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Inflation gifts restrictions for structural VARs: evidence from the US

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Abstract

We investigate the link between inflation, growth and unemployment nesting a model of fair wages into one of endogenous growth of learning-by-doing. Firms protect real wages against inflation in exchange of worker's effort. In the long-run, unemployment decreases with higher inflation and real growth rates, though less so as inflation and growth increase. We then derive long-run restrictions for structural VARs for US data and we investigate the short-run behavior of inflation, real growth and unemployment. Structural shocks to inflation reduce unemployment and increase growth; to growth reduce unemployment and leave inflation unaffected; to unemployment produce a stagflation.

Keywords: efficiency wages, money growth, long-run Phillips curve, SVARs

JEL classification codes: E3, E2, E4

1 Introduction

Bewley (1999, 160-161, 164-165, 208-209) documents that firms are concerned by the effects of inflation on the purchasing power of wages. Though they do not tend to favour wage indexation, they will be often ready to defend workers' standard of living against inflation if they perform well. This exchange of gifts - namely effort vis à vis a shield against inflation for wages' purchasing power - is what we term *inflation gifts*[2].

Vaona (2010, 2012) formalized this concept resorting to a fair wages model similar to the one by Danthine and Kurmann (2004). The effects of inflation on output and unemployment are investigated in a number of different varieties of this model and it is showed that in this context both a short and a long-run Phillips curve can emerge even under flexible prices and nominal wages.

The aim of this paper is to recast this model in a framework with endogenous growth arising from learning-by-doing. In this way, it is possible to derive long-run restrictions to estimate structural VARs (SVARs) on US data and investigate the short run behavior of the unemployment rate, the real growth rate and the inflation rate under theoretically identified shocks.

Our research question is interesting for many different reasons.

One of the most long-standing debates in economics is whether inflation can have real economic effects both in the short and in the long-run. The po-

[2] Also Akerlof (2007) argues that similar social norms exist with regard to wage setting.

litical relevance of the existence of a non-vertical Phillips curve hardly needs to be mentioned. Since Phillips (1958) modern macroeconomics was animated by debates on this issue. Authoritative surveys are already available in the literature (Karanassou et al., 2010; Gordon, 2011).

A recent growing body of literature questioned the existence of a vertical long-run Phillips curve. On the theoretical side Hughes-Hallet (2000) showed that a long-run connection between inflation and unemployment can be the result of the aggregation of regional/sectoral Phillips curves. Colombo and Weinrich (2003) define the Phillips curve as a negative relationship between wage inflation and unemployment and they highlight that this link arises in a chaotic system where quantities adjust faster than prices and agents are rationed. According to Holden (2003) and Di Bartolomeo et al. (2012), instead, this can be the result of the strategic interaction between large wage-setters.

Karanassou et al. (2005, 2008a, b, 2010) developed a "frictional growth" approach (otherwise known as "chain reaction theory") to the labour market and contrasted it with other approaches in Karanassou et al. (2007). Both theoretical and empirical results were offered, the latter ones for a number of different countries. All of them point to the existence of a long-run inflation-unemployment trade-off, which emerges due to the interaction between money growth and nominal frictions.

Graham and Snower (2004, 2008), Levin and Yun (2007) and Ahrens and Snower (2014) derived their results within New Keynesian (NK) frameworks. The first two papers uncovered the mechanics of long-run inflation non-superneutrality within standard NK models. This depends on three effects, exemplified in the presence of both Taylor wage staggering and a monopolistically competitive labour market. These channels are employment cycling, labour supply smoothing and time discounting. The first implies that, period after period, firms shifts labour demand from one cohort to the other in search for the lower real wage. Different labour kinds are not perfect substitutes and so inefficiencies arise, tending to create a negative inflation-output nexus. Under labour supply smoothing, households react to employment cycling by demanding a higher wage, as they would prefer smoother working time. This decreases labor supply and aggregate output. Finally, due to time discounting, the contract wage depends more on the current (lower) level of prices than on the future (higher) level of prices. Therefore, the greater the inflation rate, the lower the real wage over the contract period. This spurs labour demand and aggregate output. The time discounting effect dominates at lower inflation rates, while the other two effects do so at higher inflation rates. As a result, a hump-shaped long-run Phillips curve arises, which is magnified by hyperbolic discounting as highlighted by Graham and Snower (2008).

Levin and Yun (2007) showed that the natural rate hypothesis should be reconsidered once assuming endogenous price contract duration. Under this hypothesis, the long-run effects of inflation on output can be sizeable, though vanishing at high inflation rates. Ahrens and Snower (2014) introduced psychological considerations within a standard NK model with Calvo wage staggering. Wage dispersion generates envy in workers with lower income and guilt in those with higher income. According to the available empirical evidence, the former effect dominates producing an increase in output and employment in response to higher inflation at low inflation levels.

This literature aims at questioning the customary assumption to identify aggregate demand and supply shocks, namely that the former are temporary while the latter are not. As a consequence, also the concept of the NAIRU would be unsuitable for fruitful investigation of the dynamics of the unemployment rate, as also remarked by Schreiber and Wolters (2007) and Koustas (1988) from an empirical point of view. One further empirical contribution is Gallegati et al. (2011), where wavelets are used to decompose US time series according to different frequencies. It is then found that the Phillips curve - defined as a negative link between wage inflation and unemployment - can be better estimated at longer time scales compared to shorter ones. Estimates are stable from 1948 ro 1993, but not thereafter.

Our approach considers a different structure of the labour market, namely an efficiency wages one. Therefore we depart from sticky wages/prices models of the inflation-output trade-off set out, for instance, in King and Wolman (1996) among others[3]. Hence we take part to the recent renaissance of efficiency wages models in the explanation of macroeconomic trends, which

[3] A similar research strategy was pursued also by Annicchiarico et al. (2011), where the link between monetary volatility and growth was investigated.

involved both fairness and shirking theories (Danthine and Kurmann, 2004, 2008, 2010; Alexopoulos, 2004, 2006, 2007).

Our aim here is not to prove or disprove the fact that inflation has long-run real effects. Instead, we want to investigate the behavior of our macroeconomic variables of interest in the short-run, once assuming that inflation can have a long-run nexus with unemployment, consistently with our theoretical model. In other terms, we want to answer the following question: assume the existence of a long-run inflation-unemployment trade-off and that the central bank has full control of the inflation rate, what happens when the central bank temporarily lets inflation to increase? We show, therefore, a way to identify short-term shocks even in presence of long-run non-superneutralities.

The rest of this paper is structured as follows. A model nesting inflation gifts into an endogenous growth theory through learning-by-doing is set out, starting from the households' problem and the government budget constraint and moving to the firm side of the economy before giving the long-run solution. In our model, knowledge spillovers are assumed to depend on capital per worker[4]. Therefore our work is tangential also to the literature on inflation and growth, reviewed for instance in Temple (2005) and Gillman and Kejak (2005). Under this respect, our model confirms previous results obtained by

[4] Vaona (2013) shows that our results do not change much once assuming that learning-by doing depends on the aggregate capital stock instead. Impulse response functions based on calibrated parameters are also showed there. We prefer here to derive long-run restrictions to estimate SVARs because the proposed model has only one friction arising from efficiency wages. In fact, there might exist many more frictions and under these circumstances Canova (2007, 104, 131) supports the research strategy we follow.

part of the literature that inflation has negligible effects on real growth in monetary endogenous growth models (Gillman and Kejak, 2005, 115-116). Our work is also tangential to the stream of literature on unemployment and growth. Also under this respect, our model confirms widely shared beliefs that higher real growth decreases the unemployment rate (Aghion and Howitt, 1998).

Next we exploit long-run restrictions derived from our model to estimate a number of SVARs on US unemployment, real growth and inflation rates and we carry out a number of robustness checks. Under this respect, our work can be considered as an extension of seminal contributions in the field of SVAR, such as Blanchard and Quah (1989) and Cecchetti and Rich (2001), which considered unemployment and growth and inflation and growth respectively and which assumed long-run superneutrality. In our model, inflation is superneutral in the long-run with respect to growth, but not with respect to the unemployment rate. Therefore, our empirical model differs from those inspiring the literature on the effects of monetary policy not only in terms of specification, but also in terms of identification strategy as we abandon the inflation superneutrality hypothesis. Regarding the empirical model specification, our work can in fact be regarded as a synthesis between Blanchard and Quah (1989) and Cecchetti and Rich (2001). In an Appendix, available from the author upon request, we give more details on the derivation of equation (14) below, on obtaining the detrended households' maximization problem and on some further empirical robustness checks.

2 Inflation gifts in an endogenous growth model of learning-by-doing

2.1 The problem of the household and the budget constraint of the government

In our model, a continuum of households populates the economy. Within each household there exists a continuum of individuals. Both the numbers of households and individuals are normalized to 1. We share these assumptions with the models presented in Danthine and Kurmann (2004, 2008, 2010). Furthermore, similarly to the trend inflation literature and to a considerable number of other studies in the NK tradition, we resort to a money-in-the utility function setup (Ascari, 2004; Graham and Snower, 2004, 2008; Walsh, 2010, chp. 2), also because this kind of models was showed to be functionally equivalent to liquidity costs ones (Feenstra, 1986).

The households' maximization problem is

$$\max_{\{C_{t+j}(h), M_{t+j}(h), e_{t+j}(h), K_{t+j}(h)\}} \sum_{j=0}^{\infty} \beta^{t+j} E\left(U\left\{C_{t+j}(h), N_{t+j}(h)\, G\left[e_{t+j}(h)\right], V\left[\frac{M_{t+j}(h)}{P_{t+j}}\right]\right\}\right) \tag{1}$$

subject to a series of income constraints

$$C_{t+j}(h) + K_{t+j}(h) = \frac{W_{t+j}(h)}{P_{t+j}} N_{t+j}(h) + \frac{T_{t+j}(h)}{P_{t+j}} - \frac{M_{t+j}(h)}{P_{t+j}} + \frac{M_{t+j-1}(h)}{P_{t+j}} + \\ + \frac{R_{t+j}}{P_{t+j}} K_{t+j-1}(h) + (1-\delta) K_{t+j-1}(h) + Q_{t+j}(h) \quad (2)$$

where β is the discount factor, E is the expectation operator, U is the utility function, $C_{t+j}(h)$ is consumption by household h at time $t+j$, $N_{t+j}(h)$ is the fraction of employed individuals within the household, $G[e_{t+j}(h)]$ is the disutility of effort - $e_{t+j}(h)$ - of the typical working family member, $V\left[\frac{M_{t+j}(h)}{P_{t+j}}\right]$ is the utility arising from nominal money balances - $M_{t+j}(h)$ - over the price level - P_{t+j}. $W_{t+j}(h)$ and $T_{t+j}(h)$ are the household's nominal wage income and government transfers respectively. Finally, $K_{t+j}(h)$ is the capital held by household h, δ is the capital depreciation rate, R_{t+j} is the capital rental rate, and $Q_{t+j}(h)$ are profits accruing to households from firms.

