literature to compare them with.

In order to see how the model explains the evolution of inflation, we compute fundamental inflation, as described in the previous section. To compute forecasts of a single right-hand side variable determining inflation we use the coefficients presented in column (3) of Table 1. We then run a second-order vector autoregression of inflation and the deviations of $x_t = \widehat{\alpha}_3 u_t + \widehat{\alpha}_4 (u_{2t} - u_t) - \widehat{\alpha}_5 \Delta pm_t$ from its sample mean, and then apply equation (23). The resulting fundamental inflation rate, shown in Figure 8, is more volatile than observed inflation but it tracks its downward path reasonably well.[13]

We now focus on the last eight years in the sample. Over this period, inflation increased from 2.4% in 1998:4 to 4.5% in 2001:1, and then steadily fell to 3.5% in 2006:4, while the unemployment rate fell by 7 percentage points (p.p.), which represents a favorable trade-off for the Spanish economy by historical standards. Over the same period, the relative unemployment rate of immigrants rose by 3 p.p., and the price of imported inputs rose by 35 p.p., with sharp variations up and down. It should be born in mind that, as is evident from Figure 7, in the last three years of the sample fundamental inflation overpredicts actual inflation. This reveals that there is still some extra reason(s) for the moderate behavior of inflation over this last three-year period that we have yet to account for. A natural candidate is the anchoring of inflation expectations due to the operation of the single monetary policy in the Euro area.[14]

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[13] The higher volatility of π_t^* relative to those reported in Galí and Gertler (1999), Galí and López-Salido (2001) and Galí *et al.* (2002) is due to the presence of Δpm_t among its determinants.

[14] Indeed, recursive estimation of (20) since 1999 indicates that the coefficient on future inflation has been smoothly rising where the coefficient on lagged inflation has gone down, without violating the

To compute the contribution of each variable to fundamental inflation, we shut out each of the three variables which define x_t in turn. The results from this exercise are quite revealing. If unemployment had remained constant at its 1998:4 level, the inflation rate would have been 2.2 p.p. lower annually, whereas if relative immigrant unemployment had not varied from that date on, inflation would have been 0.9 p.p. higher on average every year. Thus, about half of the increase in inflation derived from the reduction in unemployment was compensated by the increase of the relative unemployment rate of immigrants. The remainder is made up by the increase in imported input prices.

We also estimate the hybrid NKPC by estimating equation (19). We find a coefficient on $E_t\pi_{t+1} - \pi_t$ of -0.118 (t-ratio: 2.64) and a coefficient on $\pi_{t-1} - \pi_{t-2}$ of 0.185 (t-ratio: 5.10). These coefficients correspond, in the model, to $\frac{\beta\theta}{\tau}$ and $-\frac{\varsigma}{\tau}$, respectively, which would imply that the discount factor β and the fraction of firms following a rule of thumb ς are both negative, which is meaningless. Thus we discard the hybrid model. Further, to account for variability of the price markup (so far assumed constant) we also introduced cyclical output and an index of globalization for the Spanish economy as further regressors in (20), but none of their coefficients turned out to be significant (t-ratios of 0.56 and 0.91, respectively). Finally, in order to test for the CRS assumption in (1), we also added Δu_t and $\Delta(u_{2t} - u_t)$ as additional regressors, but again their coefficients showed up insignificant (t-ratios of 0.36 and 1.49, respectively).

6 Sectoral New Keynesian Phillips curves

Since the previous results for the aggregate economy seem to support the moderating effect of immigration on inflation, our reasoning would receive further support if this effect is larger, when estimating NKPCs at the sectoral level, for those sectors with higher intensity of immigrant labor. Using information from the Spanish Labour Force Survey (EPA), we are able to obtain a breakdown of employment by nationality for 4 large industries: agriculture, manufacturing, construction, and services. This, together with the information on sectoral price deflators and GDP from the Spanish National

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long-run neutrality restriction. However, we have not been able to identify a variable which helps to pin down these effects.

Accounts, allows us to compute sectoral inflation measures, plus sectoral labor share and cyclical output, to be used as instrumental variables. Unfortunately, however, we lack information on sectoral unemployment by nationality. Thus, we are forced to use aggregate measures of u_t and $u_{2t} - u_t$ in the sectoral specification of equation (20). Nonetheless, to the extent that there is labor mobility across sectors, these aggregate measures of unemployment are bound to capture some of their traditional disciplinary effects on inflation.

Table 2 reports the estimation results for the (restricted) NKPC in the last three sectors mentioned above.[15] Interestingly, the effect of the relative unemployment rate is much larger and significant in the services sector where 58% of the migrants work (specially in home services, and hotels and catering), as opposed to 13% in construction and 10% in manufacturing. Thus, this fragmentary evidence seems to go in the same direction as our previous results.

7   Concluding remarks

This paper examines the evolution of the Phillips curve for the Spanish economy since 1980. In particular, we focus on what happened since the late 1990s. Starting from 1999 the unemployment rate fell by almost 7 percentage points, while inflation remained relatively subdued around a plateau of 2%-4%. Thus, the slope of the PC has become much flatter. We argue that this favorable evolution is largely due to the huge rise in the immigration rate, from 1% of the population in 1994 to 9.3% in 2006, on the labor market. We derive a New Keynesian Phillips curve with immigration, a variable which is found to shift the curve if preferences and bargaining power of immigrants and natives differ. In particular, we find that the relative unemployment rate of immigrants with respect to the national unemployment rate enters the Phillips curve, so that both its intercept and slope is shifted by the presence of immigration.

