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The Role of Inflation Differentials in Regional Adjustment: Evidence from the United States

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Abstract
Within a monetary union, regional inflation differentials lead to a competition between the real interest rate and wealth channels on the one hand and the real exchange rate channel on the other hand in the transmission of regional shocks. This may have implications for the length and vehemence of regional business cycles. This paper tries to quantify how these forces work against each other using regional data for the United States. Our estimates indicate that, following an increase in the regional inflation rate, in the short run the pro-cyclical effect through the real interest rate and wealth channels is strongest. After a period of about 3-4 years the cumulative worsening of the competitive position asserts its influence. Regional cycles in the housing market have a clear pro-cyclical effect and are, on their part, affected by regional real interest rates and real growth.

Keywords: monetary union, regional effects, inflation differentials, monetary transmission

JEL classification: E58

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1. Introduction

The European Central Bank (ECB) looks at average economic conditions in the euro-area as a whole and stresses its lack of instruments to fine-tune its policies to cyclical differences between EMU members, including differences in inflation rates. Nevertheless, regional differences in inflation rates within a monetary union exist and are a potential cause of concern for monetary authorities. A recent ECB paper (ECB, 2003) argues that a euro area wide monetary policy must consider the size, persistence and determinants of differences in inflation rates. It specifically mentions the possibility that high inflation in some regions might push inflation rates towards deflationary levels elsewhere, which in the presence of downward nominal rigidity might have adverse economic and eventually even political consequences. Therefore, according to the ECB (2003, p. 6) "the ECB's monetary policy strategy attributes a secondary role to inflation differentials when calibrating the safety margin for admissible inflation in the euro area".

The existence of regional differences in inflation rates may imply that the common monetary policy is too lax for some countries but too tight for others. Alternatively, regional inflation differentials might just be the results of differences in productivity growth. This is the well-known Balassa-Samuelson effect. A full discussion of the potential sources of regional inflation differentials is provided in Alberola (2000), who makes a distinction between a benign view of inflation differentials when caused by productivity-related convergence and a more worrying view when inflation differentials result from structural rigidities. Duarte and Wolman (2002) have recently shown that productivity shocks can account for a significant portion of inflation variation across European countries. Empirical evidence on the size and persistence of inflation differentials is provided by Cecchetti, Mark and Sonora (2000) for United States cities, by Rogers (2001) and Berk and Swank (2002) for European countries and by Alberola and Marqués (1999) for Spanish provinces. All studies conclude that relative price levels between regions converge at a surprisingly slow rate; in case of the US cities the half-life of convergence is approximately 9 years.

After the start of Economic and Monetary Union (EMU), the cross-country variation in the inflation rates of member states has in any case not fallen quickly, as Table 1 shows. In the run-up to EMU, all countries except Greece fulfilled the inflation criterion of the Maastricht Treaty; no country (except Greece) had an inflation rate higher than 1.5 percentage points above the mean inflation rate of the three members with the lowest inflation. In each year since 1999, three or more countries have failed to fulfill the Maastricht criterion, as the decrease in Greek inflation has been more than offset by increases in Dutch, Irish and Portuguese inflation rates. A comparison with the United States may be useful here. Applying the Maastricht criterion to GDP deflators for nine US districts showed that over the period 1978-2000 one or more districts regularly failed the Maastricht criterion. Fast inflation convergence in a monetary union therefore cannot be taken for granted.

In this paper we argue that regional inflation differentials within a monetary union have an important role to play in the natural adjustment towards a new equilibrium following asymmetric shocks or the asymmetric transmission of symmetric shocks. Rather than investigating the sources of regional price differences or their speed of convergence, we examine how regional inflation differentials are transmitted through the national and European economies and contribute to the adjustment mechanism within a monetary union.

On the basis of the early EMU experience, little empirical conclusions can be drawn about the role of regional inflation differentials. We therefore focus our attention on the US. Using disaggregated data we empirically examine the role of regional inflation differentials in the adjustment mechanism towards convergence. We are especially interested in two specific channels in the monetary transmission mechanism within a monetary union, each of which may hamper the cyclical convergence between member states. First, we emphasize the perverse - i.e. pro-cyclical - operation of the real interest rate channel in a monetary union. Second, we examine how wealth effects via regional housing markets may compound this pro-cyclicality. We finally examine to what extent the real exchange rate channel neutralizes these pro-cyclical factors.

Our evidence suggests that an increase in regional inflation in the short run induces procyclical effects on economic activity through lower real interest rates and higher real housing wealth. Initially, these effects dominate the anticyclical effect of the real exchange rate appreciation caused by higher regional inflation. After three to four years, the real exchange rate effect dominates and accounts for longer run convergence.

The set up of the paper is as follows. In section 2, we review the literature on the role of inflation differentials in a monetary union and present a small model. In section 3, the data are described. We present preliminary statistics and an empirical modification of the theoretical model. In section 4 we present and discuss empirical evidence, while section 5 summarizes and concludes.

2. The role of regional inflation differentials

Our starting point is the case where a country (or state) has its own monetary policy. We assume that the monetary authorities conduct an interest rate policy, as is usual nowadays. The nominal interest rate will then be increased in the presence of a positive output gap and (too) high inflationary expectations, according to some version of the Taylor-rule. This has the following two effects. First, for a given inflation rate the real interest rate increases. By way of a range of potential transmission channels - including an effect on asset prices - this will over time lead to a reduction of economic growth, a decrease in the output gap and a reduction in inflationary expectations. Second, the appreciation of the domestic currency in nominal and real terms will worsen a country's competitiveness and reduce its net exports. Here, the real interest rate channel and the real exchange rate channel reinforce each other in cooling down the economy.[1]

The following small macroeconomic model, based on Goodhart and Hofmann (2000) and strongly related to Svensson (1997), Smets (1997) and Ball (1998), serves to illustrate the role of interest rates and other financial variables in the process of monetary transmission. We note that in contrast to more recent New Keynesian models (see e.g. Clarida, Gali and Gertler, 1999) this model is backward-looking and thus valid as an approximation only.

(1) $y_{t+1} = \alpha_1 y_t - \alpha_2 (i_t - \pi_t) + \alpha_3 q_t + \alpha_4 h_t + \eta_{t+1}$

(2) $\pi_{t+1} = \pi_t + \beta y_t + \varepsilon_{t+1}$

[1] Note that the efficiency in the financial markets will ensure a prompt response of interest and exchange rates to changes in monetary policy. In case of fixed exchange rates a country's room to manoeuvre is obviously more limited, but not necessarily zero.