As it appears from the problem above, in our framework all decisions pertain to households and not to individuals. Similar assumptions were taken not only in Danthine and Kurmann (2004, 2008, 2010), but also in Merz (1995), Blanchard and Galì (2010) and Alexopoulos (2004) among others. Furthermore, though individuals are identical ex-ante, they are not so ex-post, being some of them employed and some other unemployed. Households are instead all symmetric both ex-ante and ex-post, because the fraction of employed people is the same across all households. Matching between firms and households is assumed to be random and costless. Finally, leisure does not provide any utility to agents, so their labour supply is inelastic and it is normalized to one unit of time. Also unemployment related activities do not provide any utility to agents.

On the footsteps of Akerlof (1982), in our model workers would not prefer to exert effort. However, they are ready to do so in exchange for some gift, as a real wage above some reference level. Building on Danthine and Kurmann (2004), Vaona (2012) specified the disutility of effort as

$$G\left[e_{t+j}(h)\right] = \left\{ e_{t+j}(h) - \left[\begin{array}{c} \phi_0 + \phi_1 \log \frac{W_{t+j}(h)}{P_{t+j}} + \\ + \phi_2 \log u_{t+j}(h) + \phi_3 \log \frac{W_{t+j}}{P_{t+j}} + \phi_4 \log \frac{W_{t+j-1}}{P_{t+j}} \end{array} \right] \right\}^2 \quad (3)$$

where $u_{t+j}(h) = 1 - N_{t+j}(h)$ and W_{t+j} is the aggregate nominal wage. The novelty of this specification consists in the fact that in the last term, the nominal wage at time $t+j-1$ is assessed at the prices of time $t+j$. This modelling device allows to formalize *inflation gifts*. More in detail, inflation can challenge households' living standards. Therefore, they perceive firms' pay policies preserving their purchasing power as a gift and they are ready to exert effort in exchange. In other terms, the reference wage falls with a higher inflation rate.

As customary in the relevant literature, $\phi_1, \phi_2 > 0$ and $\phi_3, \phi_4 < 0$. This means that households exert greater effort when they receive a higher real wage and when the unemployment rate is higher. On the contrary, a higher reference wage, captured by the level of the aggregate real wage and the real value of the past aggregate nominal wage, reduces effort. In (3) the reference wage only depends on aggregate variables, as in the social norm case. We do not explore the possibility that it may depend on households' variables here. This is because Vaona (2010) showed that the personal norm case can produce implausible results in presence of trend inflation.

We detrend nominal variables for nominal growth (π) and real variables for real growth (γ). The resulting maximization problem is

$$\max_{\{c_{t+j}(h),m_{t+j}(h),e_{t+j}(h),k_{t+j}(h)\}} \sum_{j=0}^{\infty} \beta^{t+j} E\left(U\left\{c_{t+j}(h), N_{t+j}(h)\, G\left[e_{t+j}(h)\right], V\left[\frac{m_{t+j}(h)}{p_{t+j}}\right]\right\}\right) \tag{4}$$

subject to a series of constraints

$$\begin{aligned} c_{t+j}(h) + k_{t+j}(h) &= \frac{w_{t+j}(h)}{p_{t+j}} N_{t+j}(h) + \frac{t_{t+j}(h)}{p_{t+j}} - \frac{m_{t+j}(h)}{p_{t+j}} + \frac{m_{t+j-1}(h)}{p_{t+j}} \frac{1}{\pi\gamma} + \\ &\quad + \frac{(1-\delta)}{\gamma} k_{t+j-1}(h) + \frac{r_{t+j}}{p_{t+j}} \frac{k_{t+j-1}(h)}{\gamma} + q_{t+j}(h) \qquad (5) \\ G\left[e_{t+j}(h)\right] &= \left\{ e_{t+j}(h) - \left[\begin{array}{c} \phi_0 + \phi_1 \log \frac{w_{t+j}(h)}{p_{t+j}} + \phi_2 \log u_{t+j}(h) + \\ + \phi_3 \log \frac{w_{t+j}}{p_{t+j}} + \phi_4 \log\left(\frac{w_{t+j-1}}{p_{t+j}} \frac{1}{\pi\gamma}\right) \end{array} \right] \right\}^2 \qquad (6) \end{aligned}$$

where lower case letters are the detrended counterparts of the upper case ones. Note that in order to avoid either the difference $e_{t+j}(h) - \left[\begin{array}{c} \phi_0 + \phi_1 \log \frac{w_{t+j}(h)}{p_{t+j}} + \\ + \phi_2 \log u_{t+j}(h) + \\ + \phi_3 \log \frac{w_{t+j}}{p_{t+j}} + \phi_4 \log\left(\frac{w_{t+j-1}}{p_{t+j}} \frac{1}{\pi\gamma}\right) \end{array} \right]$ or $e_{t+j}(h)$ to be trended, we have to assume that $\phi_1 + \phi_3 + \phi_4 = 0$. γ appears in equation (6) because the real wage grows with labor productivity to keep the labor share of income constant: see equation (20) below.

On the footsteps of Danthine and Kurmann (2004), we adopt the following specification for the utility function

$$U(\cdot) = \log c_{t+j}(h) - N_{t+j}(h)\, G\left[e_{t+j}(h)\right] + b \log\left[\frac{m_{t+j}(h)}{p_{t+j}}\right] \tag{7}$$

The first order conditions with respect to capital, effort, consumption, and money holdings imply

$$\frac{1}{c_{t+j}(h)} = E\left[\frac{r_{t+j}}{p_{t+j}}\frac{\beta}{\gamma}\frac{1}{c_{t+j+1}(h)} + \frac{1}{c_{t+j+1}(h)}\beta(1-\delta)\frac{1}{\gamma}\right] \tag{8}$$

$$e_{t+j}(h) = \left[\begin{array}{c} \phi_0 + \phi_1 \log \frac{w_{t+j}(h)}{p_{t+j}} + \phi_2 \log u_{t+j}(h) + \\ +\phi_3 \log \frac{w_{t+j}}{p_{t+j}} + \phi_4 \log\left(\frac{w_{t+j-1}}{p_{t+j}}\frac{1}{\pi\gamma}\right) \end{array}\right] \tag{9}$$

$$\left(\frac{\mu_{t+j}}{\tilde{\pi}_{t+j}}\right)^{-1} = \frac{c_{t+j-1}(h)}{c_{t+j}(h)}\left(1 - \frac{1}{i_{t+j}}\right) / \left(1 - \frac{1}{i_{t+j-1}}\right) \tag{10}$$

where μ is the money growth rate and $\tilde{\pi}_{t+j}$ is the off-trend portion of the inflation rate. Finally the government budget constraint is

$$\int_0^1 \frac{T_{t+j}(h)}{P_{t+j}} dh = \int_0^1 \frac{M_{t+j}(h)}{P_{t+j}} dh - \int_0^1 \frac{M_{t+j-1}(h)}{P_{t+j}} dh \tag{11}$$

In words, the government rebates its seignorage revenues to households by means of lump-sum transfers.

2.2 The firm side of the model

Similarly to many studies in the NK tradition, we assume the existence of an intermediate labour market and of a final product market. There is neither price nor wage stickiness both in the intermediate labour market and in the final one. An alternative, but equivalent model set up would be to use two-stage budgeting (Chambers, 1988, 112-113; Heijdra and Van der Ploeg, 2002, 360-363).

2.2.1 The intermediate labour market

In the intermediate labour market, households sell their labour force for their wage to labour intermediaries. The different labour kinds of each household are assumed to be imperfectly substitutes. They are assembled into an homogeneous labour input to be sold to firms on the final product market. The maximization problem of the representative labour intermediary is[5]

$$\max_{\{N_{t+j}(h), W_{t+j}(h)\}} W_{t+j}N_{t+j} - \int_0^1 W_{t+j}(h)N_{t+j}(h)dh \quad (12)$$

$$s.t.\ N_{t+j} = \left[\int_0^1 e_{t+j}(h)^{\frac{\theta_n - 1}{\theta_n}} N_{t+j}(h)^{\frac{\theta_n - 1}{\theta_n}} dh\right]^{\frac{\theta_n}{\theta_n - 1}} \quad (13)$$

[5] Adopting a CES aggregator in this problem allows the existence of decreasing marginal returns to each household's employment and constant returns to scale to all household's employment - two widespread assumptions in macroeconomic modelling. We, therefore, rule out the existence of either positive or negative externalities from one labour kind to the other when all of them increase. Constant returns to scale imply, under symmetry, $Q_{t+j} = 0$, notwithstanding the presence of efficiency wages.

We drop the index of labour intermediaries to simplify notation. Given that the number of labour intermediaries is normalized to one and given that they are all symmetric, W_{t+j} and $N_{t+j} \in [0,1]$ can be directly considered the aggregate wage and employment (rate), respectively. θ_n is the elasticity of substitution between different labour kinds.

Taking the ratio of the first order conditions with respect to $N_{t+j}(h)$ and $W_{t+j}(h)$ one has

$$e_{t+j}(h) = \phi_1 \tag{14}$$

Households' symmetry and (13) imply $\phi_1 = 1$ and $N_{t+j}(h) = N_{t+j}$

2.2.2 The final product market

In the final product market, perfectly competitive firms hire homogenous capital and labour inputs to produce an homogeneous output. Their maximization problem is

$$\max_{\{N_{t+j}(f),K_{t+j-1}(f)\}} P_{t+j}Y_{t+j}(f) - W_{t+j}N_{t+j}(f) - R_{t+j}K_{t+j}(f)$$

$$s.t.\ \ Y_{t+j}(f) = A_{t+j}\left[N_{t+j}(f)\frac{K_{t+j}}{N_{t+j}}\right]^{1-\alpha}[K_{t+j}(f)]^{\alpha} \tag{15}$$

where $Y_{t+j}(f)$ is output of the firm f at time $t+j$, $N_{t+j}(f)$ and $K_{t+j}(f)$ are labour and capital of firm f respectively. A_{t+j} is a productivity index and

α is a parameter. $\frac{K_{t+j}}{N_{t+j}}$ is aggregate capital per worker. In (15) we assume the existence of learning-by-doing effects. More specifically, we assume the existence of knowledge spillovers from one worker to the other, depending on the average availability of capital for each worker in the aggregate economy (Lucas, 1988; Barro and Sala-i-Martin, 1995, 152).

