WHY ARE THE 2000S SO DIFFERENT FROM THE 1970S? A STRUCTURAL INTERPRETATION OF CHANGES IN THE MACROECONOMIC EFFECTS OF OIL PRICES

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macroeconomic effects of oil prices
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ABSTRACT

In the 1970s, large increases in the price of oil were associated with sharp decreases in output and
large increases in inflation. In the 2000s, and at least until the end of 2007, even larger increases in
the price of oil were associated with much milder movements in output and inflation. Using a structural
VAR approach Blanchard and Gali (2007a) argued that this has reflected in large part a change in
the causal relation from the price of oil to output and inflation. In order to shed light on the possible
factors behind the decrease in the macroeconomic effects of oil price shocks, we develop a new-Keynesian
model, with imported oil used both in production and consumption, and we use a minimum distance
estimator that minimizes, over the set of structural parameters and for each of the two samples (pre
and post 1984), the distance between the empirical SVAR-based impulse response functions and those
implied by the model. Our results point to two relevant changes in the structure of the economy, which
have modified the transmission mechanism of the oil shock: vanishing wage indexation and an improvement
in the credibility of monetary policy. The relative importance of these two structural changes depends
however on how we formalize the process of expectations formation by economic agents.

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Introduction

In the 1970s, large increases in the price of oil were associated with sharp decreases in output and large increases in inflation. In the 2000s, and at least until the end of 2007, even larger increases in the price of oil have been associated with much milder movements in output and inflation[1]. Our goal in this paper is to look at the changes in the causal relation from the price of oil to output and inflation in order to learn about the nature of the changes occurred in the structure of the economy.

Using a structural VAR approach, Blanchard and Gali (2007a) (BG in what follows) estimated impulse response functions (IRFs) for the United States, both for the pre-1984 and the post-1984 periods, and concluded that the post-1984 effects of the price of oil on either output or the price level were roughly equal to one-third of those for the pre-1984 period.

They then explored informally the potential role of three factors in accounting for the change: a smaller share of oil in production and consumption, lower real wage rigidity, and better monetary policy. Using a calibrated new-Keynesian model, they concluded that, in combination, these factors could potentially explain the change. They did not however estimate the model, nor —except for documenting the decrease in the share of oil in production and consumption— did they estimate the change in the relevant parameters. This is the natural next step, and this is what we do in this paper.

We write down a new-Keynesian model, with imported oil used both in production and consumption and we then use a minimum distance estimator that minimizes, over the set of structural parameters and for each of the two samples, the distance between the empirical IRFs obtained by BG and those implied by the model. We reach two main conclusions.

First, from a substantive point of view, our results indicate two relevant changes in the structure of the economy which could have modified the transmission mechanism of the oil shocks: vanishing wage indexation and an improvement in the credibility of monetary policy. The identification of the relative importance of these two structural changes turns out to depend however on how we formalize the process of expectations formation by agents. To capture the degree of anchoring of expectations, we use two specifications, each of which strikes us as equally plausible. When inflation expectations are partly affected by the current level of inflation, much of the difference between the two samples is attributed to changes occurred in the labor market and it can be traced to a large decline in real wage rigidity, with a smaller role attributable to more effective monetary policy. Conversely, when households and firms partly base their expectations on lagged inflation the driving force behind the changes between the two periods is a more effective anchoring of inflation expectations, which we interpret as an improvement in monetary policy credibility, with a smaller role for more flexible real wages. Under both specifications we find evidence of a slightly stronger interest rate reaction to expected

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[1]While the large increase in the price of oil in 2008 may have played a role in the current crisis, it is clear that the sharp drop in output since then is due primarily to factors other than oil. Using data for 2008 would give an undue large role to the price of oil in decreasing output. For this reason, we have ended our sample at the end of 2007.

inflation and of a decrease in nominal price rigidity over the post-1984 period, a factor not emphasized by BG. While the second formalization yields a slightly lower value for the distance function, we find however that the difference between the two specifications is not statistically significant.

Second, from a methodological point of view, our paper sheds light on the pros and cons of impulse response matching as a strategy of estimating model parameters. On the one hand, the advantage of identifying the parameters of the model from the IRFs to oil shock is that this shock is observable and can be directly and clearly identified in the data. Hence, we trust the IRFs we ask the model to match. On the other hand, this particular shock only sheds light on some of the parameters, while being less informative about some others, and the fitting of only the set of IRFs related to oil shock does not help to disentangle between the relative role played by vanishing wage indexation and the role played by the improvement in the credibility of monetary policy.

Extending the minimum distance estimation to other well identified shocks, for which the two forces make a substantial difference, could help to disentangle their relative importance. The natural candidates to look at are well identified demand side shocks. However, the empirical investigation extended to demand side shocks lies beyond the scope of the present paper and we leave it for future research.

The paper is organized as follows. Section 1 shows the IRFs from BG. Section 2 presents the model. Section 3 discusses the results of estimation of the two benchmark specifications. Section 4 explores a number of extensions of the basic model. Section 5 concludes.

1   Impulse responses

Figure 1 reproduces the impulse responses from BG which we shall try to fit with the structural model. These are obtained from estimation of two structural VAR in six variables, GDP, employment, the wage, the GDP deflator, the CPI, the nominal price of oil, all in rates in change. Both VARs are estimated using quarterly data, the first over the sample 1970:1-1983:4, the second over the sample 1984:1-2007:3. The identifying assumption is that innovations to the price of oil within the quarter are not affected by innovations to the other variables.

The IRFs are shown for the first twenty quarters. The centered lines in each figure give the estimated impulse responses of each variable, in level, to a positive shock to a price of oil of 10%. The upper and lower lines give one-standard deviation bands, obtained through Monte Carlo simulations. In all cases, the real price of oil shows a near-random walk response (not shown here), i.e. it jumps on impact, and then stays around a new plateau.

For our purposes, the IRFs in the figure have five major characteristics:

- Slowly building effects on activity and price variables in the two samples.

- Long lasting effects on all variables in the two samples.

- A smaller effect on GDP and employment in the second than in the first sample (roughly 1/3).

- A smaller effect on the GDP deflator and CPI in the second than in the first sample (roughly 1/3).

- No significant effect on nominal wages in the second sample, compared to a strong and significant effect in the first sample.

2   A model

To interpret these IRFs and recover structural parameters, we develop a new-Keynesian model. The model is standard, except for four extensions, each needed for our purposes.

- We allow for the use of oil as an input in both production and consumption. We assume that the country is an oil importer, and take the real price of oil (in terms of domestic goods) as exogenous.

- We allow for habit formation in consumption. This is done in order to capture the first characteristic of the data listed in the previous section, namely the slow adjustment of output and employment over time. In the model, output is determined by demand, and equal to consumption, and habit formation leads to a slow adjustment of consumption.