The extended IS curve in equation (1) relates the output gap (y) to its own lagged value, the lagged ex-post real rate of interest, defined as the nominal interest rate (i) minus inflation (π) and the lagged values of two other financial variables, the real exchange rate (q) and real housing wealth (h). Equation (2) is an aggregate supply curve, relating inflation to lagged inflation and the lagged output gap. Goodhart and Hofmann (2000) close the model with a loss function of the central bank. When central banks target inflation and minimize their intertemporal loss function, they should directly react to financial variables if these affect the output gap (i.e. if $\alpha_3 \neq 0$ or $\alpha_4 \neq 0$). Assuming that central bankers have knowledge about the relationship between financial variables and the real rate of interest, Goodhart and Hofmann (2000) derive an optimal monetary policy reaction function as a weighted average of the interest rate and asset prices. Needless to say, the centralization of policymaking precludes deriving a reaction function for regions within a monetary union.

After a country joins a monetary union – or a fixed exchange rate regime for that matter –, the real interest rate channel changes face. The central bank of the monetary union conducts the same type of monetary policy using an interest rate rule. The determinants of the nominal interest rate are now the output gap and the expected inflation in the union as a whole. Asymmetric shocks within the monetary union may cause divergences between business cycles and inflation patterns in the member states. In the neutral case where the area-wide output gap is zero and expected inflation for the union is sufficiently low, the monetary authorities will have no reason to change the nominal interest rate. A member country which at that time enjoys a business cycle upturn (relative to the union) will have an above-average economic growth rate, output gap and inflation rate. Depending on the degree of inflation persistence, residents will also have higher inflationary expectations. With a uniform nominal interest rate, the domestic real interest rate will be lower than in the rest of the union.[2] Lower real interest rates discourage savings and stimulate consumption and investment. Now, the real interest rate channel no longer acts as a brake on the cycle but instead accelerates regional economic developments.[3] Note that within a monetary union, regional real interest rate differentials are exclusively caused by regional inflation differentials, not by differences in nominal interest rates.

Within the union, the real exchange rate channel remains intact. A booming regional economy still leads to a real appreciation, not via changes in the nominal exchange rate but via a change in relative prices between the domestic economy and the rest of the union. Again, the regional inflation differentials take care of the adjustment process. The elimination of adjustment through the nominal exchange rate will, however, reduce the size and speed with which the real exchange rate adjusts.

Finally, regional inflation differentials may lead to direct or indirect wealth effects with macro-economic implications. The direct channel works through the effect of inflation on nominal asset prices for e.g. stocks and real estate. Indirectly, inflation may induce changes in wealth through its effect on real interest rates. The deregulation of financial markets in recent decades and the strong cyclical movements in asset prices in several countries have led to a stronger emphasis on the macro-economic importance of assets prices (see e.g. IMF (2000, 2003), Cecchetti, Genberg, Lipsky and Wadhwani (2000) and Goodhart and Hofmann

[2] These are ex post real interest rates. The same applies to ex ante real interest rates as long as some persistence in inflation differentials induces differentials in inflationary expectations.
[3] This mechanism is akin to the Walters critique of pegged exchange rates in the presence of diverging inflation rates, see Walters (1990).

(2000)). Case, Quigley and Shiller (2001) report empirical evidence that housing prices have a stronger relationship with the business cycle than stock prices.[4] At the regional level, this may lead to a lengthening and amplification of the business cycle. A booming regional economy with high growth and inflation rates and low real interest rates may lead to an increase in both nominal and real housing prices. Such an increase in home-owners wealth stimulates consumption through balance sheet effects. Comparing Europe to the US, we note that the relatively low labor mobility in Europe reduces arbitrage between national European housing markets. Divergences in regional housing wealth are therefore more likely to occur within Europe.

For our analysis, we need to augment the above two-equation model with an equation describing the dynamics of the real housing wealth variable. Recall that Goodhart and Hofmann (2000) assume that central banks know about the relationship between the real interest rate and other financial variables and exploit this knowledge to set any combination of interest rates, exchange rates and other asset prices according to the optimal reaction function. At the regional level, however, deviations of these variables from the union-wide level cannot be controlled by the central bank. While the dynamics of the real exchange rate will logically follow from the aggregate supply curve, real housing wealth needs a separate equation. The empirical real estate literature commonly uses income and the real interest rate as the key macroeconomic factors which impact on real housing wealth, see e.g. Kenny (1999) and Baffoe-Bonnie (1998):

(3) $h_{t+1} = h_t + \gamma y_t + \delta(i_t - \pi_t) + \upsilon_{t+1}$

We end up with a small three-equation model showing the interaction between regional inflation, economic growth and housing markets. In the remainder, we use the three-equation model as the underlying benchmark framework in the empirical analysis. The next section discusses the exact empirical specifications of equations (1) to (3) in more detail.

3. Data and empirical specifications

The empirical analysis employs regional data from the United States to quantitatively examine the effect of inflation differentials on regional growth rates within an existing monetary union. For all 51 US states, annual series for nominal and real regional Gross State Product (GSP) are available from the Bureau of Economic Analysis over the period 1977-2000.[5] As regional measures for the output gap are unavailable, we instead use real regional GSP in deviation from the rest of the US as our measure of regional economic activity. This variable, denoted $y_{i\text{-}US}$, is defined as 100x the logarithm of real GSP in region *i* divided by real GSP in the rest of the US (excluding region *i*). From real and nominal GSP we can derive a regional GSP-deflator. Regional inflation (denoted $\pi_{i,t}$) is measured as the first difference of the logarithm of the regional GSP-deflator (x100). A region's inflation differential with the rest of the US is denoted $\pi_{i\text{-}US,t}$. The real exchange rate ($q_{i\text{-}US,t}$) equals the logarithm of the GSP-deflator in region *i* relative to the GSP-deflator for the rest of the US (excluding region *i*) (x100). The regional real interest rate (denoted $r_{i,t}$) is the difference between the average nominal interest rate on one-year Treasury bills (i_t) and $\pi_{i,t}$. The real interest rate differential with the rest of the US is denoted $r_{i\text{-}US,t}$. Since the nominal interest rate inside a monetary

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[4] But see Ludwig and Sloek (2002) for an opposing view.
[5] See www.bea.gov.

union is same for each region, the regional real interest differential equals minus the regional inflation differential ($-\pi_{i-US,t}$).