We then estimate this curve for Spain since 1980 and confirm that the relative immi-

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[15]We excluded agriculture because price-setting in this sector is highly affected by subsidies and supply shocks and, thus, our model does not describe it well. Indeed, when estimating an unrestricted version of (20) for this sector, the sum of the coefficients on lagged and future inflation exceeded unity (1.26) by a statistically significant amount.

grant unemployment rate is a determinant of the position of the Phillips curve. We also find that while the fall in unemployment over the last 8 years causes the inflation rate to increase by 2.2 percentage points per year, the increase of the relative unemployment rate of immigrants vis-à-vis natives accounts for an offsetting 0.9 percentage point drop in the inflation rate per year. We also estimate sectoral Phillips curves, finding that the impact of the relative immigrant unemployment rate is larger for the sectors with a higher share of immigrant employment.

Clearly, in this respect, the effect of immigration on inflation is good news for the central banks. Yet, as Bean (2006) argues, the flattening of the Phillips curve is rather more of a mixed blessing since, on the one hand, it implies that demand shocks and policy mistakes will not show up in large movements of inflation but, on the other, if inflation remains above target, a deeper slowdown or increasing immigration flows are needed to bring it down.

A   Appendix A. Some derivations

A.1   Derivation of λ

Consider the following approximation of the (log) deviation of a variable X from its steady state value, $\overline{X}$, where we omit time subscripts for notational simplicity

$$\widehat{x} = \ln\left(\frac{X}{\overline{X}}\right) \simeq \frac{X - \overline{X}}{\overline{X}}$$

so that

$$X = \overline{X}\exp(\widehat{x}) \simeq \overline{X}(1 + \widehat{x})$$

and for any power, a, of X

$$X^a = \overline{X}^a \exp(\widehat{x}) \simeq \overline{X}(1 + a\widehat{x})$$

Then, since aggregate employment is given by (2), use of the previous approximation yields

$$\overline{N}^\rho(1 + \rho\widehat{n}) = \alpha_1 \overline{N_1}^\rho(1 + \rho\widehat{n}_1) + \alpha_2 \overline{N_2}^\rho(1 + \rho\widehat{n}_2)$$

Since, in steady state, $\overline{N}^\rho = \alpha_1\overline{N_1}^\rho + \alpha_2\overline{N_2}^\rho$ and $\alpha_1 + \alpha_2 = 1$, it is straightforward to show that

$$\widehat{n} - \widehat{n}_2 = \lambda_n(\widehat{n}_1 - \widehat{n}_2)$$

where $\lambda_n = \alpha_1\left(\frac{\overline{N_1}}{\overline{N}}\right)^\rho$.

Next, given (2), the corresponding aggregate wage index, W, satisfies

$$W^{-\frac{\rho}{1-\rho}} = \alpha_1^{\frac{1}{1-\rho}} W_1^{-\frac{\rho}{1-\rho}} + \alpha_2^{\frac{1}{1-\rho}} W_2^{-\frac{\rho}{1-\rho}}$$

using the same steps as before, yields the following expression for the (log) deviations of real wages from steady state,

$$\widehat{\omega} - \widehat{\omega}_2 = \lambda_\omega(\widehat{\omega}_1 - \widehat{\omega}_2)$$

where $\lambda_\omega = \alpha_1^{\frac{1}{1-\rho}}\left(\frac{\widehat{W_1}}{\widehat{W}}\right)^{-\frac{\rho}{1-\rho}}$.

Finally, taking the marginal products in (1) w.r.t. N and N_1 in steady state and equating them to $\overline{W}$ and $\overline{W}_1$, implies that

$$\alpha_1\left(\frac{\overline{N_1}}{\overline{N}}\right)^{-(1-\rho)} = \frac{\overline{W}_1}{\overline{W}}$$

whereby

$$\alpha_1\left(\frac{\overline{N_1}}{\overline{N}}\right)^\rho = \alpha_1^{\frac{1}{1-\rho}}\left(\frac{\widehat{W_1}}{\widehat{W}}\right)^{-\frac{\rho}{1-\rho}}$$

Hence, $\lambda_n = \lambda_\omega \equiv \lambda = \alpha_1\left(\frac{\overline{N_1}}{\overline{N}}\right)^{\frac{\sigma-1}{\sigma}}$.

A.2 Determinants of the wage markup

To interpret the influence of migration on the (deviations of the) wage markup, $\widetilde{\mu}^w$, it is useful to consider a right-to-manage of wage setting where unions and firms bargain over the wage rate but the firms keeps the right to settle the level of employment unilaterally (see Layard *et al.*, 1991). As is standard in this model, unions maximize the following objective function

$$\max_{\omega} \Omega = \omega N(\omega) + \varsigma \left(UM - N(w)\right)\omega^a$$

where $N(\omega)$ denotes labor demand (with $N'(\omega) < 0$), UM the number of union members and ω^a the alternative wage, such that the relative influence of non-employed union members is $\xi < 1$. The maximization problem results in the following first-order condition:

$$N'(\omega)(\omega - \varsigma\omega^a) + N = 0$$

which is the wage-setting curve. Exogenous shifts in labor supply (L) influences the position of this curve through its effect on the alternative wage, defined as:

$$\omega^a = \frac{N}{L}\omega + (1 - \frac{N}{L})b\omega$$

That is, a non-employed worker has a chance to find a job and earn ω or remain non-employed and get an unemployment benefit which is a fraction b of the wage. Replacing this expression into the wage-setting curve gives

$$N\prime(\omega)\omega \left(1 - b\varsigma - \varsigma(1-b)\frac{N}{L}\right) + N = 0$$

which is upward sloping in the $\omega - L$ space if $N''(\omega)\omega + N'(\omega) < 0$, a condition that is satisfied by linear and concave labor demand functions. The equilibrium values of ω and N (ω^* and N^*)are determined by equating the above upward-sloping wage-setting curve and the downward-sloping labor demand function $N'(\omega)$, where unemployment is given by $L - N^*(\omega^*)$. The effects of an increase in the labor supply give rise to shifts to the right of left of the wage-setting curve and the labor supply, inducing a fall in wages and an ambiguous effect on unemployment.

If we assume that unions mainly protect native workers, i.e., $N = N_1$, it can be easily shown that the shift in labor supply is captured by the variable $(u_2 - u)$. We interpret this effect as a change in $\widetilde{\mu}^w$.

A.3 Long-run neutrality in the NKPC

As shown by Batini *et al.* (2005), an isomorphic derivation of the NKPC popularized by Galí and Gertler (1999) stems from the quadratic price adjustment model proposed by Rotemberg (1982), rather than Calvo's (1983) model of constant probability of price changes. This alternative derivation has the advantage of allowing the probability of

each firm resetting its prices to depend on the general level of inflation, since the costs of not doing so most certainly rise with this general level (see Ball *et al.*, 1988).

Let us consider the firm's problem as choosing a price path that solves

$$\min_{p_{t+s}} \sum_{s=0}^{\infty} \beta^s E_t \left(\frac{1}{2}(p_{t+s} - p_{t+s}^*)^2 - \frac{b}{2}(p_{t+s} - p_{t+s-1} - c\pi_{t+s-1}^a)^2 \right)$$

where the optimal price $p_{t+s}^* = \mu^p + mc_{t+s}^n$, with mc^n being the nominal marginal cost, π^a denotes the general level of inflation (which is taken as given by the firm), and $b > 0$ and $0 \le c \le 1$ are parameters in the loss function. When $c = 1$, price adjustment costs fully depend on the deviations from the general level of inflation . Notice that the quadratic adjustment cost term in price changes implies that the higher is π_{t+s-1}^a the more beneficial is for firms to reset prices more frequently. The Euler equation (in period t) of the above minimization yields

$$\beta b E_t p_{t+1} - (1 - b(1 + \beta))p_t + b p_{t-1} = -\widehat{p}_t$$

where

$$\widehat{p}_t = p_t^* + cb\pi_{t-1}^a - \beta cb\pi_t^a$$

The standard solution to this Euler equation is

$$p_t = \mu_1 p_{t-1} + (1 - \mu_1)(1 - \beta\mu_1)\frac{\widehat{p}_t}{1 - \beta\mu_1 L^{-1}}$$

where L^{-1} is the forward operator (e.g. $L^{-s}x_t = E_t x_{t+s}$) and μ_1 is the unique stable root of $\beta b \mu^2 - [1 - b(1 + \beta)]\mu + b = 0$. If we now subtract from the previous solution the following identity

$$p_{t-1} \equiv \mu_1 p_{t-1} + (1 - \mu_1)(1 - \beta\mu_1)\frac{p_{t-1}}{1 - \beta\mu_1}$$

we obtain a new solution in terms of firm's price inflation, π_t $(= p_t - p_{t-1})$

$$\pi_t = (1 - \mu_1)(1 - \beta\mu_1)\frac{mc + p_t + cb\pi_{t-1}^a - \beta cb\pi_t^a}{1 - \beta\mu_1 L^{-1}} - \frac{p_{t-1}}{1 - \beta\mu_1}$$

where use has been made of $mc_t^n = mc_t + p_t$. Then, since in equilibrium all firms are identical (so that $\pi = \pi^a$), straightforward algebra leads to the following NKPC:

$$\pi_t = \frac{\beta}{1 + \beta c}E_t\pi_{t+1} + \frac{c}{1 + \beta c}\pi_{t-1} + \frac{(1 - \mu_1)(1 - \beta\mu_1)}{\mu_1(1 + \beta c)}mc_t$$

If $0 < c < 1$, this NKPC corresponds to the hybrid case of Galí and Gertler (1999) where we find that in the long-run steady state, $\pi_t = E_t\pi_{t+1} = \pi_{t-1}$, there is a non-zero relationship between inflation and the real marginal cost, i.e., $\pi = \frac{(1-\mu_1)(1-\beta\mu_1)}{\mu_1(1-\beta)(1-c)}mc$.

If $c = 0$, the NKPC is equivalent to the forward-looking case of Galí and Gertler (1999), such that

$$\pi_t = \beta E_t \pi_{t+1} + \frac{(1 - \mu_1)(1 - \beta\mu_1)}{\mu_1} mc_t$$

where again, there is a long-run trade-off given by $\pi = \frac{(1-\mu_1)(1-\beta\mu_1)}{\mu_1(1-\beta)} mc$.

Finally, if $c = 1$, the NKPC becomes

$$\pi_t = \frac{\beta}{1+\beta} E_t \pi_{t+1} + \frac{1}{1+\beta} \pi_{t-1} + \frac{(1 - \mu_1)(1 - \beta\mu_1)}{\mu_1(1 + \beta)} mc_t$$

so that inflation is independent of the real marginal cost in the long run, although it influences the change in inflation, i.e., $\Delta\pi = \frac{(1-\mu_1)(1-\beta\mu_1)}{\mu_1(1-\beta)} mc$.