The first order conditions with respect to $N_{t+j}(f)$ and $K_{t+j}(f)$ imply

$$(1-\alpha)\frac{Y_{t+j}(f)}{\frac{W_{t+j}}{P_{t+j}}} = N_{t+j}(f) \quad (16)$$

$$\alpha\frac{Y_{t+j}(f)}{\frac{R_{t+j}}{P_{t+j}}} = K_{t+j}(f) \quad (17)$$

Under symmetry

$$Y_{t+j} = A_{t+j}K_{t+j} \quad (18)$$

therefore, after detrending,

$$\frac{r_{t+j}}{p_{t+j}} = \alpha A_{t+j} \quad (19)$$

$$\frac{w_{t+j}}{p_{t+j}}\frac{N_{t+j}}{y_{t+j}} = (1-\alpha) \quad (20)$$

Note that one could also write

$$\frac{w_{t+j}}{p_{t+j}} = \frac{\partial Y_{t+j}}{\partial N_{t+j}} = (1-\alpha)\,A_{t+j}\frac{k_{t+j}}{N_{t+j}} \quad (21)$$

2.3 The long-run solution

To obtain γ, consider (8). In steady state one has

$$\gamma = \beta \left(\frac{r}{p} + 1 - \delta \right) \tag{22}$$

where we drop time subscripts to denote steady state variables. Considering (19) one has

$$\gamma = \beta \left(\alpha A + 1 - \delta \right) \tag{23}$$

Combine (9) and (14) to obtain

$$\log u_{t+j}(h) = \frac{\phi_1 - \phi_0}{\phi_2} - \frac{\phi_1}{\phi_2} \log \frac{w_{t+j}(h)}{p_{t+j}} - \frac{\phi_3}{\phi_2} \log \frac{w_{t+j}}{p_{t+j}} - \frac{\phi_4}{\phi_2} \log \left(\frac{w_{t+j-1}}{p_{t+j}} \frac{1}{\pi\gamma} \right) \tag{24}$$

Under symmetry and in steady state, recalling that $\phi_1 + \phi_3 + \phi_4 = 0$, one has

$$\log u = \frac{\phi_0 - \phi_1}{\phi_2} + \frac{\phi_4}{\phi_2} \log \pi + \frac{\phi_4}{\phi_2} \log \left[\beta \left(\alpha A + 1 - \delta \right) \right] \tag{25}$$

Our model has therefore a number of implications regarding the relationship between long-run growth, unemployment and inflation. Long-run growth only depends on deep parameters and there exists a long-run link between inflation and unemployment. After Karanassou et al. (2005, 2008a, 2008b) one may calibrate $\frac{\phi_4}{\phi_2} \approx -0.29$. Note that (25) does not imply that hyperinflation reduces unemployment, given that $\lim_{\pi\to\infty} \frac{d\log u}{d\pi} = 0$. Finally a higher growth rate decreases the unemployment rate, though to a declining extent given that $\lim_{\gamma\to\infty} \frac{d\log u}{d\gamma} = 0$. We focus here on semi-elasticities instead of elasticities, because, for instance, it is economically more interesting to study the impact of either inflation or real growth passing from 1% to 2% rather than from 1% to 1.01%.[6]

3 SVARs for the US economy

3.1 Inflation gifts and long-run restrictions

As can be seen, the above model implies a number of long-run restrictions that can be exploited in estimating a SVAR on inflation, real growth and the log of the unemployment rate. We consider inflation as a monetary policy instrument as if it was under full control of the central bank. We summarize these restriction in the matrix form below.

$$\lim_{j\to\infty}\begin{pmatrix}\log\gamma_{t+j}\\ \log\pi_{t+j}\\ \log u_{t+j}\end{pmatrix} = \lim_{j\to\infty}\begin{pmatrix}\gamma'_{t+j}\\ \pi'_{t+j}\\ \log u_{t+j}\end{pmatrix} = \mathbf{C}\cdot\boldsymbol{\varepsilon} = \begin{bmatrix} . & 0 & 0\\ . & . & .\\ -0.29 & -0.29 & . \end{bmatrix}\begin{bmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\\ \varepsilon_{3t}\end{bmatrix} \tag{26}$$

[6] See, in a different context, Agénor and Montiel (2008, 98-99).

where bold letters denote either matrices or vectors and dots within **C** unrestricted parameters. ε_{1t} is the identified real growth shock, ε_{2t} is the identified inflation shock and ε_{3t} is the identified unemployment shock. Note that, consistently with our theoretical model, γ_{t+j} is one plus the growth rate of the economy, γ'_{t+j}.Therefore, (26) makes use of the approximation $\log \gamma_{t+j} = \log\left(1+\gamma'_{t+j}\right) \approx \gamma'_{t+j}$. The same applies to π_{t+j} and π'_{t+j}. The empirical importance of this approximation will become clear in the next paragraph.

The restrictions on the first row of **C** imply that inflation and unemployment do not have any long-run impact on real growth, consistently with equation (23). Building on (25) , the restrictions on the third row of **C** mean that growth and inflation have a negative long-run impact on unemployment. We start with the above mentioned calibration derived by Karanassou et al. (2005, 2008a, 2008b), but we will later explore how our baseline results are affected by assuming negative values different to -0.29, in the spirit of a sign restriction identification strategy (Fry and Pagan, 2011).

When we impose the above restrictions we do not to mean that there exists a one to one correspondence between equations (23) and (25), on one side, and the equations tracing the elements of **C** to the coefficients of the underlying non-structural VAR, on the other side - as the elements of **C** are, of course, products of the sums of the coefficients of the underlying non-structural VAR (Enders, 2004, 335). We, instead, intend to mean that the structural VAR and the model presented in the above sections should have the same long-run implications. In a similar way, the model presented in Blanchard and Quah (1989, 658) inspired the restrictions they applied without providing exact equations to implement them.

3.2 The data

We used OECD data. For the real growth rate, we relied on the Quarterly National Accounts. Inflation in CPI was obtained by the Main Economic Indicators, while the (seasonally adjusted) unemployment rate was computed on the basis of total employed and unemployed persons aged 15 or more as published by the Short-Term Labour Market Statistics Dataset. We considered both quarter-on-quarter growth rates and year-on-year ones (still at a quarterly frequency, though). All these data are available from the website http://stats.oecd.org. To compute growth rates we resort to first differences of the logs of the relevant variables.

We ran baseline estimates for the period 1979Q2 to 2010Q4 - namely from approximately the onset of the Volcker era onwards - using quarter-on-quarter growth rates. However, for robustness sake, we extended our model back to 1956Q1. Alternatively, we dropped observations after 2008Q2 to check that our results were not driven by the extraordinary time period of the post-2008 Great Depression. What is more, we redefined our variables on the basis of year-on-year growth rates to assess whether volatility affects our results. Finally we played with the restriction of the long-run impacts of inflation and growth on unemployment trying values ranging from 0 to -0.6.

The series for our baseline estimates are set out in Figure 1.

Enders (2004, 332) presents the Blanchard and Quah (1989) approach as a way to decompose transitory and permanent effects of shocks on output, which is an I(1) variable and has to be first differenced. In this view, thanks to approximation in the above section, our empirical model can here be considered to include first differences in logs of non-stationary variables, real GDP and CPI in levels, and one stationary variable, the log of the unemployment rate. This is confirmed by well known unit root and stationarity tests run on our full sample. We prefer using the complete sample not to incur in finite sample biases which often plague the results of unit root and stationarity tests. Table 1 sets out the results of these tests for real GDP, the CPI index, the real growth rate, the inflation rate and the log of the unemployment rate. Where applicable, the number of lags was chosen thanks to the Schwarz Bayesian information criterion. The fact that inflation is, according to our tests, stationary does not hamper our analysis. Fisher and Seater (1993) argue, among others, that, *in absence of a theoretical model*, tests regarding inflation long-run non-superneutrality can be offered only when inflation is subject to permanent shocks, namely it is non-stationary. However, it might well be that, first, inflation is non-superneutral in the long-run but the central bank never exploited this property and, second, that this long-run non-supeneutrality, identified by a theoretical model, affects the short-run properties of real variables. This is precisely our research question, because, stated differenty, what we cannot observe might well affect the behavior of what we observe.[7]

Table 1 - Unit root and stationarity tests

	ADF tests		**PP tests**		**KPSS**
Variable	**N. of lags**	**p-value**	**N. of lags**	**p-value**	**LM statistics**
Real GDP index	2	0.99	2	0.97	1.880575
CPI index	7	0.99	7	0.75	1.906194
γ	1	0.00	1	0.00	0.248689
π	2	0.03	2	0.00	0.331185
$\ln u$	1	0.01	1	0.01	0.226033

Notes: the base year of the CPI index is 2010, while that for the real GDP index is 2010Q4. The ADF, PP and KPSS acronyms respectively stay for the Augmented Dickey-Fuller and the Phillips and Perron unit root tests and for the stationarity test by Kwiatkowski et al. (1992). The 1%, 5% and 10% asymptotic critical values for the last test are 0.739, 0.463, and 0.347 respectively. For the KPSS test we adopted a Newey-West automatic bandwidth selection using Bartlett's kernel. Phillips-Perron tests were carried out adopting an AR-OLS spectral estimation method. The deterministic portion of the models underlying all the test in Table 1 is composed by a constant only, consistently with the specification of SVARs below, that do not include time trends as well.

[7]For instance the non-accelerting inflation rate of unemployment is very difficult to pin down, yet many of its supporters are convinced by its importance to explain inflation dynamics.

3.3 Baseline results

In our baseline results, the majority of customary lag-length criteria, namely a likelihood ratio test, the final prediction error and the Akaike's information criterion pointed to a third order VAR, while the Schwarz Bayesian and the Hannan and Quinn information criteria would point to a second order VAR. We stick with the majority of the tests.

The stability of the VAR was confirmed by the fact that its eigenvalues all lay within the unit circle, being the modulus of the greatest equal to 0.83 and the smallest to 0.2. Therefore, our VAR admitted the Wold decomposition and the computation of impulse-response functions. Adopting a third order VAR, we tested for the absence of third order serial correlation by means of a Lagrange multiplier tests, which returned a p-value of 0.25. A similar p-value was returned by a test for the absence of first order serial correlation.