In our regional analysis both $r_{i-US,t}$ and $q_{i-US,t}$ are driven by $\pi_{i-US,t}$, because nominal interest rates and nominal exchange rates play no role. This could lead to an identification problem. Note, however, that a temporary (one-time) increase in the regional inflation differential leads to a temporary lowering of $r_{i-US,t}$ but to a permanent increase in $q_{i-US,t}$. Note also that the impact of the two effects on economic activity should have a different sign. We use these distinctions to identify the different effects of the real interest rate and real exchange rate channels on regional economic activity.

Nominal regional housing wealth ($H_{i,t}$) is defined as the product of the regional owner-occupied housing stock times the regional housing price, cf. Case, Quigley and Shiller (2001). The owner occupied housing stock by state is available from the US Bureau of the Census.[6] As these data are measured once in a decade, we have linearly interpolated them to arrive at an annual time series. The median nominal housing price for single-family previously occupied homes is available by state from the Mortgage Interest Rate Survey published by the Federal Housing Finance Board.[7] We combined the housing prices for the year 2000 with annual averages of the regional housing price indices from the Office of Federal Housing Enterprise Oversight (OFHEO), which go back to 1975.[8] Nominal regional housing wealth is deflated by the regional GSP deflator to arrive at the real regional housing wealth ($h_{i,t}$). However, using the level of this variable creates the problem that structural differences between regional housing markets unrelated to the business cycle patterns which we are focusing on, may distort our results. Such structural differences could be due to location, urbanization and the composition of the housing stock. Because of this, we will use 100x the log difference of nominal and real regional housing wealth (respectively denoted $\Delta H_{i,t}$ and $\Delta h_{i,t}$). For both measures, we define a differential versus the rest of the US, respectively denoted $\Delta H_{i-US,t}$ and $\Delta h_{i-US,t}$. In practice, these variables are very strongly correlated with changes in the OFHEO regional housing price indices, as price rather than volume effects dominate year-on-year changes in housing wealth.[9]

Finally, we include an oil price variable as a proxy for possible supply shocks in the regional aggregate supply curve given by equation (2). We hypothesize that an energy shock will affect energy-producing and energy-consuming regions in the US very differently. The variable $p_{oil,t}$ is constructed as 100x the logarithm of the Producer Price Index for Energy and Fuels relative to the US GDP deflator. We do not include technology-related supply shocks because we assume that different regions of a well-integrated and well-developed area like the US would be affected similarly by such shocks.

Figures 1 and 2 give an impression of the variation in regional inflation rates and growth rates in real housing wealth within the US. Each year shows the minimum, maximum and median across all 51 states, as well as the 10^{th} and 90^{th} percentiles. The variation in regional inflation varies through time, with peaks at the start of the 1980s, in 1986 and again in 2000. In all cases this coincided with high energy price volatility influencing the GDP deflators of energy-producing states (e.g. Alaska and Texas). The difference between the 10^{th} and 90^{th} percentiles, which is less sensitive to oil price related outliers, fluctuated between 2 and 6% in the 1978-

[6] See www.census.gov.
[7] See www.fhfb.gov.
[8] See www.ofheo.gov.
[9] This also implies that the interpolation of the housing stock data will have little effect on the results.

1986 period, after which it decreased to 0.5-2% in the period 1987-1997. In recent years, it has again increased somewhat to a range of 2-2.5%. Figure 2 shows the regional variation in the growth of real housing wealth to be much higher than the variation in regional inflation rates, which conforms with prior notions of more limited arbitrage between regionally segmented housing markets. The cross-sectional variation has decreased in the 1990s. The most recent years seem to indicate that the convergence during the 1990s may be a temporary phenomenon: between 1997 and 2000 the difference between the 10^{th} and 90^{th} percentiles increased from 4.4 to almost 11 percentage points. But even this divergence is modest when we compare it to the EMU, where in 1998 the difference between the minimum and maximum nominal housing price growth rates across member states equaled 20 percentage points (ECB, 2000).

We next turn to the issue of stationarity. Applying the Im, Pesaran and Shin (1997) (IPS) panel unit root test, we could reject the null hypothesis of non-stationarity for $\Delta h_{i\text{-}US,t-1}$ and $r_{i\text{-}US,t-1}$, but not for $y_{i\text{-}US}$ and $q_{i\text{-}US}$. The results for the IPS t-bar statistic are respectively -2.63, -2.85, -1.51 and -1.21 with a 5% critical value of -1.73 (for N=50 and T=20). As is well known, with a relatively short sample period the power of unit root tests is limited. For example, using the Kwiatkowski-Phillips-Schmidt-Shin (1992) unit root test on the individual time series we could not reject stationarity of $y_{i\text{-}US}$ for 23 out of 52 states. Apart from the results of the unit root test statistics, it is theoretically not at all obvious that y and q should be non-stationary, as all of our variables are defined in deviation from the rest of the US. We will proceed in a pragmatic way, by estimating our main equation – the extended IS equation - in both a levels and a first difference version. The residuals of the levels regressions will be checked for a unit root using the IPS-test. Regarding the aggregate supply relationship, we find that $\pi_{i\text{-}US,t}$ basically follows an autoregressive pattern with only a very limited role for other variables. For real housing wealth we use first differences for reasons discussed above.

Based on the above considerations, we specify modified forms of equations (1) to (3) to estimate empirically. As our empirical analysis focuses on regional economic divergences from the rest of the monetary union, all regional variables are defined relative to the rest of the US.[10] Similar to Goodhart and Hofmann (2000), we estimate the each equation (IS, aggregate supply and housing wealth) separately in a panel context. For the IS equation, we arrive at the following:

$$(1a)\quad y_{i-US,t+1} = \alpha_{0,i} + \alpha_1 y_{i-US,t} + \alpha_2 r_{i-US,t} + \alpha_3 q_{i-US,t} + \alpha_4 \Delta h_{i-US,t}$$

$$(1b)\quad \Delta y_{i-US,t+1} = \alpha_{0,i} + \alpha_1 \Delta y_{i-US,t} + \alpha_2 \Delta r_{i-US,t} + \alpha_3 \pi_{i-US,t} + \alpha_4 \Delta^2 h_{i-US,t}$$

Equations (1a) and (1b) model regional economic activity (in deviation from the rest of the US) in respectively log levels and growth rates. In the levels regression, $r_{i\text{-}US}$ and $q_{i\text{-}US}$ are used to estimate the strength of the real interest rate and the real exchange rate channel, while $\Delta h_{i\text{-}US}$ measures the strength of the wealth channel. For the first difference regressions, we difference all variables, including $\Delta h_{i\text{-}US}$.[11] Equations (1a) and (1b) also allow for autocorrelation in the dependent variable. The oil price variable is excluded from the specification as supply shocks are transmitted via the aggregate supply curve. Equation (2a)

[10] Alternatively, we could have refrained from taking differences vis-a-vis the US and have included time dummy variables instead, to account for nation-wide movements in the variables. This alternative approach yielded very similar results.