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- We allow for real wage rigidity, one of the potential factors emphasized by BG. We formalize it as a slow adjustment of the real wage at which workers are willing to work to their marginal rate of substitution. That real wage rigidity may have decreased over time seems plausible, as weakening unions, increasing competition and declining minimum wage have made the structure of labor compensation much more flexible in the 2000s than it was in the 1970s.

- To capture the notion of policy credibility, we allow agents' inflation expectations to depend directly on current or past inflation. The smaller the dependence on current or past inflation, the better anchored are inflation expectations, and the more favorable is the trade-off between inflation and output. That inflation expectations may have become better anchored over time also strikes us as plausible. BG provide direct evidence of a decrease in the response of expected inflation to the oil price shock since the mid-1980s, while the strength of the response of the nominal interest rate has not changed much across sample periods. Variations in the dynamics of expectations play a key role in the "good policy" hypothesis of the Great Moderation (Clarida, Gali and Gertler (2000), Lubik and Schorfheide (2004), Boivin and Giannoni (2002 and 2006), Castelnuovo and Surico (forthcoming), and Canova and Gambetti (2009 and forthcoming) for a dissenting view)

The rest of the section presents only the implied log-linearized equations, leaving the full derivation to the appendix. Lower case letters represent deviations from steady state, lower case letters with a hat are proportional deviations from steady state.

2.1 Oil in production and in consumption

Production is characterized by a Cobb-Douglas production function in labor and oil:

$$\widehat{q}_t = \alpha_n \ \widehat{n}_t + \alpha_m \ \widehat{m}_t \tag{1}$$

where $\widehat{q}_t$ is (gross) domestic product, $\widehat{n}_t$ is labor, $\widehat{m}_t$ is the quantity of imported oil used in production, $\alpha_n + \alpha_m \leq 1$. Technological progress does not affect the IRF to oil and can thus be ignored here.

Consumption is characterized by a Cobb-Douglas consumption function in output and oil:

$$\widehat{c}_t = (1 - \chi)\widehat{c}_{q,t} + \chi\widehat{c}_{m,t} \tag{2}$$

where $\widehat{c}_t$ is consumption, $\widehat{c}_{q,t}$ is consumption of the domestically produced good, $\widehat{c}_{m,t}$ is consumption of imported oil.

In this environment, it is important to distinguish between two prices, the price of domestic output $\widehat{p}_{q,t}$ and the price of consumption $\widehat{p}_{c,t}$. Let $\widehat{p}_{m,t}$ be the price of oil, and $\widehat{s}_t \equiv \widehat{p}_{m,t} - \widehat{p}_{q,t}$ be the real price of oil, which is assumed to follow a first order autoregressive process. From the definition of consumption, the relation between the consumption price and the domestic output price is given by:

$$\widehat{p}_{c,t} = \widehat{p}_{q,t} + \chi \ \widehat{s}_t \tag{3}$$

The important parameters for our purposes are α_m and χ, the share of oil in production and in consumption.

2.2 Households

The behavior of households is characterized by two equations. The first one characterizes consumption:

$$\widehat{c}_t = \frac{h}{1+h}\widehat{c}_{t-1} + \frac{1}{1+h}E_t\widehat{c}_{t+1} - \frac{(1-h)}{(1+h)\,\sigma}\left(i_t - \pi^e_{c,t+1} + \log\beta\right) \tag{4}$$

Consumption depends on itself lagged, itself expected, and on the real interest rate in terms of consumption. The parameter σ is the household risk aversion coefficient; together with h, it determines the response of consumption to the real interest rate. The parameter $h \in [0,1)$ captures habit formation (the utility of consumption depends on $C - hC(-1)$, where C is current consumption, and $C(-1)$ is lagged aggregate consumption). The higher the value of h, the slower the adjustment of the consumption; when $h = 0$, the relation reduces to the usual Euler equation.

The second equation characterizes labor supply, or equivalently, the real consumption wage at which workers are willing to work (the "supply wage"):

$$\widehat{w}_t - \widehat{p}_{c,t} = \gamma\left(\widehat{w}_{t-1} - \widehat{p}_{c,t-1}\right) + (1-\gamma)\left\{\phi\widehat{n}_t + \frac{\sigma}{1-h}\left[\widehat{c}_t - h\widehat{c}_{t-1}\right]\right\} \tag{5}$$

where $\widehat{w}_t$ denotes the nominal wage. The supply wage depends on itself lagged, and on the marginal rate of substitution. The marginal rate of substitution depends in turn on employment, with elasticity ϕ, where ϕ is the inverse of the Frisch elasticity, and on $\widehat{c}_t - h\widehat{c}_{t-1}$, with elasticity $\sigma/(1-h)$. The parameter $\gamma \in [0,1)$ captures the extent of real wage rigidity, which is needed in order to generate a meaningful trade-off between stabilization of inflation and the welfare relevant output gap (Blanchard and Gali, 2007b). When $\gamma = 0$, the supply wage is equal to the marginal rate of substitution. The higher the value of γ, the higher the degree of real wage rigidity.

2.3 Firms

Domestic goods are imperfect substitutes in consumption, and firms are thus monopolistic competitors. Given the production function, cost minimization implies that the firms' demand for oil is given by:

$$\widehat{m}_t = -\widehat{\mu}_t - \widehat{s}_t + \widehat{q}_t \tag{6}$$

where $\widehat{\mu}_t$ is the log deviation of the price markup, $\mathcal{M}_t$. Using this expression to eliminate m_t in the production function gives a reduced-form production function:

$$\widehat{q}_t = \frac{1}{1-\alpha_m}\left(\alpha_n\widehat{n}_t - \alpha_m\widehat{s}_t - \alpha_m\widehat{\mu}^p_t\right) \tag{7}$$

Given employment, output is a decreasing function of the real price of oil.

Combining the cost minimization conditions for oil and for labor with the aggregate production function yields the following factor price frontier:

$$(1 - \alpha_m)\,(\widehat{w}_t - \widehat{p}_{c,t}) + (\alpha_m + (1 - \alpha_m)\chi)\,\widehat{s}_t + (1 - \alpha_n - \alpha_m)\,\widehat{n}_t + \widehat{\mu}_t = 0 \qquad (8)$$

Given productivity, an increase in the real price of oil must lead to one or more of the following adjustments: (i) a lower consumption wage, (ii) lower employment, (iii) a lower markup.

This equation defines the real consumption wage consistent with a given markup set by firms; we can think of it as giving us the "demand wage" as a function of employment. This will be useful below.

Firms are assumed to set prices à la Calvo (1983), an assumption which yields the following log-linearized equation for domestic output price inflation (domestic inflation for short):

$$\widehat{\pi}_{q,t} = \beta\widehat{\pi}^e_{q,t+1} - \lambda_p\,\widehat{\mu}_t \qquad (9)$$

where $\lambda_p \equiv [(1 - \theta)(1 - \beta\theta)/\theta][(\alpha_m + \alpha_n)/(1 + (1 - \alpha_m - \alpha_n)(\epsilon - 1))]$, θ denotes the fraction of firms that leave prices unchanged during a given period, β is the discount factor of households and ϵ is the elasticity of substitution between domestic goods in consumption.