Note that given the turbulence in the data during the eighties and in 2008Q2 showed in Figure 1, we inserted two dummies for those periods, whose coefficients were significantly different from zero at the 5% level in all equations, with the exception of the eighties dummy in the equation for the log of the unemployment rate. On the basis of (26) , our VAR was overidentified and so it was possible to test for overidentifying restrictions whose validity was confirmed by a likelihood ratio test with a p-value of

0.97. Estimated $\hat{\mathbf{C}}$ was equal to

$$\hat{\mathbf{C}}_1 = \begin{bmatrix} \underset{(0.00)}{0.005} & 0 & 0 \\ \underset{(0.00)}{-0.002} & \underset{(0.00)}{0.005} & \underset{(0.00)}{0.004} \\ -0.29 & -0.29 & \underset{(0.00)}{0.826} \end{bmatrix} \qquad (27)$$

where p-values are in parentheses.

Impulse-response functions with parametric bootstrapped standard errors are set out in Figure 2. Note that bootstrapping is in general able to overcome possible departures from homoskedasticity, as implied, for instance, by changes in inflation volatility. An identified shock in growth does not affect inflation, but significantly reduces unemployment for about 15 quarters. A structural inflation shock increases growth at first, but its effect turns to be slightly negative after four quarters, before being insignificantly different from zero. Its effect on unemployment is larger and more persistent. The logged unemployment rate decreases before turning insignificantly different from zero after about 10 quarters. An identified shock on logged unemployment produces a stagflation. Inflation increases, but growth decreases, though not to a significant extent.

In Figure 3 we rescaled impulse-response functions so to have a better idea of the economic magnitudes of the change in the involved variables after a shock. Given that the SVAR is expressed in logs we actually consider percentage changes. The change in the unemployment rate after a one percent temporary shock in the growth rate reaches its maximum effect of -5% after five quarters. A structural one percent inflation shock induces an immediate change in the growth rate of the order of about 1% and in the unemployment rate of 12% after 3 quarters. Recall that we are not dealing with absolute changes, therefore this last figure means that, if the unemployment rate is at 5%, it will reach 4.4% after three quarters and then it will start going back to 5%. Finally, a 1% structural shock in the unemployment rate will induces only a 0.1% response of the inflation rate.

It is also interesting to consider the forecast error variance decompositions of our SVAR as done in Figure 4. The short-run real growth rate dynamics is driven mainly by its own shocks and to a lesser extent by inflation and unemployment ones. On the other hand, real growth shocks play a minor role in the dynamics of the inflation and unemployment rate, which are more driven by their shocks - regarding the inflation rate dynamics with an equal weight, while regarding the log of the unemployment rate at first with an equal weight and then with a growing importance of unemployment shocks compared to inflation ones.

3.4 Robustness checks

3.4.1 Extending the sample back to the fifties

In our first robustness check we considered data back to 1956Q1. All customary lag-length criteria pointed to a third order VAR. The stability of the

VAR was confirmed by its eigenvalues all laying within the unit circle, being the modulus of the greatest equal to 0.92 and the smallest to 0.34. Therefore, it was again possible to compute impulse-response functions. No evidence of serial correlation of the first, second and third orders were found by Lagrange multiplier tests, which returned p-values of 0.39, 0.16 and 0.55 respectively.

On the basis of t-tests, we imposed a number of restrictions on the coefficients of the underlying VAR, namely we set to zero the coefficients of the lags of γ_t' and π_t' in the real growth equation and the coefficients of the lags of π_t' and of $\ln u_{t-3}$ in the inflation equation.

The estimated $\hat{\mathbf{C}}$ was equal to

$$\hat{\mathbf{C}}_2 = \begin{bmatrix} \underset{(0.00)}{0.005} & 0 & 0 \\ \underset{(0.00)}{0.017} & \underset{(0.00)}{0.038} & \underset{(0.00)}{0.015} \\ -0.29 & -0.29 & \underset{(0.00)}{0.85} \end{bmatrix} \tag{28}$$

where p-values are in parentheses. The likelihood ratio test for overidentifying restrictions had a p-value of 0.96.

Impulse-response functions with parametric bootstrapped standard errors are set out in Figure 5 and the are very similar to those in Figure 2.

3.4.2 What if time stopped before the Great Recession?

We next went back to our baseline sample and we dropped observations after 2008Q1 to be sure that our results were not driven by the Great Recession.

Hence our observation period was 1979Q2-2008Q1. The emerging picture looked very similar to those illustrated above. All lag-length criteria pointed to a third order VAR but the Schwarz Bayesian information one. So we stuck with the majority of them. All eigenvalues lay within the unit circle being in modulus between 0.93 and 0.27. Lagrange multiplier tests for first, second and third order autocorrelation in the residuals reported p-values between 0.72 and 0.77.

The estimated $\hat{\mathbf{C}}$ was equal to

$$\hat{\mathbf{C}}_3 = \begin{bmatrix} \underset{(0.00)}{0.005} & 0 & 0 \\ \underset{(0.00)}{-0.008} & \underset{(0.00)}{0.011} & \underset{(0.00)}{0.020} \\ -0.29 & -0.29 & \underset{(0.00)}{0.747} \end{bmatrix} \tag{29}$$

The test for overidentifying restriction did not reject their validity reporting a p-value of 0.06. For sake of brevity, from here on we focus on the effect of structural inflation shocks, which is of main interest in the present work. Figure 6 shows impulse-response functions which are very similar to those already showed above.

3.4.3 Considering year-on-year growth rates

We further redefined γ'_t and π'_t not as quarter on quarter change rates, but rather as year-on-year quarterly change rates. Once again our results stood the proof of the data. We considered our baseline observation period. All lag-length criteria pointed to a third order VAR. All eigenvalues lay within the unit circle being in modulus between 0.93 and 0.16. Lagrange multiplier tests for first, second and third order autocorrelation in the residuals were 0.61, 0.42 and 0.14 respectively.

The estimated $\hat{\mathbf{C}}$ was equal to

$$\hat{\mathbf{C}}_4 = \begin{bmatrix} \underset{(0.00)}{0.017} & 0 & 0 \\ \underset{(0.02)}{-0.02} & \underset{(0.00)}{0.073} & \underset{(0.00)}{0.077} \\ -0.29 & -0.29 & \underset{(0.00)}{0.898} \end{bmatrix} \tag{30}$$

The overidentifying restriction was not rejected as the relevant likelihood ratio test had a p-value of 0.25. Impulse-response functions after a structural shock to π_t' are set out in Figure 7. They are not too different from those in Figure 6, with the only exception that the initial boom in the real growth rate turns into a slump after about 5 quarters. However, taking the sum of the impulse-response function up to the 14th quarter, when it turns statistically not significantly different from to zero, it is possible to obtain a positive value (0.000947).

3.4.4 Playing with the long-run impacts of inflation and growth on unemployment

The last robustness check we performed is changing the value of the long-run coefficient of the impacts of structural shocks of inflation and growth on the unemployment rate. We explored a range running from 0 to -0.6.[8] We took as point of reference our baseline observation period.

As a first piece of evidence, it is interesting to plot the p-value of the test for long-run restrictions against the value of the assumed long-run effects of inflation and growth on unemployment (Figure 8). As can be seen, p-values have a clear bell shape. Overidentifying restrictions were more likely to be accepted as values got closer to the one we adopted in our above analysis. The contrary holds once picking values farther from -0.29 and, especially, once assuming inflation super-neutrality.

What happens to impulse-response functions? Figure 9 answers this questions, once focusing on the structural inflation shock and on the values of the long-run impacts of inflation and growth for which overidentifying restrictions are not rejected. As can be seen, impulse-response functions do not change much, with the exception of the one of unemployment. In this case, the short-run negative impact of inflation on unemployment strengthens the greater is the long-run one, instead the positive impact arising after about 11-15 quarters weakens. However, from previous analysis, we know this positive impact is not statistically different from zero.

[8] Extending the range to positive numbers would be in contrast to our model above, where $\frac{\phi_4}{\phi_2} < 0$.

4 Conclusions, interpretation and policy implications

In the present paper we merged a model of inflation gifts with one of endogenous growth through learning-by-doing depending on the average capital per worker in the whole economy. We then derived long-run restrictions to estimate a number of different SVARs on US data spanning from 1956Q1 to 2010Q4.

Under a theoretical point of view, inflation is showed to have a long-run negative impact on unemployment, which can be calibrated on the basis of the relevant empirical literature. The long-run impact of inflation on growth, instead, is nil. Real growth reduces the long-run unemployment rate.

Under an empirical point of view, in the short run a structural shock to inflation reduces unemployment and increases growth; a structural shock to growth reduces unemployment and leaves inflation unaffected; finally, a structural shock to unemployment produces a stagflation either without affecting growth or reducing it for some quarters. These results are robust to a number of different checks we carried out throughout the paper.

The present paper can therefore be considered as one further hit against the existence of the NAIRU. Its originality consists in the approach taken throughout our research which combines a fully microfounded model belonging to the efficiency wages tradition together with SVAR estimations. We show that in this context it is possible to obtain plausible short-run results even abandoning the superneutrality hypothesis.

Of course, upon abandoning the assumption of the NAIRU and the possibility to identify demand shocks on the basis of their transience, we need a different economic interpretation to assess whether the shocks we identify are either demand or supply ones. In order to achieve it, making reference to the building blocks of the traditional AS-AD model can be useful. The AD curve is the locus of points on the output-price level space where investment is equal to savings (both being functions of the nominal interest rate) and the money market is in equilibrium. On the other hand, the AS curve is the locus of points where input markets are in equilibrium. In our identification strategy, all shocks pass through input markets and, therefore, they can be considered as supply side shocks.

We can give some examples to illustrate this point by making reference to a graph of the labour market, as depicted in Figure 10. On the horizontal axis there is the quantity of labour available in the economy (L), which is equal to one and inelastic, given the above normalizations and assumptions regarding households and individuals. On the vertical axis there is the real wage. The wage setting curve (WS) is equation (24), namely the locus of points where the unemployment rate and the real wage are such that (14) holds. Labour demand (LD) depicts the equality between the real wage and the marginal product of labour.

Building on this graph, we can offer an interpretation of the impulse response functions set out in Figures 2 and 3. A temporary exogenous shock in growth, captured in our model by an increase in A_{t+j}, lowers the reference wage and would tend to increase effort. Firms reply by shifting down WS to WS' and increasing employment. At the same time, the growth shock shifts LD outward to LD'. We have, therefore, a decrease in the unemployment rate. The central bank does not react to these developments (Figure 11).

A temporary inflation shock lowers the reference wage tending to increase effort. Once again, firms reply by shifting down WS to WS'. Growth increases so that the capital intensity of the economy and the marginal product of labour fall. In fact, growth depends on the real rental rate of capital (see equation 8), which has to increase to let demand for capital to decrease shifting the LD curve down to LD' and allowing the economy to reach a stable path[9] (Figure 12).