[11] We also estimated (1b) including $\Delta h_{i\text{-}US}$ instead $\Delta^2 h_{i\text{-}US}$. This led to a somewhat higher coefficient on $\Delta h_{i\text{-}US}$. Apart from that, results were similar.

below is based on the aggregate supply relationship, which has been expanded by allowing for an effect of growth in regional nominal housing wealth on regional price levels and inflation rates.

$$\text{(2a)}\quad \pi_{i-US,t+1} = \beta_{0,i} + \beta_1 \pi_{i-US,t} + \beta_2 \Delta y_{i-US,t} + \beta_3 \Delta H_{i-US,t} + \beta_{4,i} \Delta p_{oil,t+1} + \beta_{5,i} \Delta p_{oil,t}$$

As discussed above, our aim is not to explain cross-state differences in real housing wealth, which would require a set of variables able to account for structural factors influencing regional housing markets. Therefore, equation (3a) is estimated in first differences. Again, supply shocks are excluded.[12]

$$\text{(3a)}\quad \Delta h_{i-US,t+1} = \gamma_{0,i} + \gamma_1 \Delta h_{i-US,t} + \gamma_2 \Delta y_{i-US,t} + \gamma_3 r_{i-US,t}$$

We now turn to the discussion of the empirical findings.

4. Empirical results

The results of a panel estimation of equations (1a) and (b) are reported in Table 2. We have used weighted least squares with cross-section weights to reduce the effects of cross-sectional heteroskedasticity. We also include fixed effects. The levels regression includes an AR(1) term to account for residual correlation. After the inclusion of lagged growth rates, the estimation period is reduced to 22 years (1979-2000) for the levels regression and 21 years for the first difference regression, which for 51 states brings the total number of observations to respectively 1122 and 1071. Due to the panel nature of our data, we have estimated (each variant of) the IS equation separately from the other two equations.

For the levels regression, Table 2 shows that all variables have the correct sign and are significant at a 5% level. An increase in the real housing wealth growth differential by one percentage point increases y_{i-US} by 0.158 percentage point one year later. A one percentage point increase in the regional inflation differential leads to an appreciation of the real exchange rate. This results in a relatively small reduction of y_{i-US} of 0.063 in the next year. The increase in the regional inflation differential also reduces the real interest rate differential, leading to a much stronger response on Δy_{i-US} of 0.486 percentage point in the following year. Applying the IPS t-bar test on the residuals of the levels regression yields a test statistic of -3.14 (with a 5% critical value of -1.73 for N=50 and T=20), implying that the residuals do not contain a unit root. Our results for equation (1a) corroborate Goodhart and Hofmann's (2000) findings for international country data. They find a significant effect of real interest rates and real property prices on national output gaps, but fail to find an important role for the real exchange rate.

Within a one year time horizon, the pro-cyclical real interest rate effect thus clearly dominates the anti-cyclical real exchange rate channel. The longer-term dynamics, however, will be different, as regional inflation pressures influence the real exchange rate through the level (recall that q_i equals the logarithm of the quotient of the regional and national deflators) whereas the real interest rate is influenced via the growth rate. Therefore, one-time shocks to the regional inflation differential permanently affect $q_{i,t}$ but temporarily affect $r_{i-US,t}$. In

[12] Estimation of the IS equation and the real housing wealth equation with current and lagged growth rates of the oil price included yielded qualitatively similar results.

addition, the wealth channel will play a more important role beyond the one year horizon. We will elaborate on the longer term dynamics below.

Results for the first difference regression (1b) are somewhat weaker. The coefficients for real housing wealth and the real interest rate are lower but still significant. The change in the real exchange rate ($\pi_{i-US,t}$), while still insignificant at a 5% level, is now of the wrong sign. The identification problem could be responsible for this, as the change in the real exchange rate equals minus the real interest rate differential. As noted by Goodhart and Hofmann (2000), in empirical research Δy is alternately regressed on r or Δr, implying that the positive sign of $\pi_{i-US,t}$ could just be the impact of r on Δy. Because of this complication we will proceed using the estimates from equation (1a) in our simulation exercise below.

Table 3 presents the estimation results for equation (2a) and (3a). Regarding equation (2a), the dominant effect on $\pi_{i-US,t}$ is its own lagged value. The state-specific influence of the energy price variables explains a large proportion of the variability in regional inflation differentials.[13] The coefficients of $\Delta H_{i-US,t-1}$ and $\Delta y_{i-US,t-1}$ are significant at a 5% level. However, the coefficient of $\Delta y_{i-US,t-1}$ is of the wrong sign.[14] Regarding equation (3a), all variables have the anticipated sign and are significant at a 5% level. Combining equations (1a) and (3a) shows how the mutual reinforcement of economic growth and housing prices leads to a pro-cyclical effect, whereby higher regional economic growth induces a boom in the local housing market, which in turn increases regional growth through wealth effects. A higher real interest rate reduces real housing price growth by around 0.373 percentage point. This effect is highly significant.

We now turn to a simulation exercise whereby we expose the estimated equations to an inflation shock. This analysis is subject to the important caveat that our inflation shock has not been identified as either a supply or a demand shock. Thus, we change regional inflation ceteris paribus all contemporaneous variables and thereby abstract from the negative or positive contemporaneous correlation between price and output following respectively a supply or demand shock.[15] For an individual US region, it will obviously matter much whether it is hit by a supply or demand shock. Below, however, we focus only on the effect of higher regional inflation via real interest rates, the real exchange rate and the housing market. Hartley and Whitt (2003) provide a literature overview of the decomposition of GDP shocks in to supply and demand shocks. They conclude that permanent demand shocks have been the dominant source of variance in output growth in the US, although a consensus on this is lacking in this literature and results are sensitive to the methodology which is used. When, as Hartley and Whitt (2003) claim, demand shocks dominate US output growth, the contemporaneous correlation between price and output might further amplify the regional business cycle via e.g. the housing market equation. We leave this issue unexplored.