2.4   Consumption, output, employment, and GDP

The condition that trade be balanced (as oil is imported) gives us a relation between consumption and output:

$$\widehat{c}_t = \widehat{q}_t - \chi\widehat{s}_t - \eta\widehat{\mu}_t \qquad (10)$$

where $\eta \equiv \alpha_m/(\mathcal{M} - \alpha_m)$.

Using the reduced-form production function (7) gives a relation between consumption and employment:

$$\widehat{c}_t = \frac{\alpha_n}{1 - \alpha_m}\widehat{n}_t - \left(\chi + \frac{\alpha_m}{1 - \alpha_m}\right)\,\widehat{s}_t + \left(\eta - \frac{\alpha_m}{1 - \alpha_m}\right)\,\widehat{\mu}_t \qquad (11)$$

The characterization of the equilibrium does not require to introduce either value added or the value added deflator. But these are needed to compare the implications of the model to the data.

The value added deflator $p_{y,t}$ is implicitly defined by $\widehat{p}_{q,t} = (1 - \alpha_m)\widehat{p}_{y,t} + \alpha_m\,\widehat{p}_{m,t}$. Rearranging terms gives:

$$\widehat{p}_{y,t} = \widehat{p}_{q,t} - \frac{\alpha_m}{1 - \alpha_m}\,\widehat{s}_t \qquad (12)$$

thus implying a negative effect of the real price of oil on the GDP deflator, given domestic output prices.

The definition of value added, combined with the demand for oil, yields the following relation between GDP and gross output:

$$\widehat{y}_t = \widehat{q}_t + \frac{\alpha_m}{1 - \alpha_m}\,\widehat{s}_t + \eta\,\widehat{\mu}_t \qquad (13)$$

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2.5 Monetary policy

Monetary policy is characterized by a Taylor rule in which the interest rate responds to the deviation of expected CPI inflation from a zero target inflation:

$$i = -\log \beta + \phi_\pi (E_t \pi_{c,t+1}) \tag{14}$$

In order to analyze to what extent anti-inflation credibility may have played a role for the decrease in the dynamic effects of oil shocks, we depart from the standard forward looking inflation expectations for agents other than the central bank, and we explore two apparently similar, and equally plausible ex-ante specifications. In the first case, we allow expectations to depend directly on current inflation; in the second, we allow expectations to depend directly on inflation in the previous quarter. In both cases we interpret the parameter $\lambda \in [0,1]$ as capturing the quality of monetary policy. The lower λ, the less credible monetary policy, the worse the anchoring of inflation expectations and the worse the implied trade-off between inflation and output. Both model specifications capture the idea that, when credibility is low, the central bank is unable to establish an anchor for inflation expectations, which thus turn out to be strongly connected with actual inflation dynamics.

i) In the first specification we assume that economic agents form expectations of inflation according to:

$$\pi_{c,t+1}^e = (1-\lambda)\,\pi_{c,t} + \lambda E_t \pi_{c,t+1} \tag{15}$$

$$\pi_{q,t+1}^e = (1-\lambda)\,\pi_{q,t} + \lambda E_t \pi_{q,t+1} \tag{16}$$

ii) In the second specification we assume that economic agents form expectations of inflation according to:

$$\pi_{c,t+1}^e = (1-\lambda)\,\pi_{c,t-1} + \lambda E_t \pi_{c,t+1} \tag{17}$$

$$\pi_{q,t+1}^e = (1-\lambda)\,\pi_{q,t-1} + \lambda E_t \pi_{q,t+1} \tag{18}$$

The difference between the two specifications seems minor. Yet, as we shall show, it gives rise to very different interpretations of the data.

2.6 Equilibrium absent nominal rigidities

Absent nominal rigidities, the firms' markup would be constant, and the evolution of the economy would be characterized by the condition that the supply wage, implied by equations (5) and (11), be equal to the demand wage, implied by equation (8) with $\widehat{\mu}_t \equiv 0$. That condition would determine employment and, in turn, output, consumption, and GDP:

$$\widehat{n}_t = \Gamma_1 \widehat{s}_t + \Gamma_2 \widehat{s}_{t-1} + \Gamma_3 \widehat{n}_{t-1} \tag{19}$$

where $\Gamma_1 \equiv \frac{[\sigma(1-\gamma)-(1-h)][\alpha_m+\chi(1-\alpha_m)]}{\phi(1-\gamma)(1-h)(1-\alpha_m)+\sigma\alpha_n(1-\gamma)+(1-h)(1-\alpha_m-\alpha_n)}$,
$\Gamma_2 \equiv \frac{[(1-h)\gamma-\sigma h(1-\gamma)][\alpha_m+\chi(1-\alpha_m)]}{\phi(1-\gamma)(1-h)(1-\alpha_m)+\sigma\alpha_n(1-\gamma)+(1-h)(1-\alpha_m-\alpha_n)}$, $\Gamma_3 \equiv \frac{\gamma(1-\alpha_m-\alpha_n)(1-h)+\sigma h\alpha_n(1-\gamma)}{\phi(1-\gamma)(1-h)(1-\alpha_m)+\sigma\alpha_n(1-\gamma)+(1-h)(1-\alpha_m-\alpha_n)}$

Two results will be useful for the interpretation of the estimation results to be provided below.

- The sign of the long run effects of an increase in the price of oil on employment depends on σ. The reason is the same as in the familiar case of technological progress. A higher price of oil implies a lower real consumption wage, and thus a decrease in labor supply. It also implies a decrease in consumption, thus a negative wealth effect, and an increase in labor supply. For $\sigma = 1$, the substitution and wealth effects cancel and employment is constant. If $\sigma < 1$, then the substitution effect dominates, and employment decreases. If $\sigma > 1$, then employment increases.

  As the model implies that the economy tends to return over time to its equilibrium absent nominal rigidities, the fact that the IRFs show long lasting effects will tend to lead to values of σ smaller than one.

- The sign of the short run effects of an increase in the price of oil on employment depends on the sign of $(1 - h)/[\sigma(1 - \gamma)] - 1$. If, for example, $\sigma = 1$ so there is no long run effect, the sign depends on $h - \gamma$. The higher the degree of real wage rigidity, the more likely employment is to decrease in the short run; the higher the degree of habit formation, the stronger the wealth effect and the more likely employment is to increase in the short run.

2.7 Equilibrium with nominal rigidities

In the presence of nominal rigidities, aggregate demand (here consumption demand), equation (4), determines output and employment. The supply wage, given by equations (5) and (11) and the factor price frontier, equation (8), determine the markup of firms. The markup then determines inflation, through equation (9).