Figure 13 shows the effect of a temporary exogenous shock in the unemployment rate. The WS curve shifts upward to WS'. The central bank needs to inflate the economy to bring it on a stable path. In so doing it lowers the reference wage, inducing more effort and, in the end, more employment as firm strive to keep effort constant. WS' moves to WS". All variables go back to their steady state levels as temporary shocks die away.

Our policy recommendation is that the FED should not be afraid to let inflation grow to reduce the unemployment rate. This is valid both for the long- and the short-runs, though long-run unemployment reductions will van-

[9] The fact that the path is stable is testified by impulse-response functions going to zero as time passes.

ish for too high inflation rates. We can offer more specific advice regarding the short run. If a shock can be unequivocally identified as a growth one, the central bank does not need to intervene to stabilize the economy. Intervention is required in case of a temporary unemployment shock. On the basis of our impulse-response functions (Figure 2) we can also suggest a practical way to distinguish the two cases. Identified growth shocks are short-lived and the are accompanied by a reduction in unemployment. On the contrary, unemployment shocks are not accompanied by significant changes in growth. So when there is evidence that growth is close to its trend value and unemployment is far from it (as it may happens in episodes of jobless growth), the central bank should inflate the economy to stabilize it.

Regarding the recent Great Depression, our model is a clear simplification of reality - as most models are. Therefore, we refrain from giving full advice on how to solve it. For instance, we stress more the labour market than the financial ones, which had a prominent role in the current crisis, that had important fiscal, regulatory and institutional aspects too (Swan, 2009; Tagkalakis, 2013). However, according to our analysis letting inflation increase more than what Figure 1 shows - even on a temporary basis - would not have harmed both growth and unemployment. The literature discussed above lets to think that this conclusion can be valid also for other countries than the US. Applications of our model to these countries remains an interesting direction for future research.

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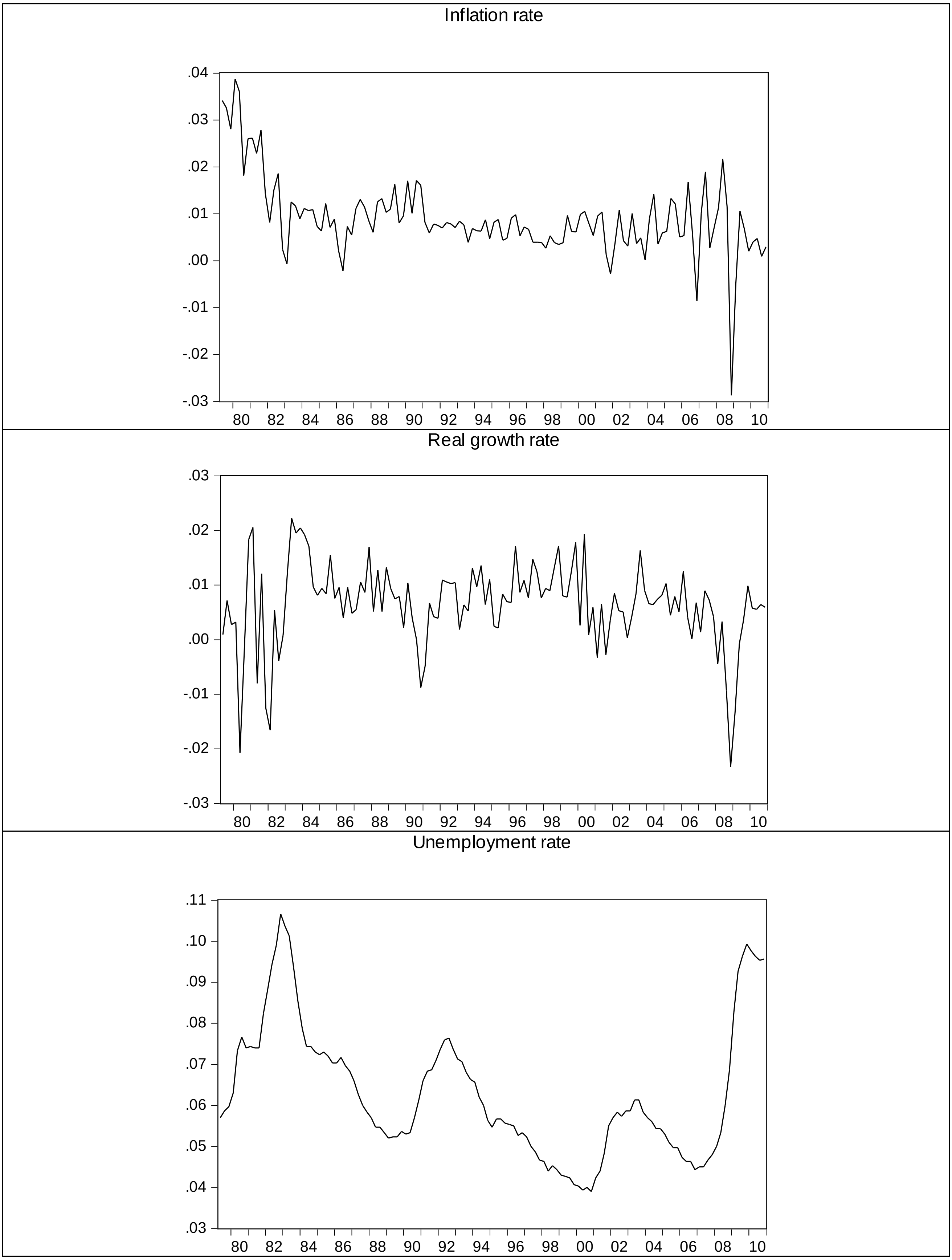
Figure 1 - Time series of the US inflation, real growth and unemployment rates from 1979Q2 to 2010Q4



Note: consistently with our theoretical model the inflation rate was computed as the natural log of 1 plus the ratio of price indexes at times *t* and *t-1*. We proceeded in a similar way for the real growth rate.

Figure 2 -Impulse-response functions to identified shocks (1979Q2 to 2010Q4)

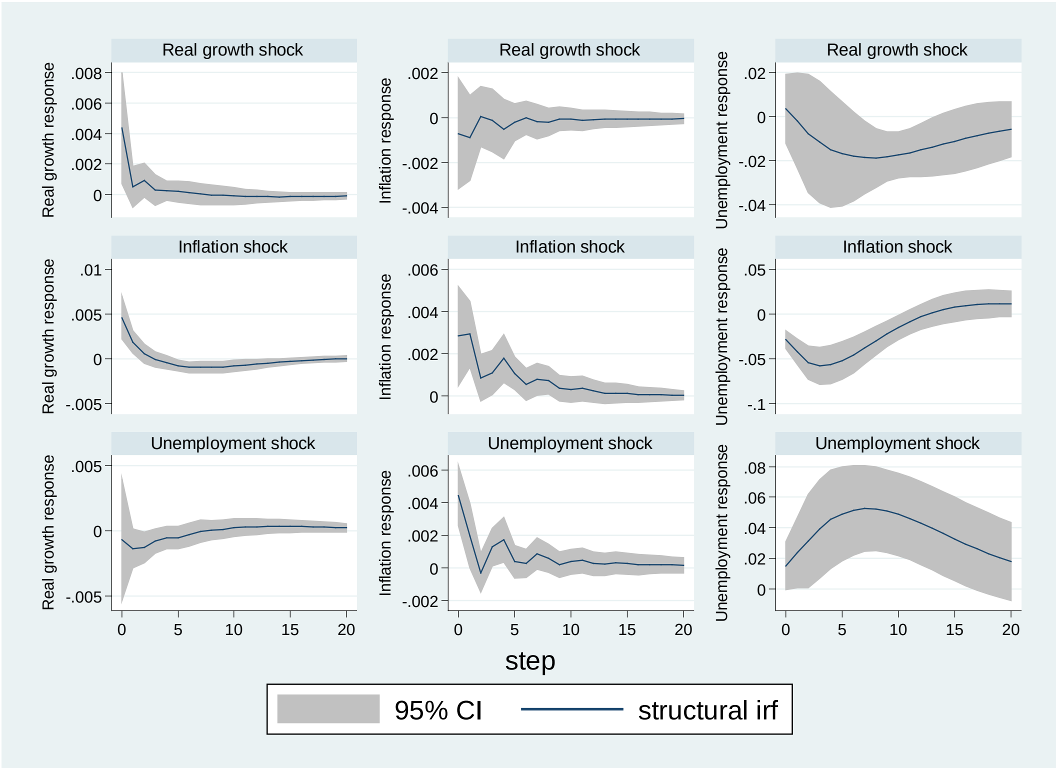
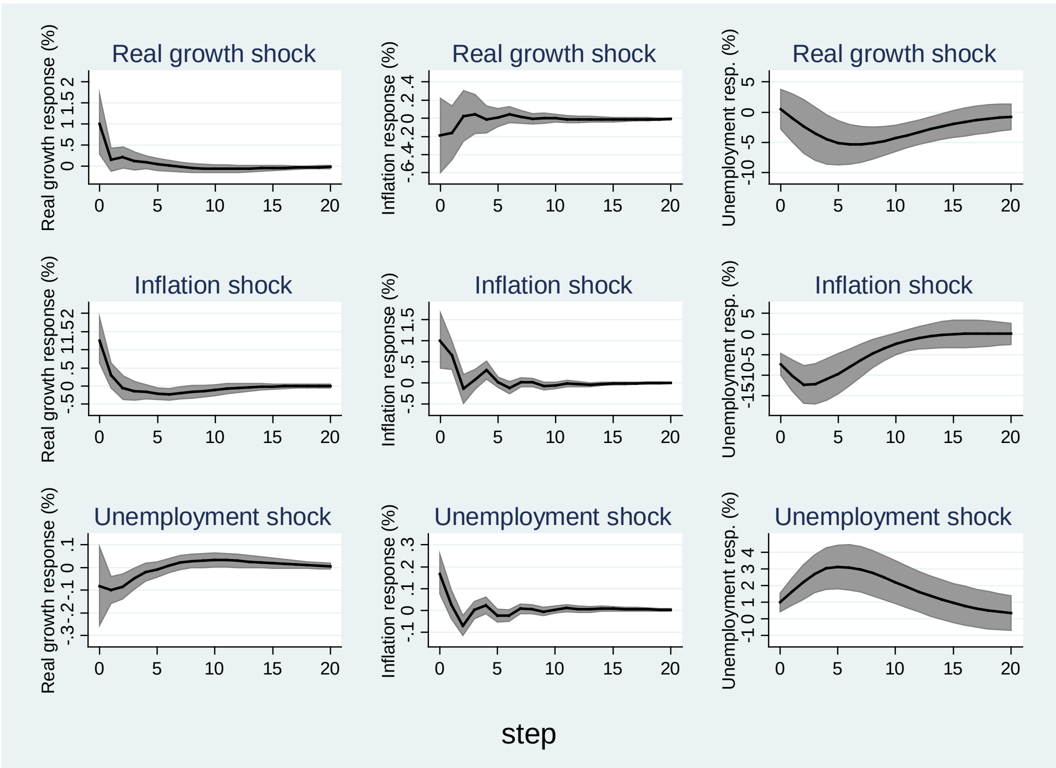


Figure 3 -Unit impulse-response functions to identified shocks (1979Q2 to 2010Q4)



Note: grey areas mark 95% confidence intervals, while black lines impulse-response functions to unit shocks.