As discussed in section 4.5, an alternative way of obtaining long-run neutrality in the NKPC is to assume real wage sluggishness.

A.4   Calibration of the parameters

The estimation of equation (24) yields 4 estimated coefficients (imposing that $\alpha_1 + \alpha_2 = 1$), while from (19) we have the following 8 free parameters: β, γ, α, θ, λ, ϕ_2, ϕ_1, and δ. We calibrate α, λ, and ϕ_2/ϕ_1 and identify β, γ, θ, and δ. We can identify the following parameters from the estimation of (24):

(1) β, from the estimated coefficient on $E_t \pi_{+1}$, $\widehat{\psi}_1^f$, which is equal to 0.46 with standard error (s.e.) of 0.101. Hence, since $\psi_1^f = \frac{\beta}{1+\beta}$, we get $\widehat{\beta} = 0.852$ with s.e. $(\widehat{\beta}) = 0.343$, using the delta method (t-ratio= 2.48).

(2) κ_f, from the estimated coefficient of Δpm_t which is $\frac{\alpha\kappa_f}{(1+\beta)} = 0.0165$ with s.e. of 0.0057. Using $\alpha = 0.54$, computed as the share of intermediate inputs in gross output in the Spanish economy over the period 1980-2004 according to the EU KLEMS database (www.euklems.net) and $\beta = 0.852$, yields $\widehat{\kappa}_f = 0.057$ with $s.e.(\widehat{\kappa}_f) = 0.0195$ (t-ratio = 2.92).

(3) θ, from $\kappa_f = \frac{(1-\beta\theta)(1-\theta)}{\theta} = 0.057$, which yields $\widehat{\theta} = 0.825$ (the other root is larger than one), with $s.e.(\widehat{\theta}) = 0.0432$ (t-ratio=19.09).

(4) γ cannot be estimated directly from (20). However, we can get $\Gamma = \frac{\gamma}{1-\alpha+\gamma\alpha}$ from estimating equation (10) using GMM. We get the following results (t-ratios in parentheses):

$$
\begin{array}{llllll}
\omega_t= & 0.514 & +0.924\omega_{t-1} & +0.039n_t & +0.009(n_{2t} - n_t) & -0.295(u_{2t} - u_t) \\
& (1.89) & (53.87) & (1.67) & (2.59) & (5.91) \\
& & +0.005\Delta pm_t & & & \\
& & (0.574) & & &
\end{array}
$$

and a J-statistic of 0.11, where the instrument set contains 4 lags ω_t and of the other 4 regressors. This yields $\widehat{\Gamma} = 0.923$ with $s.e.(\widehat{\Gamma}) = 0.0173$. Hence, $0.0173 = \frac{\gamma}{1-0.46+\gamma 0.54}$, which yields $\widehat{\gamma} = 0.848$, with $s.e.(\widehat{\gamma}) = 0.0318$ (t-ratio= 26.67).

(5) δ, from the ratio of the coefficients of u_t and $u_{2t} - u_t$ which is $= \frac{-0.088}{-0.067} = 1.31$. Hence $1.31 = \frac{\psi}{\phi_{21} + \delta} = \frac{\phi_1 + (1-\lambda)(\phi_2 - \phi_1)}{(1-\lambda)(\phi_2 - \phi_1) + \delta}$. Unfortunately, we cannot identify ϕ_2 and ϕ_1 separately. However, if we impose $\phi_2/\phi_1 = 2$, and use $1 - \lambda = 0.03$ (which is mean share of immigrants in employment over 1980-2006), then $\widehat{\delta} = 0.762$ and $s.e.(\widehat{\delta}) = 0.336$,($t$-ratio= 2.27). The results on $\widehat{\delta}$ are not very sensitive to the assumed value of ϕ_2/ϕ_1. For example, if $\phi_2/\phi_1 = 4$, then $\widehat{\delta} = 0.748$ and $s.e.(\widehat{\delta}) = 0.297$ (t-ratio= 2.53).

B   Appendix B. Variable definitions and sources

Nominal and Real GDP. GDP from Spanish National Accounts produced by Instituto Nacional de Estadística (INE, www.ine.es) Base 1995, linked forward to Base 2000 at 1995:1 using growth rates. Seasonally adjusted by INE.

Inflation. Change in GDP deflator from Spanish National Accounts by INE. Computed as quarterly change in nominal GDP minus quarterly change in real GDP.

Labor share. Remuneration of employees multiplied by the ratio of employment to employees and divided by nominal GDP. This entails assuming that the self-employed earn the same labor income as employees.

Employment and unemployment for natives and immigrants. From the Spanish Labor Force Suvey (Encuesta de Población Activa) by INE, linking 1976, 1987, 2001, and 2005 definitions. Workers with double nationality are considered as immigrants throughout the sample. There is no data on immigrants before 1987:2, so we assume that they have the same unemployment rate as natives through that quarter. Seasonally adjusted using Program TSW.

Imported input prices. Price index for imported intermediate inputs from Ministerio de Economía y Hacienda, SERSIE Database (www.meh.es).

Degree of openness. Real imports plus exports divided by real GDP from INE. Same procedures as for real GDP.