Monetary policy, given by equation (14), determines the interest rate, and thus affects consumption, output and employment. If monetary policy maintains a level of employment equal to that which is obtained absent nominal rigidities, inflation, measured using

the output price, is constant. If it tries to maintain higher employment, then inflation is higher.

The coefficients associated with nominal rigidities and with monetary policy play the following role. A lower value of θ (i.e. lower nominal rigidity) leads to a stronger effect of a given decrease in the markup on inflation. Thus, for a given policy rule, it leads to a larger initial increase in inflation and a larger initial decline in output.

A higher value of ϕ_π leads to a smaller increase in inflation but at the expense of a larger decrease in output.

Under both specifications for inflation expectations, the lower λ, the worse the trade-off between stabilization of quantities and stabilization of prices in response to oil price shocks. Credibility gains, captured by a higher λ, improve the trade-off facing policy-makers and make it possible to have a smaller impact of a given oil price increase on both inflation and output.

Furthermore, as shown in figure 2, the shape of the dynamic effects are notably different across the two model specifications.

When we assume that people form their expectations according to equations (15) and (16), the response of inflation expectations is stronger the lower is λ, but its dynamics are not affected: the largest increase occurs at the start, going subsequently to zero.

On the contrary, when we consider a backward looking behavior according to equations (17) and (18), not only the magnitude but also the shape of the inflation expectations' response is affected. In this case, the lower is λ, the more hump-shaped the inflation expectations response.

3   Estimation of the Benchmark

Call X the vector of the 13 parameters of the model. Let $\Psi(X)$ be the set of impulse responses of $\widehat{p}_{c,t}$, $\widehat{p}_{y,t}$, $\widehat{w}_t$, $\widehat{y}_t$ and $\widehat{n}_t$ over the first 20 quarters to an increase in the price of oil implied by X, and let $\widehat{\Psi}$ be the estimated IRFs from BG presented in Figure 1. The minimum distance estimator of X we use is given by[2]

$$X = \mathrm{argmin}[\widehat{\Psi} - \Psi(X)]'D^{-1}[\widehat{\Psi} - \Psi(X)] \tag{20}$$

where D is a diagonal matrix, with the sample variances of the $\widehat{\Psi}$ along the diagonal (so that the more tightly estimated IRFs get more weight in estimation).

X is given by $X \equiv (\alpha_n, \alpha_m, \beta, \chi, \phi, \sigma, \epsilon, h, \gamma, \theta, \phi_\pi, \lambda, \rho)$. We estimate X separately for each of the two samples, 1970:1 to 1983:4, and 1984:1 to 2007:3.

Estimating all 13 parameters would be asking too much of the data. Thus, we choose a number of coefficients a priori:

The coefficients capturing the role of oil in production and in consumption, α_m and χ, can be constructed directly. Following the computations in BG, we choose $\alpha_m = 1.5\%$

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[2]Impulse response matching, as a way of estimating model parameters, has been recently put forward by Christiano at al (2005).

and $\chi = 2.3\%$ for the first sample, $\alpha_m = 1.2\%$ and $\chi = 1.7\%$ for the second sample. The way in which these shares affect the outcome is through the expression $\alpha_m + (1 - \alpha_m)\chi$ (as can be seen by looking at the term in $\widehat{s}$ in the factor price frontier, (8)). So these numbers imply that, other things equal, the effect of a given increase in the price of oil in the second sample is only 3/4 of the effect in first sample.

We assume that, in the short run, firms have enough capital capacity that they operate under constant returns to labor and oil, so $\alpha_n = 1 - \alpha_m$. We calibrate the autoregressive parameter of the oil shock $\rho = 0.999$, in order to have the price of oil being very close to random walk, as it is in the data, while retaining stationarity to have a determinate steady state.

With respect to preferences, we assume $\beta = 0.99$, $\epsilon = 6.0$ (so that the desired markup of firms over marginal cost is 20%), and a Frisch elasticity $\phi = 1.0$. Given the long lasting effects of the price of oil in the IRFs, we do not impose long-run neutrality ($\sigma = 1$), and allow for σ to be estimated. As both consumption and labor supply decisions depend on interactions of σ and h, and we let the data determine σ, we do the same for h.

This leaves us with six parameters to be estimated, σ and h for preferences, γ for real wage rigidity, θ for nominal price rigidity and ϕ_π and λ for monetary policy.

3.1 Benchmark parameters

The results of the estimations of the benchmark under specification i and ii are shown in Table 1 and 2, respectively. The last column gives the minimized value of the distance function. The implied and actual IRFs under the model specification (i) and under the model specification (ii) are shown in Figure 3a and 3b respectively[3]. Standard errors are reported in parenthesis.

Table 1. Benchmark Estimated Parameters
specification (i)

	σ	h	γ	θ	ϕ_π	λ	Distance Function
Pre-1984	0.111 (0.062)	0.971 (0.049)	0.968 (0.125)	0.678 (0.101)	2.887 (1.395)	0.987 (0.289)	115.0314
Post-1984	0.145 (0.043)	0.898 (0.531)	0.033 (0.056)	0.134 (0.027)	3.785 (1.625)	1.000 (0.593)	65.5805

[3]Clarida, Gali and Gertler (2000) have highlighted the role of indeterminate equilibriums in the pre-1979 period. We pursue an alternative line of explanation here, which does not rely on sunspot fluctuations in the pre-1984 sample. Thus, in the numerical minimization of (20) we consider only the combinations of the structural parameters such that the model satifies Blanchard and Kahn (1980) conditions. Besides, we impose restrictions on the sign and the magnitude of the parameters which are consistent with their meaning.

Table 2. Benchmark Estimated Parameters
specification (ii)

	σ	h	γ	θ	ϕ_π	λ	Distance Function
Pre-1984	0.100*	0.911	0.284	0.231	2.038	0.103	84.1481
	(0.002)	(0.483)	(0.378)	(0.154)	(0.736)	(0.505)	
Post-1984	0.152	0.897	0.094	0.126	3.937	0.970	65.2519
	(0.046)	(0.029)	(0.116)	(0.016)	(0.479)	(0.078)	

Notes: Standard errors in parentheses. A star denotes that the estimate reaches the lower bound imposed in estimation.

For the first sample the minimized value of the distance function under specification (ii) is somewhat lower than under specification (i). This raises the question of whether we can reject the first specification relative to the second. However, the distribution of the distance function is unknown (as we are not using the efficient weighting matrix, we cannot use the Hansen's J statistic). In order to compare the measures of goodness of fit between the two models, we thus use a bootstrap methodology to compute the empirical probability density function of the statistic given by the difference between the goodness of fit of the two model specifications[4]. The empirical density function is a bell curve centered at zero. The difference between the goodness of fit of the two model specifications is not statistically significant at the 95% confidence level: we conclude that the better fit of the second specification is not significantly better. Thus, in the rest of the paper, we treat the two specifications in parallel.