Figure 4 - Forecast error variance decompositions

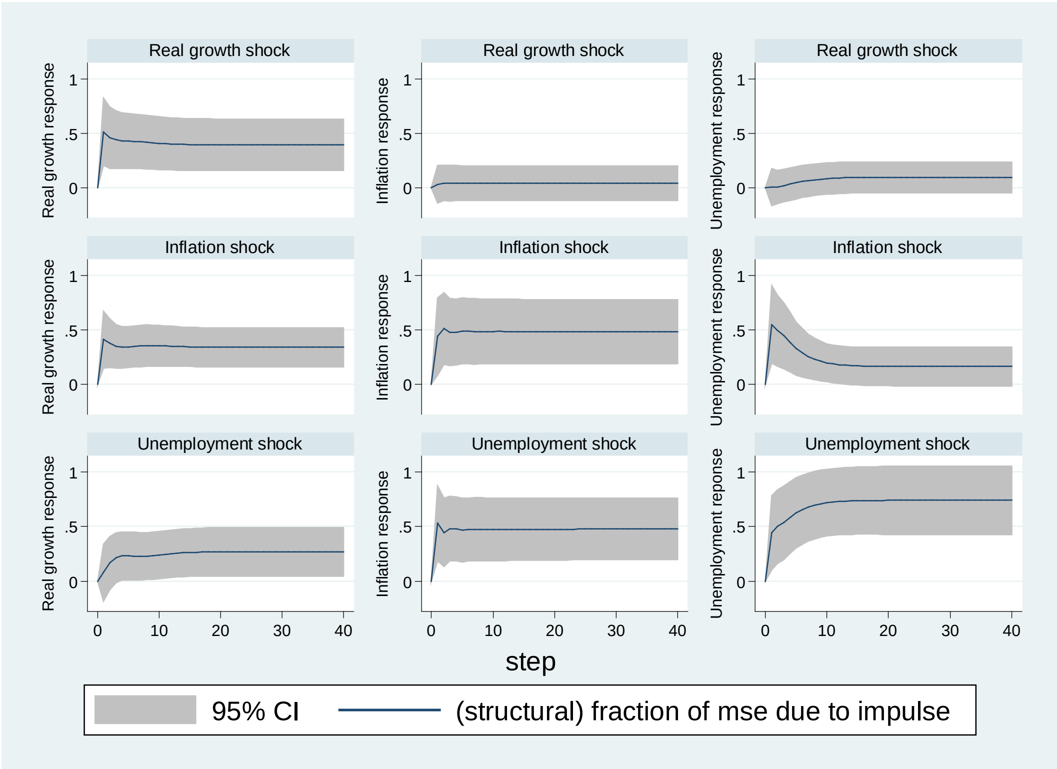


Figure 5 - Impulse-response functions to identified shocks (1956Q1 to 2010Q4)

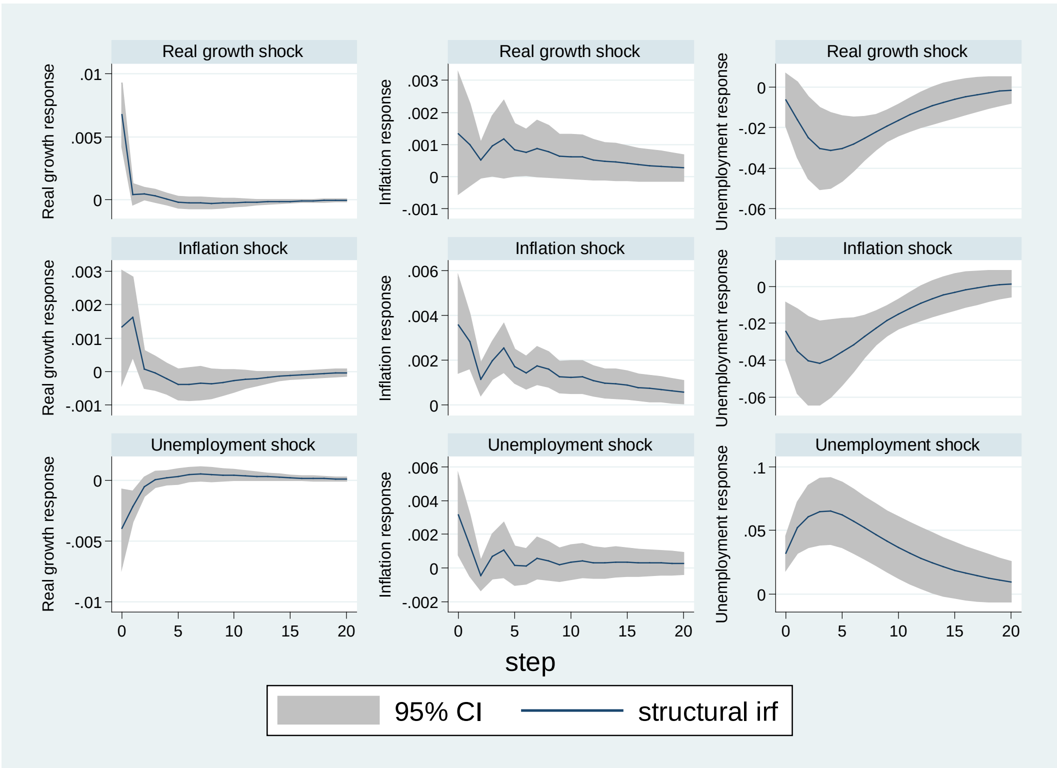


Figure 6 - Impulse-response functions to identified inflation shocks (1979Q2 to 2008Q1)

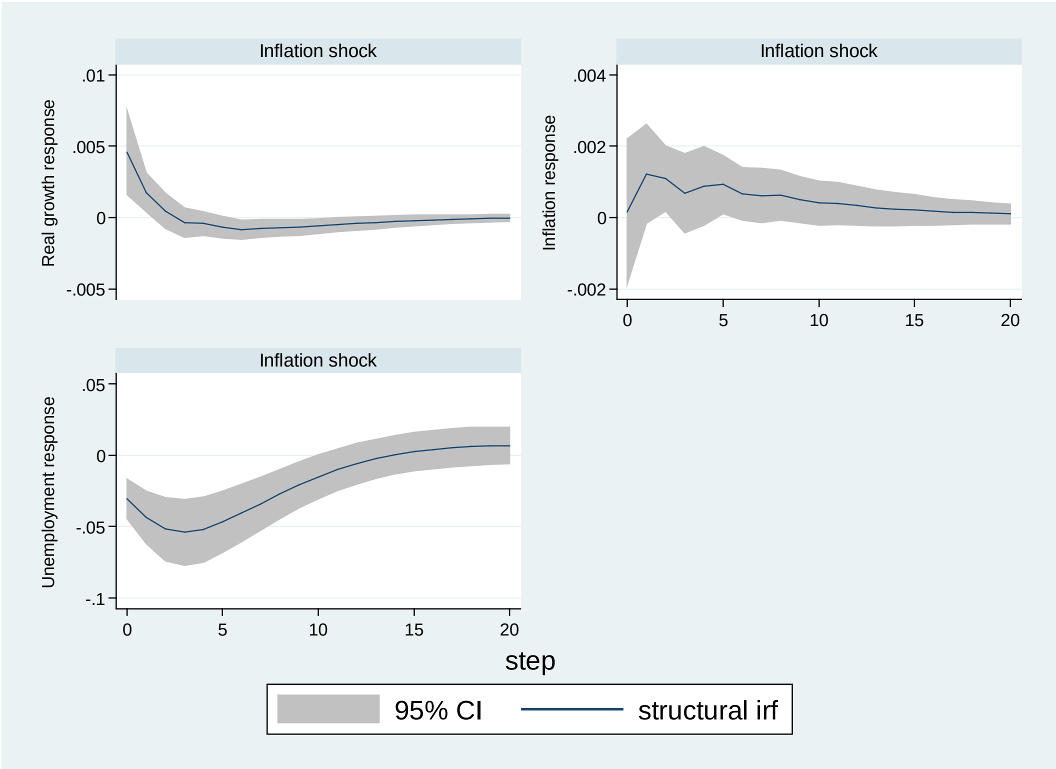


Figure 7 - Impulse-response functions to identified inflation shocks - year-on-year change rates and quarterly data (1979Q2 to 2010Q4)

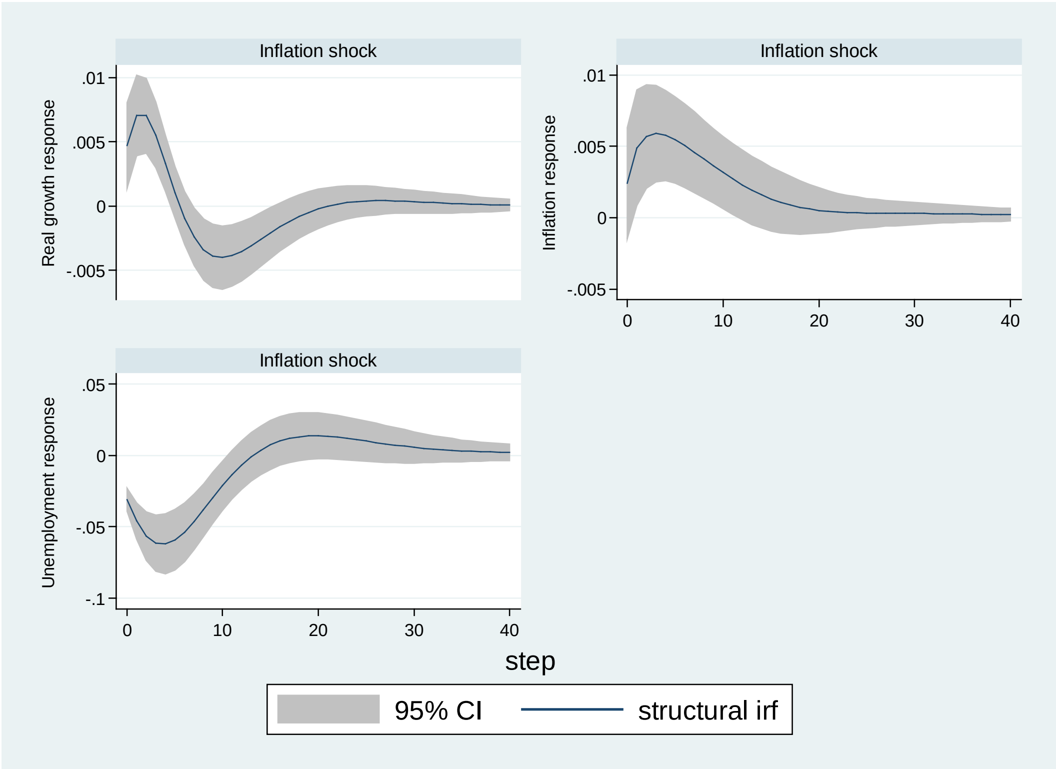


Figure 8 - P-values of the test for over-identifying restrictions for different assumptions on the long-run impacts of inflation and real growth on unemployment