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Table 1. Estimates of the Forward-Looking NKPC for Spain (GMM)

	(1) Unrestricted		(2) Unrestricted		(3) Restricted	
	coeff.	t-ratio	coeff.	t-ratio	coeff.	t-ratio
Future inflation	0.462	(4.47)	0.399	(3.94)	0.46	–
Lagged inflation	0.527	(5.29)	0.583	(6.15)	0.54	–
Unemployment	-0.082	(4.25)	-0.086	(4.08)	-0.089	(5.13)
Rel. immigrant unempl.	-0.064	(2.08)	-0.041	(1.25)	-0.069	(2.71)
Imported input prices	0.018	(2.34)	0.018	(2.39)	0.017	(2.88)
Rel. immigrant unempl. squared			-1.200	(0.87)		
J-statistic	0.11		0.11		0.11	
Implied parameters:						
β					0.852	(2.48)
θ					0.825	(19.09)
γ					0.848	(26.67)
δ					0.762	(2.27)

Period: 1982:1-2006:3. No. of observations: 99. t-ratios in parentheses. The parameters are estimated calibrating the following values for the remaining parameters: $\alpha = 0.54$, $\lambda = 0.97$, and $\phi_2/\phi_1 = 2$ (see Appendix A.4).

Table 2. Estimates of Sectoral Forward-Looking NKPC for Spain (GMM)

	(1) Manufacturing		(2) Construction		(3) Services	
	coeff.	t-ratio	coeff.	t-ratio	coeff.	t-ratio
Future inflation	0.46	–	0.45	–	0.49	–
Lagged inflation	0.54	–	0.55	–	0.51	–
Unemployment	-0.022	(0.68)	-0.040	(2.04)	-0.062	(8.30)
Rel. immigrant unempl.	-0.018	(0.38)	-0.078	(1.90)	-0.126	(2.82)
Imported input prices	0.035	(2.76)	0.016	(2.09)	0.018	(0.53)
J-statistic	0.12		0.14		0.13	
Implied discount rate:						
β	0.852	(2.45)	0.818	(2.77)	0.960	(2.83)

Period: 1982:1-2006:3. No. of observations: 99. t-ratios in parentheses.
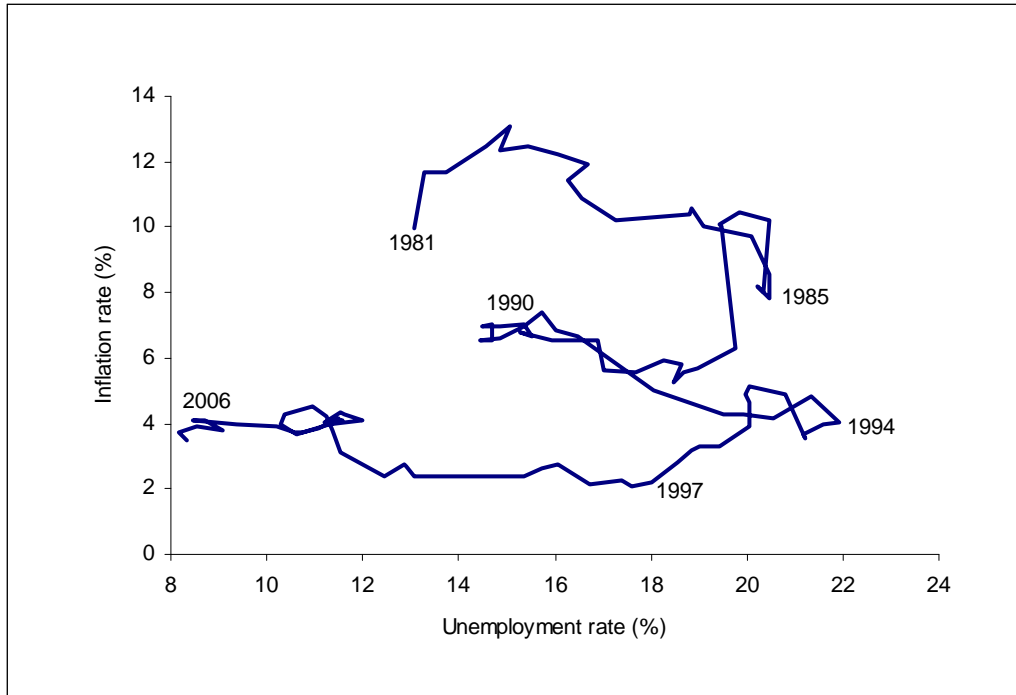
Figure 1: Inflation and unemployment in Spain, 1980-2006
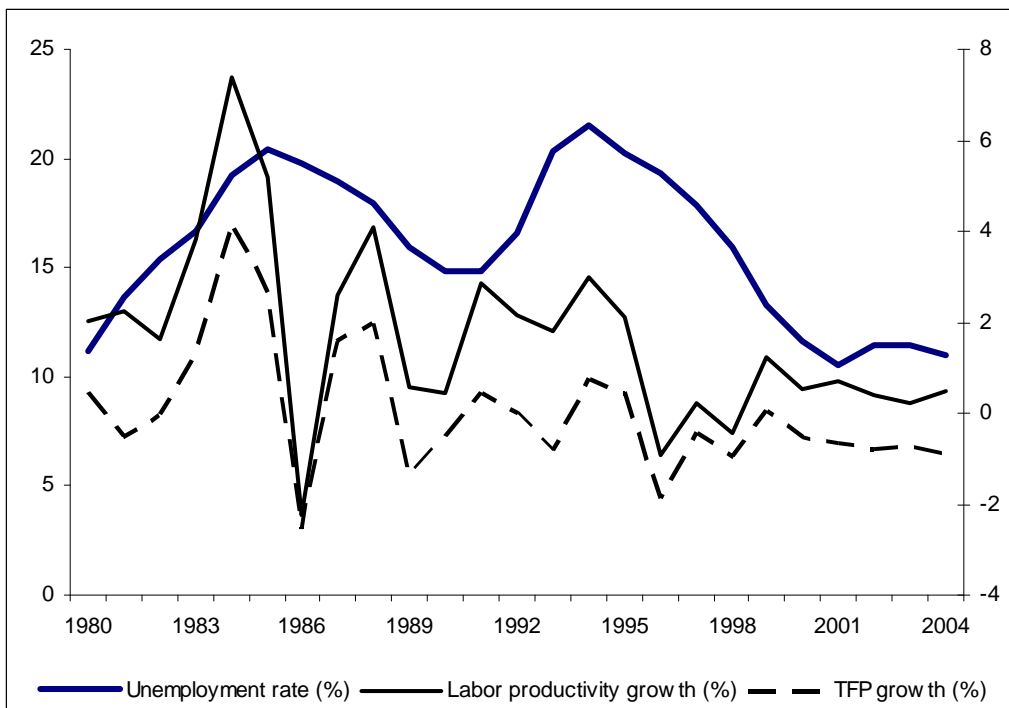
Figure 2: Unemployment rate and productivity growth (right scale), 1980-2004