Tables 1 and 2 and Figures 2a and 2b then suggest the following conclusions:

- Regardless of the ex ante assumption on the way people form their expectations, the model provides a good fit of the impulse responses in both samples. The implied IRFs are typically within the one-standard deviation bands. The lower value of the distance function obtained for the pre-1984 sample under model specification (ii) is due to an excellent fit of the price and wage dynamics, whereas the larger decrease in quantities is captured less well by the model.

- While the estimates for the post-1984 sample are remarkably stable across the model specifications, for the pre-1984 sample there are different sets of parameters that work nearly equally well across the two equally plausible ex-ante specifications.

  Under the model specification (i), the main difference between the two samples is attributed to a dramatic decline in the degree of real wage rigidity γ, from 0.968 in

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[4]We generate bootstrap residuals by randomly drawing with replacement from the set of estimated residuals. We construct bootstrap time-series by adding the randomly resampled residuals to the predicted values and re-estimate the parameters from the fictitious data. On the basis of these parameters, we compute the statistic of interest.

the first sample, to 0.03 in the second. The estimated value of λ does not suggest an important role for the improvement in monetary policy credibility.

Using the terminology often used by central banks, this can be described as strong "second-round" effects pre-1984, and weak or non existent ones post-1984. Faced with similar initial increases in the CPI (the "first round" effects), and for given employment, workers in the 1970s asked for and obtained increases in nominal wages, which then led to higher prices, confronting the central bank with a worse trade-off between activity and inflation. In the 2000s, the same initial increases in the CPI have not led to increases in nominal wages, and thus to further increases in prices.

When people are assumed to form their expectations according to the model specification (ii), although the estimated value of γ is still higher in the pre-1984 than in the post-1984 sample, the crucial role in explaining the different effects of oil price shocks is played by a strong improvement in the anchoring of inflation expectations, i.e., by an increase in the estimated value of λ, which we interpret as an increase in central bank credibility.

In the pre-1984 sample, after the oil shock, the adjustment of inflation expectations is slow, but increases over time. Conversely, in the post-1984 sample inflation expectations rise at the start but people anticipate that inflation will decrease later on. The central bank's inability to anchor expectations, coupled with a milder reaction of the nominal interest rate, makes monetary policy much less effective in the pre-1984 sample than in the post-1984 one, thus leading to greater macroeconomic volatility.

- The values of σ and h are fairly similar across the two samples and across the model specifications. This is good news, as we would hope preferences to be relatively stable over time. The low value of σ implies a large negative long-run effect of an increase in the price of oil on employment.

- Under both specifications, the degree of nominal price rigidity θ is estimated to have decreased over time. This runs against our (and we would guess, most economists') priors. First, as inflation has decreased over time, we would expect price setters to change prices less often. Secondly, a number of recent papers find a flatter Phillips curve characterizing the Great Moderation,which would suggest a slower price adjustment in the post 1984 period. If indeed present, the lower degree of nominal price rigidities may come as a consequence of the higher competition experienced in the last decades, which has probably forced firms to adjust prices more often.

In the pre-1984 sample, model specification (i) is associated with a higher estimated degree of price stickiness ($\theta = 0.678$) than the model specification (ii) ($\theta = 0.231$). As a matter of fact, the estimated value of θ is linked to the estimated value of the degree of real wage rigidity γ. The reason is as follows. The estimated high degree of real wage rigidity in the first sample implies a large negative initial effect on the natural level of employment (the level that would obtain in the absence of nominal rigidities). Given actual employment and for a given degree of nominal rigidity, this

would lead to even more inflation in the first sample than is actually observed in the data. Thus, the model estimates θ, the degree of nominal rigidity, to be higher in the first sample than in the second one, especially under the model specification (i).

- The weight on expected inflation in the Taylor rule is consistent across specifications, and it is estimated to be higher in the second sample than in the first one (3.785 versus 2.887 under the first specification, and 3.937 versus 2.037 under the second specification). This higher weight cannot however, by itself, explain the smaller effects on both activity and inflation: a stronger anti-inflationary stance can reduce the volatility of inflation but increase that of GDP.

Our two benchmark estimates point to two relevant changes in the structure of the economy which have modified the mechanism through which oil price shocks propagate in the economy: a more flexible labor market and a more credible monetary policy.

Some findings are consistent across model specifications: a somewhat stronger interest rate response to variations in expected inflation, a decrease in real wage and nominal price rigidity (although the magnitude of such decreases is very different across the two model specifications) and some role attributed to the smaller share of oil in production and consumption. However, it is hard to identify which of the two structural changes is the major factor behind the smaller effects of oil price shocks in the 2000s than in the 1970s. The interpretations of the macroeconomic changes in the effects of oil prices provided by the two model specifications are very different.

Estimation of the benchmark under the model specification (i) denies a role for the anchoring of expectations and points to changes in the labor market occurred in term of an increase of real wage flexibility as the main driving force behind the observed change in the economy's response to the oil price shock. Conversely, estimation of the benchmark under the second specification identifies the source of the milder reaction of prices and quantities in monetary policy, which has become more stabilizing, as a result of a greater effectiveness in the anchoring of expectations coupled with a stronger interest rate reaction.

The rest of our paper explores the robustness of these conclusions.

4 Extensions

4.1 Alternative estimated IRFs

The benchmark estimated parameters shown in tables 1 and 2 are obtained using an underlying VAR estimated with variables in rates of change. Estimating everything in first differences could force long run effects on value added and employment. We thus explore the effects on the benchmark estimated parameters of an alternative VAR specification, which uses rates of change for prices and wage and log-deviations from a linear trend for the quantity variables. Figure 4 reproduces the IRFs obtained from the estimation of the level/growth specification of the VAR. The results of the structural estimation using such specification are shown in table 3 for the model specification (i) and in table 4 for the

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model specification (ii). The implied and actual IRFs under the model specifications (i) and (ii) are shown in figures 5a and 5b.

Table 3. Benchmark Estimated Parameters using the IRFs obtained from
level/growth specification of the VAR

model Specification (i)	σ	h	γ	θ	ϕ_π	λ	Distance Function
Pre-1984	0.390	0.909	0.943	0.531	5.000*	1.000	93.8261
Post-1984	0.839	0.461	0.089	0.100*	3.008	1.000	94.9744

Table 4. Benchmark Estimated Parameters using the IRFs obtained from
level/growth specification of the VAR

model Specification (ii)	σ	h	γ	θ	ϕ_π	λ	Distance Function
Pre-1984	0.148	0.869	0.376	0.201	2.387	0.162	56.7910
Post-1984	0.873	0.459	0.204	0.100*	3.387	0.950	94.0661

Notes: A star denotes that the estimate reaches the lower (θ) or the upper (ϕ_π) bound imposed in estimation.

The main conclusions are robust to the level/growth specification of the VAR.