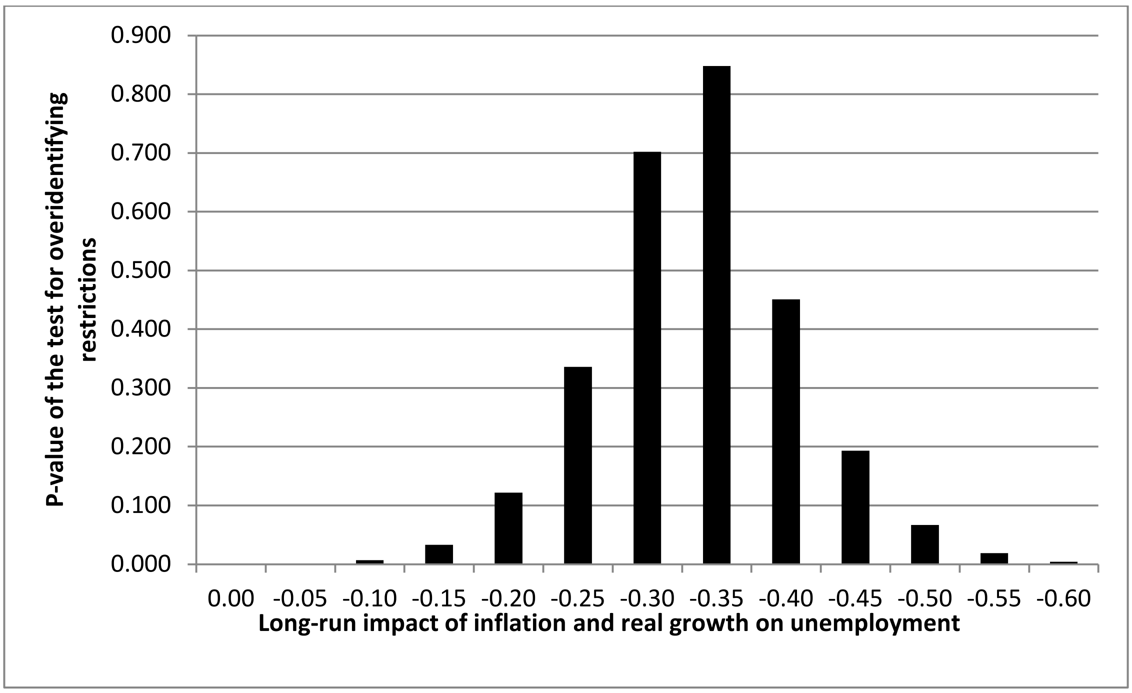


Figure 9 - Impulse-response functions to a structural inflation shock for different long-run assumptions of the effects of growth and inflation on unemployment

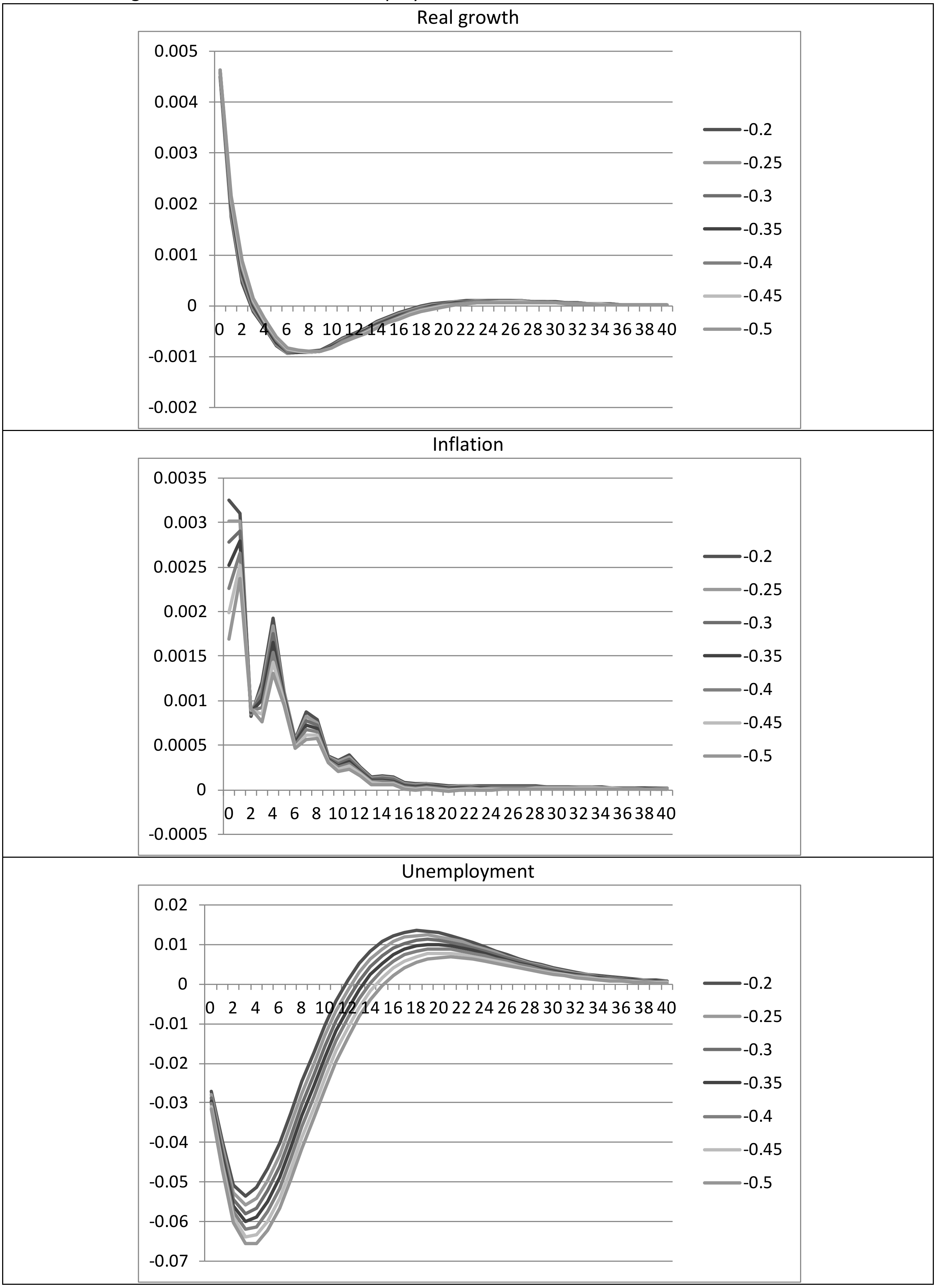
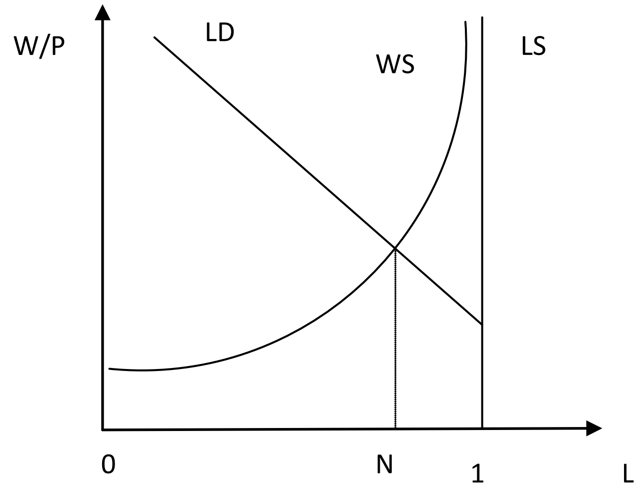
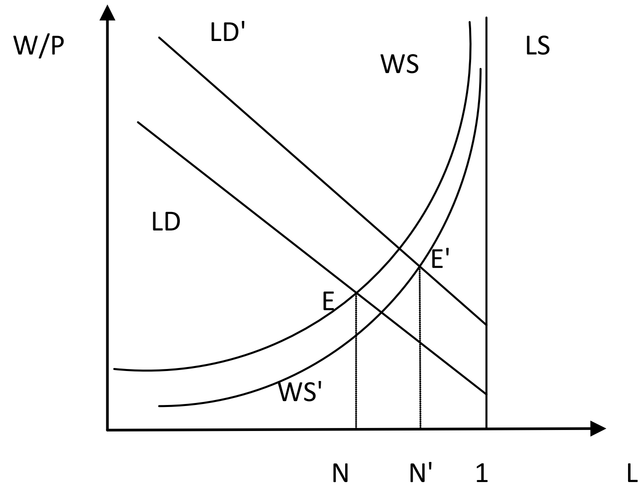


Figure 10 - The labour market in the inflation gifts model



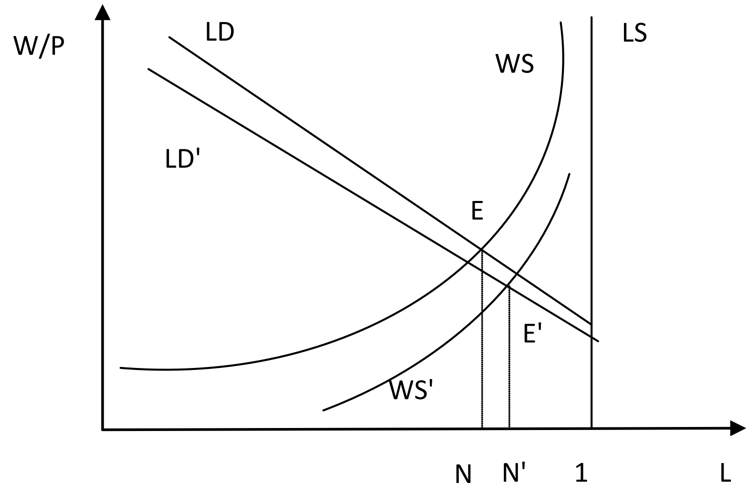
Notes WS is the wage setting curve, LS is the labour supply curve, LD is the labour demand curve, L measures the total amount of labour available in the economy, and W/P is the real wage. Total labour supply is equal to one and inelastic due to the normalizations and assumptions regarding households and individuals illustrated in the main body of the paper. From 0 to N, we have the employment interval, while from N to 1 the unemployment interval.