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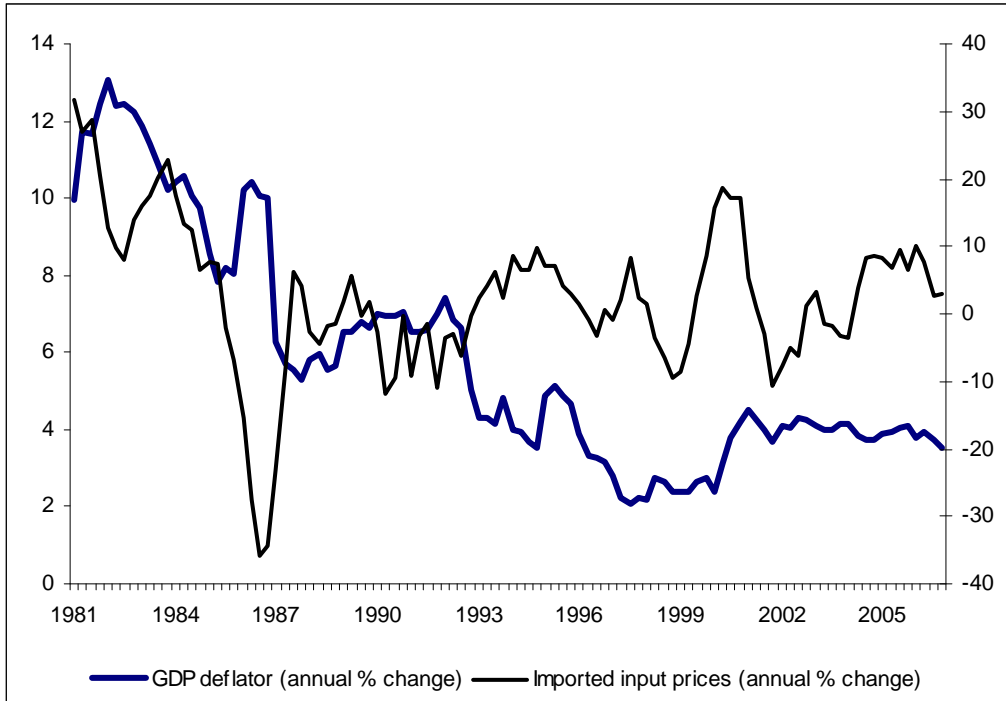
Figure 3: Inflation and the growth rate of imported input prices (right scale), 1980-2006
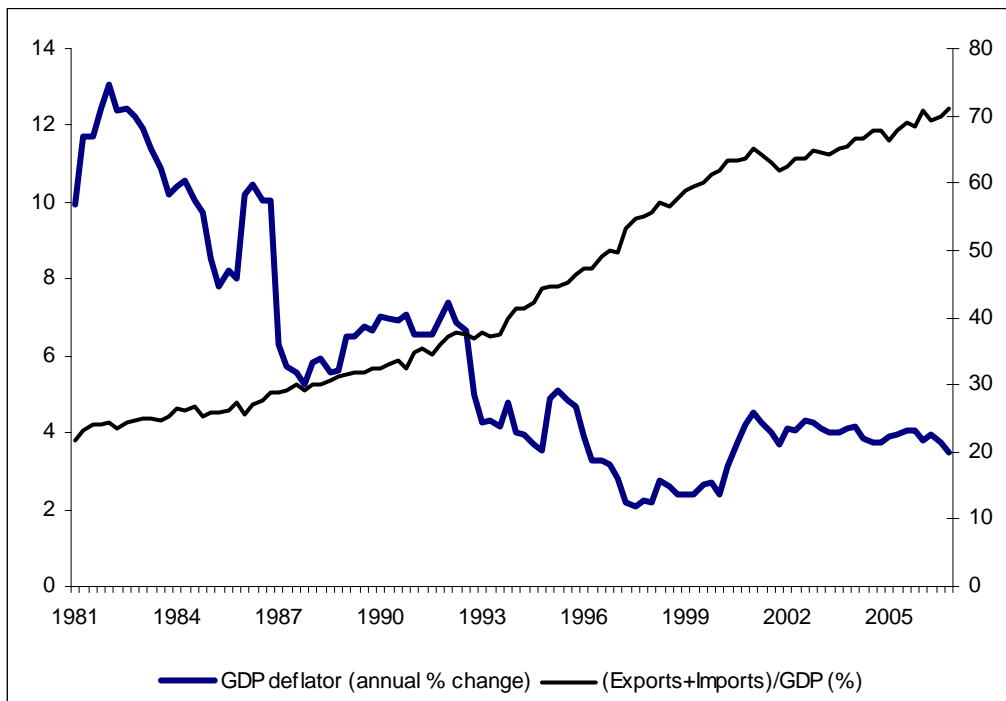