When we assume that inflation expectations partly depend on the current level of inflation, the driving force behind the changes in the macroeconomic effects of oil price shocks is the dramatic decline in real wage rigidities, coupled with the substantial drop in price stickiness. When we assume that inflation expectations partly depend on the lagged level of inflation, much of difference between the two periods can be traced to a large decline in monetary policy ability to anchor agents expectations.

The estimated parameters mostly affected by the change in the underlying VAR specification are the risk aversion coefficient σ and the degree of habit persistence h. For both samples and for both formalizations of expectations the estimated value of σ is higher and the estimated value of h is lower under the level/growth specification of the VAR than under the VAR estimated with all variables in rates of change.

Under the level specification of the VAR the effects of the oil price shock on employment and value added disappear in the long run, while in the short run they are roughly equal to those obtained using the growth-specification of the VAR. Since the sign of the long run effects of an oil price shock on value added and employment depends on σ, vanishing long lasting effects imply an estimated value of σ closer to 1. The sign of the short run effects of an oil price increase depends on $[(1-h)/\sigma(1-\gamma)] - 1$. Having estimated a higher value for σ, the model selects a lower h to keep the short run responses unchanged.

4.2 Leontief technology

The Cobb-Douglas production function assumes unit elasticity between oil and labor, which surely overestimates this elasticity in the short run. For this reason, we explore a

Leontief model, where labor and oil are combined in fixed proportions. The production function is given by:

$$\widehat{q}_t = \widehat{n}_t = \widehat{m}_t \tag{21}$$

Consumption is still characterized by the Cobb-Douglas function in output and oil (2) and the relation between the consumption price and the domestic output price is still given by equation (3). The Euler equation (4) and the supply wage (5) hence continue to characterize the behavior of households. Real marginal cost is given by:

$$\widehat{mc}_t = \alpha_n \left(\widehat{w}_t - \widehat{p}_{q,t} \right) + \alpha_m \widehat{s}_t \tag{22}$$

As before, we follow the formalism proposed in Calvo (1983), and assume that in each period a measure $(1 - \theta)$ of firms reset their prices. This yields the following equation for domestic inflation:

$$\widehat{\pi}_{q,t} = \beta \widehat{\pi}^e_{q,t+1} + \frac{(1 - \theta)(1 - \beta\theta)}{\theta} \widehat{mc}_t \tag{23}$$

With balanced trade the following relation must hold:

$$\widehat{c}_t = \widehat{q}_t - \left(\chi + \frac{\alpha_m}{\mathcal{M} - \alpha_m} \right) \widehat{s}_t \tag{24}$$

The specification of technology implies a relation between value added and gross output:

$$\widehat{y}_t = \widehat{q}_t \tag{25}$$

while the value added deflator is given by:

$$\widehat{p}_{y,t} = \widehat{w}_t \tag{26}$$

Inflation expectations are still given by (15) and (16) under the model specification (i) and by (17) and (18) under the model specification ii)

Tables 5 and 6 report the estimated parameters[5]. Figures 6a and 6b display estimated and implied IRFs.

Table 5. Estimated Parameters under Leontief technology. Specification (i)

	σ	h	γ	θ	ϕ_π	λ	Distance Function
Pre-1984	0.637	0.870	0.991	0.947	3.113	1.000	133.6951
Post-1984	0.100*	0.937	0.001*	0.662	3.430	1.000	38.5495

[5]Parameters are estimated using the benchmark VAR.

Table 6 Estimated Parameters under Leontief technology. Specification (ii)

	σ	h	γ	θ	ϕ_π	λ	Distance Function
Pre-1984	0.100*	0.919	0.265	0.485	2.037	0.000	72.6659
Post-1984	0.100*	0.926	0.094	0.737	3.387	0.677	34.9838

Notes: A star denotes that the estimate reaches the lower bound imposed in estimation.

The main conclusions are robust to changes in the specification of technology. The vanishing real wage rigidities are the driving force behind the change in the effects of oil shocks under the model specification (i). The improvement in the anchoring of expectations is the major force leading to the decline in macroeconomic volatility after the oil shock under the model specification (ii).

The degree of price stickiness is however higher in both samples and for both model specification than under the Cobb Douglas specification. The reason is as follows. Since there is no substitution of labor for oil in response to the oil price increase, the Leontief technology produces initial larger effects on both quantities and prices. As lower nominal rigidity implies larger initial rises in inflation and larger initial drops in output, through a stronger reaction of inflation to a given decrease in the markup, the Leontief technology requires more price stickiness to fit the data than the Cobb Douglas technology.

It is worth noting that, taking into account the value attained by the distance function, in the second sample the model with Leontief Technology outperforms that with Cobb Douglas technology. In the pre 1984 sample the two models are nearly equivalent in providing the IRFs matches.

4.3   Variable desired markups

Rotemberg and Woodford (1996) have argued that another effect was at work behind the size of the observed effects of oil price shocks in the 1970s, namely, an endogenous increase in the firms' markups leading to a larger decrease in output. We capture the idea that the change in the relevance of the oil price as a source of economic fluctuations could have been caused by variations in the degree of the countercyclicality of markups by specifying the desired markup as a function of the real price of oil s. The endogenous rise in the desired markup significantly increases the predicted effects of an oil price shock on both quantities and prices. As shown in Appendix b, this assumption modifies domestic inflation (9) which now contains an additive cost push shock:

$$\widehat{\pi}_{q,t} = \beta \, E_t\{\widehat{\pi}_{q,t+1}\} - \lambda_p \widehat{\mu}_t + \lambda_p \frac{\phi_\varepsilon}{\varepsilon - 1} \widehat{s}_t \tag{27}$$

where $\phi_\varepsilon \in [0,1)$ is a measure of the sensitivity of the desired markup to changes in the real price of oil.

Tables 7 and 8 shows the results of estimation, conditional on different values of ϕ_ε[6]. Depending on the sample and the specification, the distance function is minimized for

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[6]Parameters are estimated using the benchmark VAR.

values of ϕ_ε between 0.05 and 0.2. Allowing the desired markup to be sensitive to the real price of oil reduces the differences in the conclusions reached under the two model specifications. The reason is that, under the second model specification, in the pre-1984 sample the higher volatility of both prices and quantities induced by increasing desired markups is counterbalanced by a less reactive private sector (σ, γ and θ increase with the calibrated value of ϕ_ε) and by a more credible central bank (λ increases with the calibrated value of ϕ_ε).