Based on the point estimates of the coefficients from equations (1a), (2a) and (3a), we have simulated the effect of a positive one-off one standard deviation shock to the regional inflation differential (which over the sample period equals 1.50%) on the regional growth differential, the real exchange rate, the real interest rate differential and the differential in real housing wealth growth. Box 1 lists the relationships. We have started from a position where no variable deviated from the national average. We also assume the absence of any energy

[13] The adjusted R^2 climbed from 0.31 to 0.64 after the inclusion of the energy price variables.

[14] Substituting a regional measure of the output gap, measured using the Hodrick-Prescott filter, did not lead to a change in sign.

[15] Part of the supply shocks work through oil prices which are included in equation (2a).

price shocks. Through equation (2a) the inflation shock has an autoregressive effect. Figure 3 shows that the inflation shock has a permanent effect on the real exchange rate and a temporary effect on the real interest rate, the growth in real housing wealth and real GSP growth. Note that the real interest rate effect decreases much more quickly than the housing wealth effect, which results from the mutual reinforcement between of real economic growth and housing wealth growth. In year four, the real regional growth rate changes sign. From then on the pro-cyclical variables (lagged real growth, the real interest rate channel and the wealth channel) no longer outweigh the counter-cyclical real exchange rate channel. The long-run effect of the regional inflation shock to real regional economic growth is zero. Figure 4, however, shows that there is a permanent effect on the level of output ($y_{i\text{-}US,t}$), corresponding to the permanent effect on the real exchange rate. Figure 4 also shows how the explanatory variables in equation (1a) contribute to this. In constructing Figure 4, we have attributed the effect of the lagged endogenous variable to the real interest rate, the real exchange rate and the real housing wealth growth variables, using the coefficients in equation (1a). In the first year, the direct positive effect of a lower regional real interest rate dominates the negative effect on the real exchange rate. The real interest rate effect continues to play a role through the lagged endogenous variable. However, whereas the interest rate effect starts to dampen relatively quickly, the cumulative effect of the real exchange rate appreciation is lasting. From year three onwards, the effects of lagged real housing price growth kicks in. Note that this partial analysis abstracts from any stabilizing effects of national monetary policy through the nominal interest rate or indirectly through economic growth in the rest of the US.

It is tempting to relate these findings to what has happened in European countries during their brief stay in the EMU. In The Netherlands, for example, above-average inflation rates (due to, among others, a fiscal policy shock) resulted in low real interest rates and contributed to the boom in the housing market. Right now, the impact of the cumulative worsening in the Dutch competitive position is being felt. This experience seems to fit our findings very well. In summary, while regional inflation shocks may lead to short-term exuberance, they may result in a long-term headache.

In the current economic climate, monetary authorities probably worry more about deflationary tendencies than about inflation shocks. In principle, the symmetrical set up of our model makes it straightforward to infer the consequences of a regional deflationary shock. Higher regional real interest rates will discourage consumption and investment, stimulate savings and slow down local housing markets. Over time, the improvement in the competitive position versus the rest of the monetary union should lead to convergence. We recognize, however, that the presence of nominal debt and downward nominal wage rigidity may complicate matters. The worsening of the balance sheets of households, firms and financial institutions as a result of a debt-deflation may increase bankruptcies and disrupt financial intermediation, while downward wage rigidity might aggravate the output response.

We have tested for asymmetrical effects of the real interest rate variable in equations (1a) and (3a) and of the real exchange rate variable in equation (1a). The results in Table 4 show that the output equation displays no statistically significant asymmetric effects. In equation (3a), however, real housing wealth growth does show an interesting significant asymmetrical effect. The effect of a lower real interest rate due to positive regional inflation is low and insignificant compared to the strong and significant response of real housing wealth growth to a higher real interest rate due to deflation. So deflation may jeopardize the stability of regional housing markets. To avoid these potential asymmetrical effects, the central bank of the monetary union would be wise to target a union-wide inflation rate high enough to facilitate regional adjustment at below-average but positive inflation rates.

5. Conclusions

Within a monetary union, regional inflation differentials lead to a competition between the real interest channel and the real exchange rate channel in the transmission of regional shocks. This has implications for the length and vehemence of regional business cycles. This paper tries to quantify how these forces work against each other in the United States. Our estimates indicate that, following an increase in regional inflation, in the short run the pro-cyclical effect through the real interest rate and wealth channels is strongest, but that after a period of about 3-4 years the cumulative worsening of the competitive position asserts its influence. Regional cycles in the housing market have a clear pro-cyclical effect and are, on their part, affected by real regional interest rates and real growth.

We close by cautioning against the extrapolation of our findings to Europe. Nevertheless, we expect that the time it will take the real exchange rate channel to dominate the real interest rate and wealth channels will be even longer in Europe, as the US economy is more flexible and better integrated than the European economy and segmentation in regional housing markets is stronger in Europe than in the United States. We conclude that in a monetary union, the real exchange rate has a hard time competing with the real interest rate and wealth channels; as a result, the length and amplitude of regional business cycles may increase. As effective policy instruments at the regional level are scarce in a monetary union, this observation points to the need for improving the functioning and integration of product, labor, financial and housing markets in Europe.

References

Alberola E. (2000), Interpreting inflation differentials in the euro area, Economic Bulletin, Banco de Espana, April.

Alberola E. and J.M. Marqués (1999), On the relevance and nature of regional inflation differentials: the case of, Working paper, Banco de Espana, no. 9913.

Baffoe-Bonnie, J. (1998), The Dynamic Impact of Macroeconomic Aggregates on Housing Prices and Stock of Houses: A National and Regional Analysis, The Journal of Real Estate Finance and Economics, vol. 17, no. 2, 179-197.

Ball, L., (1998), Policy Rules for Open Economies, NBER Working Paper No. 6760.

Berk, J.M. and J. Swank, (2002), Regional price adjustment in a monetary union, the case of EMU, MEB series De Nederlandsche Bank, no. 7.

Case, K.E., J.M. Quigley and R.J. Shiller (2001), Comparing wealth effects: the stock market versus the housing market, UC Berkeley working paper, no. E01-308.

Cecchetti, S.G., H. Genberg, J. Lipsky and S. Wadhwani (2000), Asset prices and central bank policy, CEPR/ICMB Geneva Reports on the World Economy 2.

Cecchetti, S.C., N.C. Mark and R. Sonora (2000), Price level convergence among United States cities: lessons for the European Central Bank, NBER working paper, no. 7681.

Clarida, R., Gali, J. and M. Gertler (1999), The Science of Monetary Policy: A New Keynesian Perspective, Journal of Economic Literature, Volume 37, p. 1661-1707.