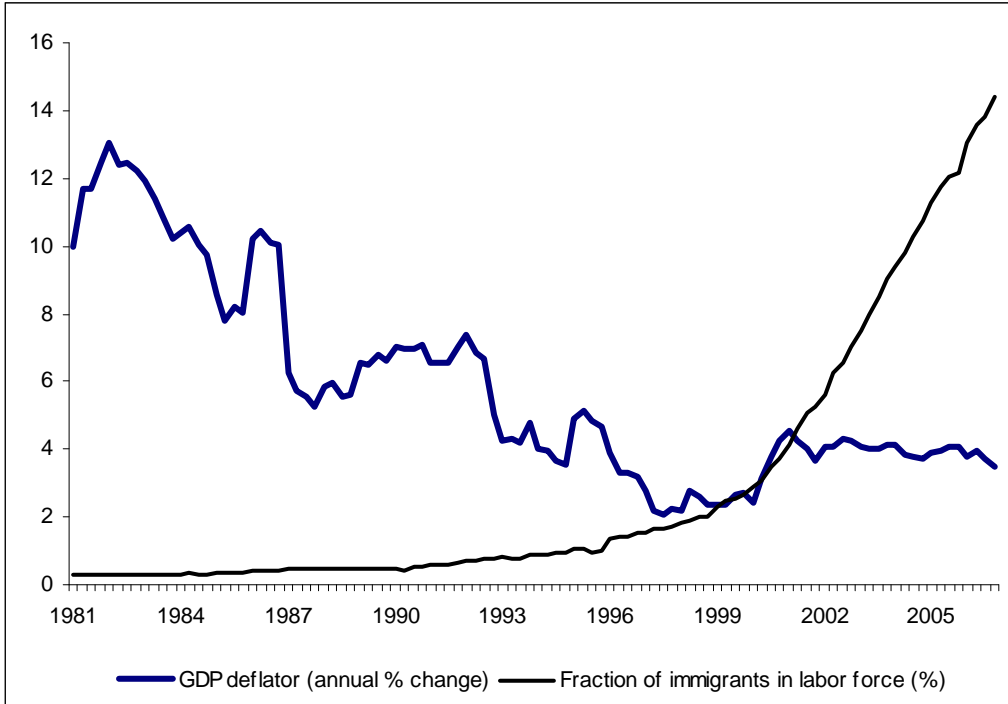Figure 4: Inflation and the degree of openness (right-scale), 1980-2006

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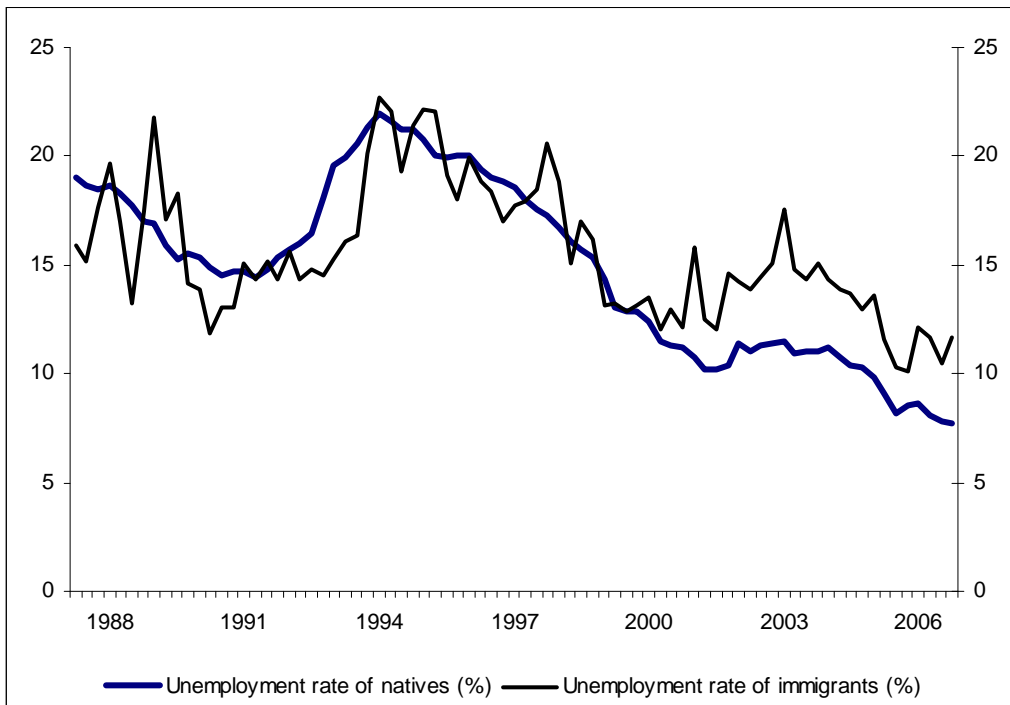Figure 5: Inflation and the fraction of immigrants in the labor force, 1980-2006