Table 7. Robustness to introducing variable desired markups. Specification (i)

ϕ_ε	Pre-1984 Sample							Post-1984 Sample						
	σ	h	γ	θ	ϕ_π	λ	D.F.	σ	h	γ	θ	ϕ_π	λ	D.F.
0.00	0.111	0.971	0.968	0.678	2.887	0.987	115.0314	0.145	0.898	0.033	0.134	3.785	1.000	65.5805
0.05	0.112	0.966	0.953	0.721	2.537	0.837	113.889	0.270	0.878	0.299	0.224	5.000	1.000	62.3030
0.10	0.278	0.951	0.959	0.731	3.287	0.837	108.022	0.440	0.847	0.489	0.369	4.797	1.000	68.6370
0.15	0.477	0.934	0.963	0.735	3.487	1.000	105.785	0.624	0.708	0.299	0.500	1.898	1.000	81.4697
0.20	0.629	0.935	0.967	0.758	4.087	0.927	105.016							
0.25	0.737	0.935	0.968	0.765	4.283	1.000	105.685							
0.30	0.847	0.939	0.971	0.784	4.573	0.987	107.578							

Table 8. Robustness to introducing variable desired markups. Specification (ii)

ϕ_ε	Pre-1984 Sample							Post-1984 Sample						
	σ	h	γ	θ	ϕ_π	λ	D.F.	σ	h	γ	θ	ϕ_π	λ	D.F.
0.00	0.100^*	0.911	0.284	0.231	2.037	0.103	84.1481	0.152	0.897	0.094	0.126	3.937	0.970	65.2519
0.05	0.100^*	0.971	0.783	0.357	3.113	0.138	86.3120	0.293	0.871	0.340	0.238	5.000	0.902	61.6554
0.10	0.103	0.975	0.861	0.647	2.872	0.539	85.094	0.454	0.847	0.507	0.382	5.000	0.916	68.2704
0.15	0.107	0.979	0.886	0.707	3.017	0.592	87.0394	0.641	0.651	0.176	0.510	1.485	0.962	81.4112
0.20	0.192	0.961	0.890	0.753	2.672	0.620	91.3670	0.784	0.765	0.644	0.604	2.663	1.000	98.6415
0.25	0.162	0.959	0.858	0.781	2.177	0.604	96.9929							
0.30	0.420	0.828	0.871	0.825	1.437	0.644	103.2897							

Notes: A star denotes that the estimate reaches the lower bound imposed in estimation.

5 Concluding Remarks

Using an identified VAR over the pre- and post- 1984 periods BG provided evidence of a significant reduction in the effects of oil price shocks on both prices and quantities in the latter period. In this paper we have looked at the effects of oil prices to learn about changes occurred in the structure of the economy. We have presented a New Keynesian model and used a minimum distance estimator that minimizes the distance between the empirical IRFs obtained by BG and those implied by the model. This estimation points to relevant structural changes which have modified the mechanism through which oil price shocks propagate in the economy.

Two sets of parameters work nearly equally well across the two different specifications for the process of expectations' formation which we have considered. While this is not a case of weak identification, as the two sets of parameters do not work equally well for a given model, small variations in specification lead to large differences in the relative role of two major structural changes. If inflation expectations are assumed to be partly based on the current level of inflation, the structural change behind the differences across the two periods is a dramatic decline in real wage rigidities, with a smaller role for better monetary policy. A story of more flexible labor market, weakening unions and vanishing wage indexation thus emerges as the major explanation. Conversely, if inflation expectations are assumed to be partly based on the lagged level of inflation, the major explanation behind the changes is a more effective anchoring of inflation expectations, which we interpret as an improvement in monetary policy credibility, with a smaller role left for lower wage rigidities. The conclusions associated with each formalization are reasonably robust to an alternative VAR specification and to a number of modifications of the model.

Our paper thus sheds light on the pros and cons of impulse response matching as a strategy of estimating model parameters. On the one hand, the advantage of identifying the parameters of the model from the IRFs to oil shock is that the shock to oil is observable and can be directly identified in the data. On the other hand, the particular shock only sheds light on some of the parameters and the fitting of only one set of IRFs does not help to disentangle between the role played by vanishing wage indexation and the role played by the improvement in the credibility of monetary policy.

This suggests a more general strategy. In order to discriminate between the relative roles of these two structural changes, one should extend the minimum distance estimation to fit not only the IRFs to oil shocks, but also the IRFs to other clearly identified shocks for which the two structural changes make a substantial difference. If shocks to monetary policy were easy to identify, they would provide a natural candidate: higher real wage flexibility leads to an increase in the response of prices to monetary policy; better anchoring of expectations leads to a decrease in the response of prices to monetary policy. The challenge, as is well known, is that these shocks are not easy to identify. A question is whether other, more easily identified, shocks, can serve the same purpose. We leave further exploration along these lines to future research.

We assume a continuum of infinitely-lived households, indexed by j. They seek to maximize:

$$E_0 \sum_{t=0}^{\infty} \beta^t \{U\left(C_t\left(j\right), C_{t-1}\right) - V\left(N_t\left(j\right)\right)\} \tag{28}$$

where $C_t \equiv \chi^{-\chi}\left(1-\chi\right)^{-(1-\chi)} C_{m,t}^{\chi} C_{q,t}^{1-\chi}$ and where $C_{m,t}$ denotes consumption of (imported) oil, $C_{q,t}$ is a CES index of domestic goods, N_t denotes employment or hours worked, χ is the equilibrium share of oil in consumption. We assume that households are concerned with "catching up with the Joneses": there is a certain degree of external habit persistence, indexed by the parameter $h \in [0,1)$; C_{t-1} is the aggregate consumption level in period t-1

$$U\left(C_t\left(j\right), C_{t-1}\right) \equiv \frac{\left(C_t\left(j\right) - hC_{t-1}\right)^{1-\sigma}}{1-\sigma} \tag{29}$$

$$V\left(N_t\left(j\right)\right) \equiv \frac{N_t^{1+\phi}(j)}{1+\phi} \tag{30}$$

The period budget constraint is given by:

$$P_{q,t} C_{q,t}\left(j\right) + P_{m,t} C_{m,t}\left(j\right) + Q_t^B B_t\left(j\right) = B_{t-1}\left(j\right) + W_t N_t(j) + \Pi_t \tag{31}$$

where $P_{q,t} \equiv \left(\int_0^1 P_{q,t}\left(i\right)^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}}$ is a price index for domestic goods, $P_{m,t}$ is the price of oil (in domestic currency), W_t is the nominal wage and Π_t are profits. Q_t^B is the price of a one-period nominally riskless domestic bond, paying one unit of domestic currency. B_t denotes the quantity of that bond purchased in period t. The optimal allocation of expenditures between imported and domestically produced good implies:

$$P_{q,t} C_{q,t} = \left(1 - \chi\right) P_{c,t} C_t \tag{32}$$

$$P_{m,t} C_{m,t} = \chi P_{c,t} C_t \tag{33}$$

where $P_{c,t} \equiv P_{m,t}^{\chi} P_{q,t}^{1-\chi}$ is the CPI index. The first order conditions associated with the household problem are:

$$\left(C_t - hC_{t-1}\right)^{-\sigma} = \beta E_t \left\{ \frac{P_{c,t}}{Q_t^B P_{c,t+1}} \left(C_{t+1} - hC_t\right)^{-\sigma} \right\} \tag{34}$$

$$\frac{W_t}{P_{c,t}} = N_t^{\phi} \left[C_t - hC_{t-1}\right]^{\sigma} \tag{35}$$

Loglinearizing equation 34 yields equation 4. Loglinearizing equation 35 and assuming a slow adjustment of wages to labor market conditions yields equation 5.