Duarte, M. And A.L. Wolman (2002), Regional inflation in a currency union: fiscal policy versus fundamentals, ECB working paper, no. 180.

European Central Bank (2000), Asset prices and price stability, April, ECB Frankfurt.

European Central Bank (2003), Inflation differentials in the euro area: potential causes and policy implications, September, ECB Frankfurt.

Goodhart, C. and B. Hofmann (2000), Asset prices and the conduct of monetary policy, paper presented at the Swedish Riksbank Conference on Monetary Policy.

Hartley, P.R. and J.A. Whitt (2003), Macroeconomic fluctuations: Demand or supply, permanent or temporary?, European Economic Review, Volume 47, Issue 1, (February) p. 61-94.

Im, K. S., Pesaran, M. H., and Shin, Y. (1997), Testing for Unit Roots in Heterogenous Panels, University of Cambridge, revised version of the DAE Working Paper No 9526.

International Monetary Fund (2000), World Economic Outlook, June, IMF, Washington.

International Monetary Fund (2003), World Economic Outlook, April, IMF, Washington.

Ludwig, A. and T. Sloek (2002), The impact of changes in stock prices and house prices on consumption in OECD Countries, IMF Working Paper WP/02/1.

Kenny, G. (1999), Modelling the demand and supply sides of the housing market: evidence from Ireland, Economic Modelling, 16, 389-409.

Kwiatkowski D., P. C. B. Phillips, P. Schmidt and Y. Shin, (1992), Testing the Null hypothesis of Stationarity against the Alternative of a Unit Root, Journal of Econometrics, 54, 159-178.

Rogers, J.H. (2001), Price level convergence, relative prices and inflation in Europe, International Finance Discussion Paper, Board of Governors of the Federal Reserve System, no. 699.

Smets, F., (1997), Financial Asset Prices and Monetary Policy: Theory and Evidence, CEPR Discussion Paper No. 1751

Svensson, L., (1997), Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets, European Economic Review, 41, p. 1111-1146.

Walters, A, A. (1990), Sterling in Danger: The Economic Consequences of Pegged Exchange Rates, London, Fontana/Collins/Institute of Economic Affairs.

Table 1: Recent inflation divergence in the EMU

annual inflation rates (%)	1997	1998	1999	2000	2001	2002
Austria	1.2	0.8	0.5	2	2.3	1.7
Belgium	1.5	0.9	1.1	2.7	2.4	1.6
Finland	1.2	1.4	1.3	3	2.7	2.0
France	1.3	0.7	0.6	1.8	1.8	1.9
Germany	1.5	0.6	0.6	2.1	2.4	1.3
Greece	5.4	4.5	2.1	2.9	3.7	3.9
Ireland	1.2	2.1	2.5	5.3	4	4.7
Italy	1.9	2	1.7	2.6	2.3	2.6
Luxembourg	1.4	1	1	3.8	2.4	2.1
Netherlands	1.9	1.8	2	2.3	5.1	3.9
Portugal	1.9	2.2	2.2	2.8	4.4	3.7
Spain	1.9	1.8	2.2	3.5	3.2	3.6
Euroarea	1.6	1.1	1.1	2.3	2.5	2.3
Average of lowest 3	1.2	0.7	0.6	2.0	2.1	1.5
# countries with inflation higher than 1.5 points above average of lowest 3	1	1	4	3	4	5

Source: Eurostat, HCIP inflation.

Table 2: Regional divergences in real GSP

Equation:	(1a) $y_{i\text{-}US,t+1}$		(1b) $\Delta y_{i\text{-}US,t+1}$
$y_{i\text{-}US,t}$	0.917*	$\Delta y_{i\text{-}US,t}$	0.347*
	(85.58)		(11.73)
$\Delta h_{i\text{-}US,t}$	0.158*	$\Delta^2 h_{i\text{-}US,t}$	0.090*
	(11.01)		(5.92)
$r_{i\text{-}US,t}$	-0.486*	$\Delta r_{i\text{-}US,t}$	-0.267*
	(7.26)		(3.18)
$q_{i\text{-}US,t}$	-0.063*	$\pi_{i\text{-}US,t}$	0.167
	(2.52)		(1.77)
AR(1)	0.219		
	(6.23)		
Weighted statistics:			
adj. R^2	0.999		0.327
p-value F-statistic	0.000		0.000
DW statistic	1.99		2.14
# observations	1122		1071
IPS t-bar	-3.14*		

Note: Annual data: 1977-2000. GLS panel estimation with cross section weights, fixed effects and White heteroscedasticity-consistent standard errors; t-values in parentheses; IPS t-bar is the Im, Pesaran and Shin test statistic for a unit root in the residuals. Fixed effects are not reported.

* significant at a 5% significance level.

Table 3: Regional divergences in inflation and real housing wealth growth

Equation:	(2a) $\pi_{i-US,t+1}$		(3a) $\Delta h_{i-US,t+1}$
$\pi_{i-US,t}$	0.287^*	$\Delta h_{i-US,t}$	0.530^*
	(7.72)		(20.22)
$\Delta H_{i-US,t}$	0.015^*	$\Delta y_{i-US,t}$	0.442^*
	(5.75)		(10.31)
$\Delta y_{i-US,t}$	-0.030^*	$r_{i-US,t}$	-0.373^*
	(4.15)		(3.53)
$\Delta p_{oil,t+1}$	included†		
$\Delta p_{oil,t}$	included†		
Weighted statistics:			
adj. R^2	0.644		0.479
p-value F-statistic	0.000		0.000
DW statistic	2.17		1.929
# observations	1122		1122

Note: Annual data: 1977-2000. GLS panel estimation with cross section weights, fixed effects and White heteroscedasticity-consistent standard errors; t-values in parentheses. Fixed effects are not reported.

* significant at a 5% significance level.

†Cross-section specific coefficients and t-values are not reported.

Table 4: Asymmetric effects

Equation:	(1a) $y_{i\text{-}US,t+1}$		(3a) $\Delta h_{i\text{-}US,t+1}$
coefficient $r_{i\text{-}US,t}$		coefficient $r_{i\text{-}US,t}$	
with positive inflation shock	-0.568*	with positive inflation shock	-0.086
	(4.87)		(0.51)
with negative inflation shock	-0.400*	with negative inflation shock	-0.667*
	(3.68)		(4.30)
Wald test (p-value)	0.35	*Wald test (p-value)*	0.023*
coefficient $q_{i\text{-}US,t}$			
with positive inflation shock	-0.051*		
	(1.62)		
with negative inflation shock	-0.076*		
	(2.64)		
Wald test (p-value)	0.44		

Note: This table reports possible asymmetric effects of the real interest rate and the real exchange rate in equations (1a) and (3a). The p-value of the Wald statistic indicates whether the difference between the coefficients under positive or negative inflation shocks is statistically significant.