Figure 6: Unemployment rates of natives and immigrans, 1987-2006
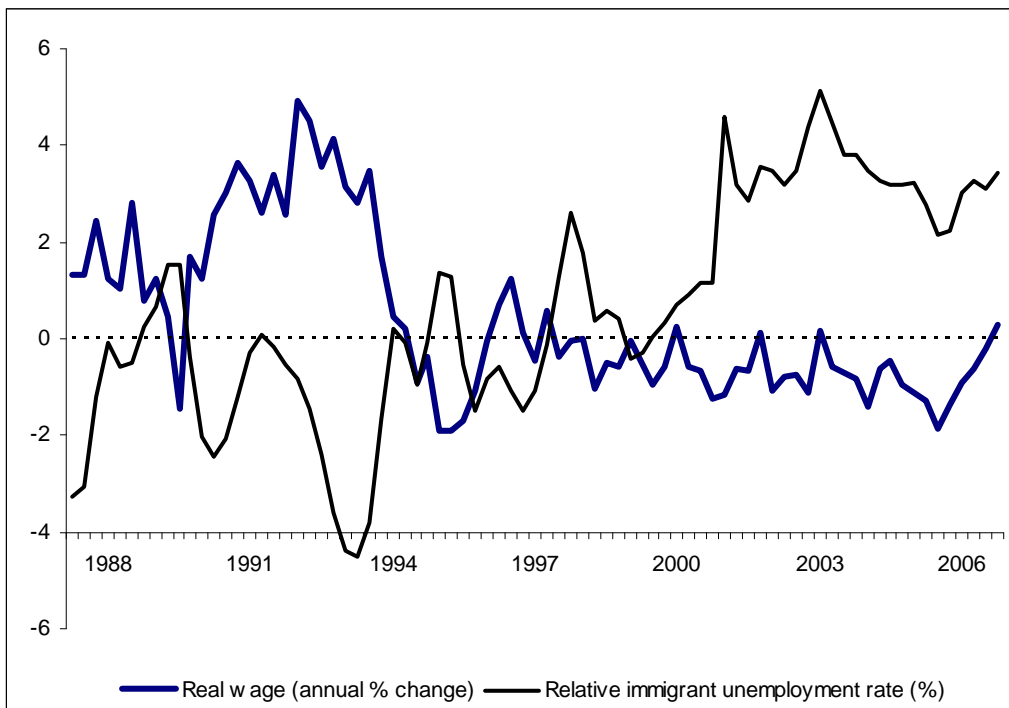
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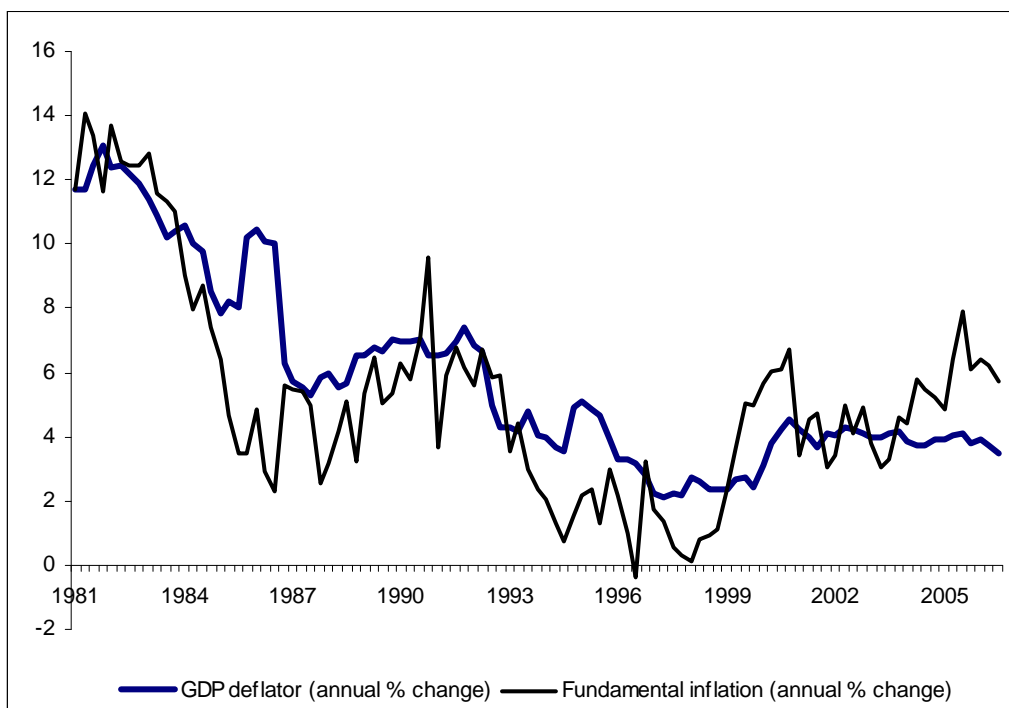Figure 7: Real wage growth and relative immigrant unemployment rate, 1987-2006

Figure 8: Actual and fundamental inflation, 1981-2006