Figure 11 - A temporary growth shock in the inflation gifts model



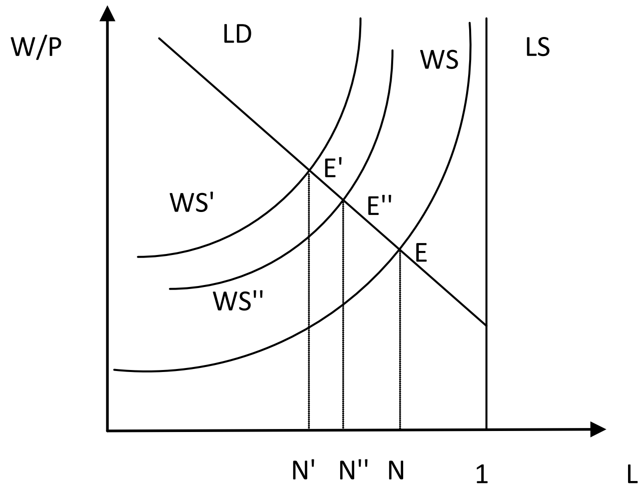
Notes: WS is the wage setting curve, LS is the labour supply curve, LD is the labour demand curve, L measures the total amount of labour available in the economy, and W/P is the real wage. Total labour supply is equal to one and inelastic due to the normalizations and assumptions regarding households and individuals illustrated in the main body of the paper. The shock moves the economy from E to E', decreasing employment from N to N'. The economy then returns to E as the effect of the shock progressively dies away.

Figure 12 - A temporary inflation shock in the inflation gifts model



NotesWS is the wage setting curve, LS is the labour supply curve, LD is the labour demand curve, L measures the total amount of labour available in the economy, and W/P is the real wage. Total labour supply is equal to one and inelastic due to the normalizations and assumptions regarding households and individuals illustrated in the main body of the paper. The shock moves the economy from E to E', increasing employment from N to N'. The economy then returns to E as the effect of the shock progressively dies away.

Figure 13 - A temporary unemployment shock in the inflation gifts model



Notes: WS is the wage setting curve, LS is the labour supply curve, LD is the labour demand curve, L measures the total amount of labour available in the economy, and W/P is the real wage. Total labour supply is equal to one and inelastic due to the normalizations and assumptions regarding households and individuals illustrated in the main body of the paper. The shock moves the economy from E to E', increasing employment from N to N'. The economy then returns to E as the effect of the shock progressively dies away.

Appendix (not for publication) to Inflation gifts restrictions for structural VARs: evidence from the US

In the present Appendix we show how to derive equation (14) in the main body of the text and how to detrend variables in the household's maximization problem. We further estimate our SVAR on a different sample than in the main body of the text.

1 The intermediate labour market

As stated in the main body of the text, firms in the intermediate labour market face the following maximization problem

$$\max_{\{N_{t+i}(h),W_{t+i}(h)\}} W_{t+i}N_{t+i} - \int_0^1 W_{t+i}(h)N_{t+i}(h)dh$$
$$s.t.\ N_{t+i} = \left[\int_0^1 e_{t+i}(h)^{\frac{\theta_n-1}{\theta_n}} N_{t+i}\left(h\right)^{\frac{\theta_n-1}{\theta_n}} dh\right]^{\frac{\theta_n}{\theta_n-1}}$$

By substituting the constraint into the objective function it is possible to obtain the following unconstrained maximization problem

$$\max_{\{N_{t+i}(h),W_{t+i}(h)\}} W_{t+i}\left[\int_0^1 e_{t+i}(h)^{\frac{\theta_n-1}{\theta_n}} N_{t+i}\left(h\right)^{\frac{\theta_n-1}{\theta_n}} dh\right]^{\frac{\theta_n}{\theta_n-1}} - \int_0^1 W_{t+i}(h)N_{t+i}(h)dh$$

Keeping in mind equation (9) in the main body of the text, the first order conditions with respect to $N_{t+i}(h)$ and $W_{t+i}(h)$ respectively are

$$W_{t+i}\left[\int_0^1 e_{t+i}(h)^{\frac{\theta_n-1}{\theta_n}} N_{t+i}\left(h\right)^{\frac{\theta_n-1}{\theta_n}} dh\right]^{\frac{\theta_n}{\theta_n-1}-1} e_{t+i}(h)^{\frac{\theta_n-1}{\theta_n}} N_{t+i}\left(h\right)^{\frac{\theta_n-1}{\theta_n}-1} = W_{t+i}(h)$$

$W_{t+i}\left[\int_0^1 e_{t+i}(h)^{\frac{\theta_n-1}{\theta_n}} N_{t+i}(h)^{\frac{\theta_n-1}{\theta_n}}\, dh\right]^{\frac{\theta_n}{\theta_n-1}-1} e_{t+i}(h)^{\frac{\theta_n-1}{\theta_n}-1} N_{t+i}(h)^{\frac{\theta_n-1}{\theta_n}} \phi_1 \frac{P_{t+i}}{W_{t+i}(h)}\frac{1}{P_{t+i}} = N_{t+i}(h)$

Taking the ratio of the two equations above

$\frac{e_{t+i}(h)}{N_{t+i}(h)}\frac{1}{\phi_1}W_{t+i}(h) = \frac{W_{t+i}(h)}{N_{t+i}(h)}$

$e_{t+i}(h) = \phi_1$

Households' symmetry and the production function imply $N_{t+i}(h) = N_{t+i}$ and $\phi_1 = 1$.

2 More on detrending

Once making explicit nominal and real trends, the objective function of the household changes into

$$U = \sum_{i=0}^{\infty} \beta^{t+i} E\left\{\log\left[c_{t+i}(h)\gamma^{t+i}\right] - N_{t+i}(h)\, G\left[e_{t+i}(h)\right] + b\log\left[\frac{\pi^{t+i} m_{t+i}(h)}{\pi^{t+i} p_{t+i}}\gamma^{t+i}\right]\right\}$$

$$U = \sum_{i=0}^{\infty} \beta^{t+i} E\left(\log\left[c_{t+i}(h)\right] - N_{t+i}(h)\, G\left[e_{t+i}(h)\right] + b\log\left[\frac{m_{t+i}(h)}{p_{t+i}}\right] + \beta^{t+i}(1+b)\log\left(\gamma^{t+i}\right)\right)$$

Consider the last term in the left hand side of the equation above. By exploiting the properties of logarithms one has

$$\beta^{t+i}(1+b)\log\left(\gamma^{t+i}\right) = \beta^{t+i}(1+b)(t+i)\log(\gamma)$$

We can therefore focus on $\lim_{t+i\to\infty} (\beta)^{t+i}(t+i)$. By de l'Hôpital rule and the chain rule for derivation one has $\lim_{t+i\to\infty}\frac{(t+i)}{(\beta)^{-t+i}} = \lim_{t+i\to\infty} -\frac{1}{(\beta)^{-t+i}\log\beta} = \lim_{t+i\to\infty} -\frac{(\beta)^{t+i}}{\log\beta} = 0$, being $\beta < 1$. Therefore utility is bounded.

The series of budget constraints turns out to be

$$c_{t+i}\left(h\right)\gamma^{t+i}+k_{t+i}(h)\gamma^{t+i}=\frac{\pi^{t+i}w_{t+i}\left(h\right)}{\pi^{t+i}p_{t+i}}\gamma^{t+i}N_{t+i}(h)+\frac{\pi^{t+i}t_{t+i}\left(h\right)}{\pi^{t+i}p_{t+i}}\gamma^{t+i}-$$
$$-\frac{\pi^{t+i}m_{t+i}\left(h\right)}{\pi^{t+i}p_{t+i}}\gamma^{t+i}+\frac{m_{t+i-1}\left(h\right)\pi^{t+i-1}}{p_{t+i}\pi^{t+i}}\gamma^{t+i-1}+$$
$$+\left(1-\delta\right)k_{t+i-1}(h)\gamma^{t+i-1}+\frac{\pi^{t+i}r_{t+i}}{\pi^{t+i}p_{t+i}}k_{t+i-1}(h)\gamma^{t+i-1}+q_{t+i}(h)\gamma^{t+i-1}$$

Note that the real wage has the same trend growth than average productivity to keep the labor share of income constant (see equations 16 and 20 in the main body of the text). Simplifying for γ and π it is possible to obtain equation (5) in the main body of the text.

Equation (3) turns out to be

$$G\left[e_{t+i}(h)\right]=\left\{e_{t+i}(h)-\left[\begin{array}{c}\phi_0+\phi_1\log\frac{\pi^{t+i}w_{t+i}(h)}{\pi^{t+i}p_{t+i}}+\phi_2\log u_{t+i}(h)+\phi_3\log\frac{\pi^{t+i}w_{t+i}}{\pi^{t+i}p_{t+i}}+\\+\phi_4\log\left(\frac{\pi^{t+i-1}w_{t+i-1}}{\pi^{t+i}p_{t+i}}\frac{1}{\gamma}\right)+\left(\phi_1+\phi_2+\phi_3\right)\log\gamma^{t+i}\end{array}\right]\right\}^2$$

where the economic necessity of $(\phi_1+\phi_2+\phi_3)=0$ is transparent. Again one needs to simplify for γ and π to obtain equation (6) in the text.

3 One further robustness check

As a further robustness check we estimated a VAR (3) in the real growth rate, the inflation rate and the log of the unemployment rate on a sample spanning from 1970Q1 to 2010Q4. Customary tests discussed in the main body of the text support the model and impulse response functions do not change much with respect to baseline ones as showed by Figure A1.

Figure A1 -Impulse-response functions to identified shocks (1970Q1 to 2010Q4) - not for publication