* significant at a 5% significance level.

Box 1: Model used for simulation

$$y_{i-US,t+1} = 0.917\ y_{i-US,t} - 0.486\ r_{i-US,t} - 0.063\, q_{i-US,t} + 0.158\ \Delta h_{i-US,t}$$
$$\pi_{i-US,t+1} = 0.287\ \pi_{i-US,t} - 0.030\ \Delta y_{i-US,t} + 0.015\ \Delta H_{i-US,t}$$
$$\Delta h_{i-US,t+1} = 0.530\ \Delta h_{i-US,t} + 0.442\ \Delta y_{i-US,t} - 0.373\, r_{i-US,t}$$
$$q_{i-US,t+1} = q_{i-US,t} + \pi_{i-US,t+1}$$
$$r_{i-US,t+1} = -\pi_{i-US,t+1}$$
$$\Delta H_{i-US,t+1} = \Delta h_{i-US,t+1} + \pi_{i-US,t+1}$$

Figure 1: Inflation rates across US States

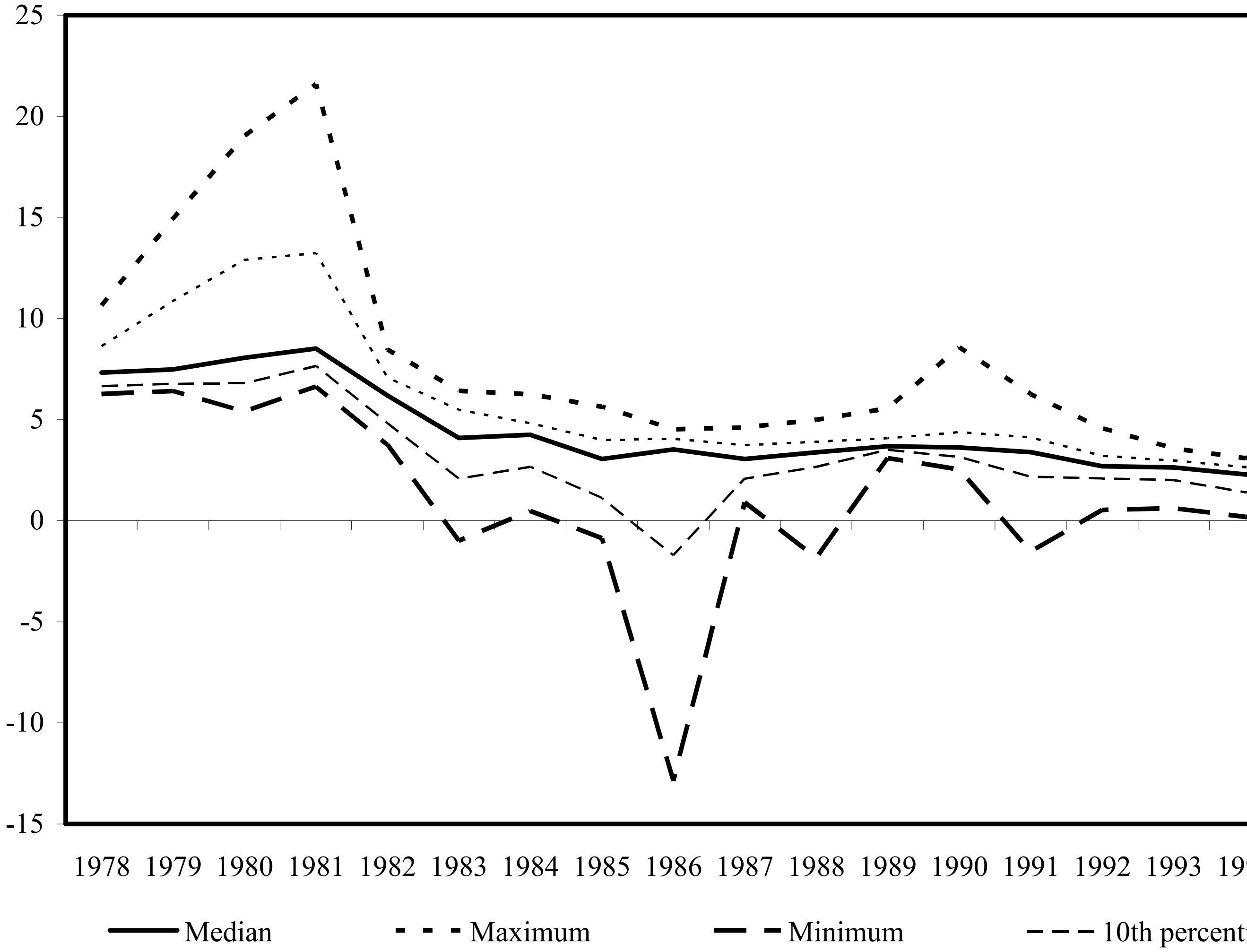

Figure 2: Real housing wealth growth rates across US Sta

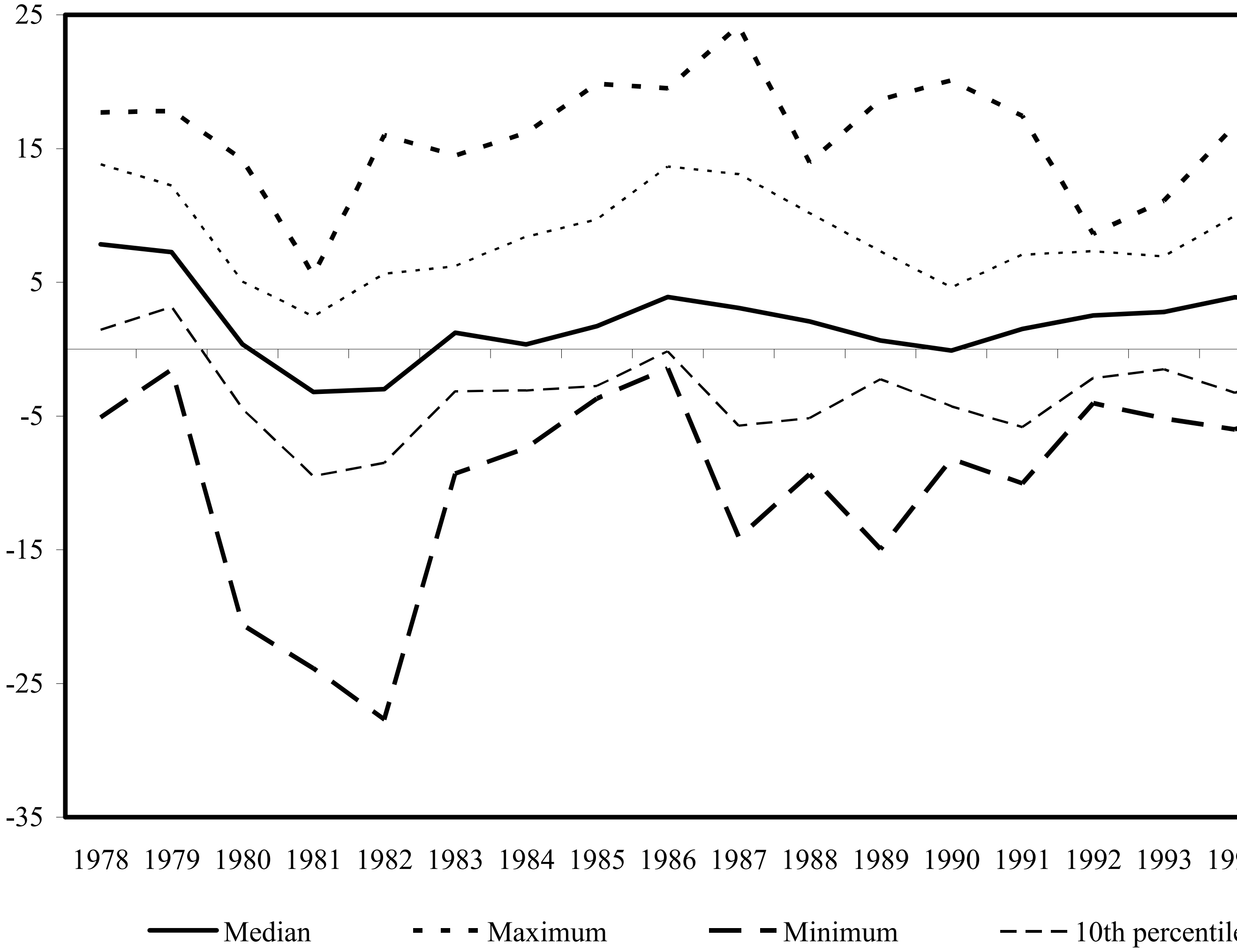

Figure 3: Effect of a one standard deviation shock to the inflation diff

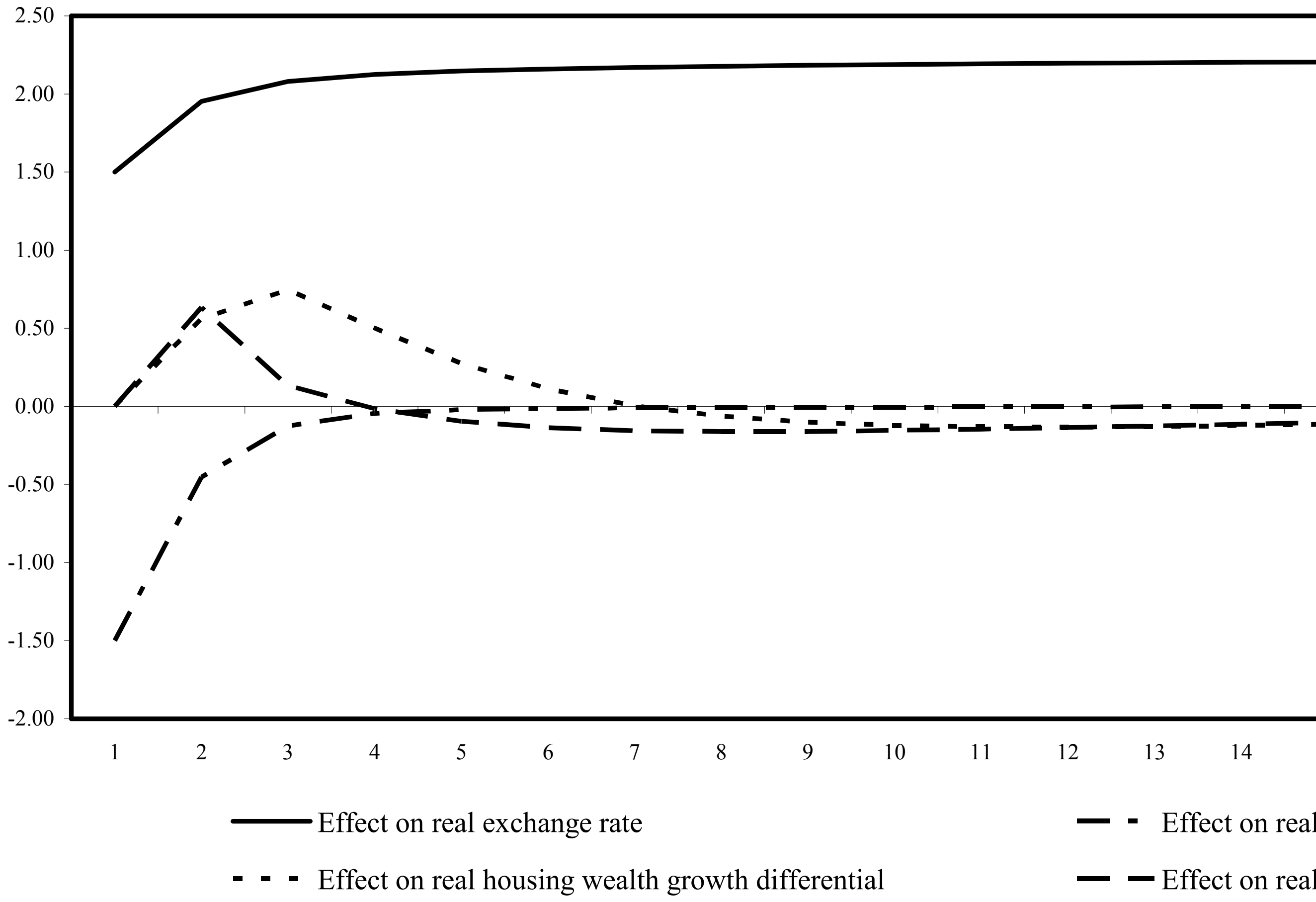

Figure 4: Decomposition of the effect of a one standard deviation shock to the inflat output differential