Appendix B: Derivation of the New Keynesian Phillips Curve with variable desired markups

A firm reoptimizing in period t will choose the price $P^*_{q,t}$ solving the following problem:

$$\max_{P^*_{q,t}} \sum_{k=0}^{\infty} \theta^k E_t \left\{ \Lambda_{t,t+k} \left[P^*_{q,t} Q_{t+k/t} - \Psi_{t+k} \left(Q_{t+k/t} \right) \right] \right\}$$

subject to the sequence of demand constraints

$$Q_{t+k/t} = \left(\frac{P^*_{q,t}}{P_{q,t+k}} \right)^{-\varepsilon_{t+k}} C^q_{t+k}$$

where $\Lambda_{t,t+k} \equiv \beta^k \left(\frac{C^q_{t+k} - hC^q_{t+k-1}}{C^q_t - hC^q_{t-1}} \right)^{-\sigma} \left(\frac{P_{q,t}}{P_{q,t+k}} \right)$ is the stochastic discount factor; $\Psi_t (\cdot)$ is the cost function; $Q_{t+k/t}$ is the level of output in period $t + k$ for a firm whose price was last set in period t; ε_{t+k} is a stochastic parameter which determines the variable desired markup in the goods market.

We obtain the first order condition:

$$\sum_{k=0}^{\infty} \theta^k E_t \Lambda_{t,t+k} \left[(1 - \varepsilon_{t+k}) \frac{C^q_{t+k}}{P^{-\varepsilon_{t+k}}_{q,t+k}} \left(P^*_{q,t} \right)^{-\varepsilon_{t+k}} + \varepsilon_{t+k} \psi_{t+k/t} \frac{C^q_{t+k}}{P^{-\varepsilon_{t+k}}_{q,t+k}} \left(P^*_{q,t} \right)^{-\varepsilon_{t+k}-1} \right] = 0 \quad (36)$$

or equivalently:

$$\sum_{k=0}^{\infty} \theta^k E_t \Lambda_{t,t+k} Q_{t+k/t} \left[(\varepsilon_{t+k} - 1) P^*_{q,t} - \varepsilon_{t+k} MC_{t+k/t} P_{q,t+k} \right] = 0 \quad (37)$$

where $\psi_{t+k/t} \equiv \Psi'_{t+k} \left(Q_{t+k/t} \right)$ and $MC_{t+k/t} \equiv \frac{\psi_{t+k/t}}{P_{q,t+k}}$ are respectively the nominal and the real marginal cost in period $t + k$ for a firm that last reset its price in period t. Log-linearizing around a zero inflation steady state yields:

$$\widehat{p}^*_{q,t} = (1 - \theta\beta) \sum_{k=0}^{\infty} \theta^k \beta^k \left[\widehat{p}_{q,t+k} - \frac{\widehat{\varepsilon}_{t+k}}{\varepsilon - 1} + \widehat{mc}_{t+k/t} \right] \quad (38)$$

Taking into account the aggregate price index:

$$P^{1-\varepsilon_t}_{q,t} = \theta P^{1-\varepsilon_t}_{q,t-1} + (1 - \theta) \left(P^*_{q,t} \right)^{1-\varepsilon_t} \quad (39)$$

we get the following domestic inflation, where the variable desired markup operates as a cost push shock:

$$\widehat{\pi}_{q,t} = \beta \ E_t \{ \widehat{\pi}_{q,t+1} \} - \lambda_p \left(\widehat{\mu}_t + \frac{1}{\varepsilon - 1} \widehat{\varepsilon}_t \right) \quad (40)$$

Assuming that $\widehat{\varepsilon}_t = -\phi_\varepsilon \widehat{s}_t$ yields equation 27.

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Figure 1. Impulse responses to an oil price shock
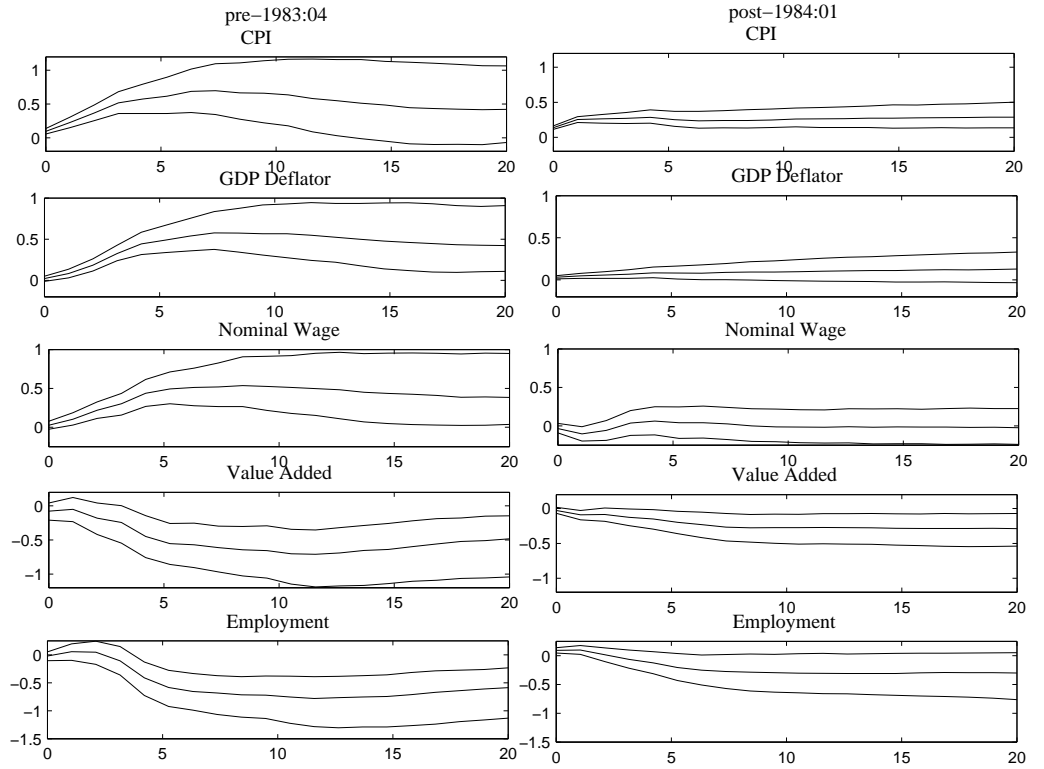
Figure 2. Domestic Inflation Expectations response to an oil price shock
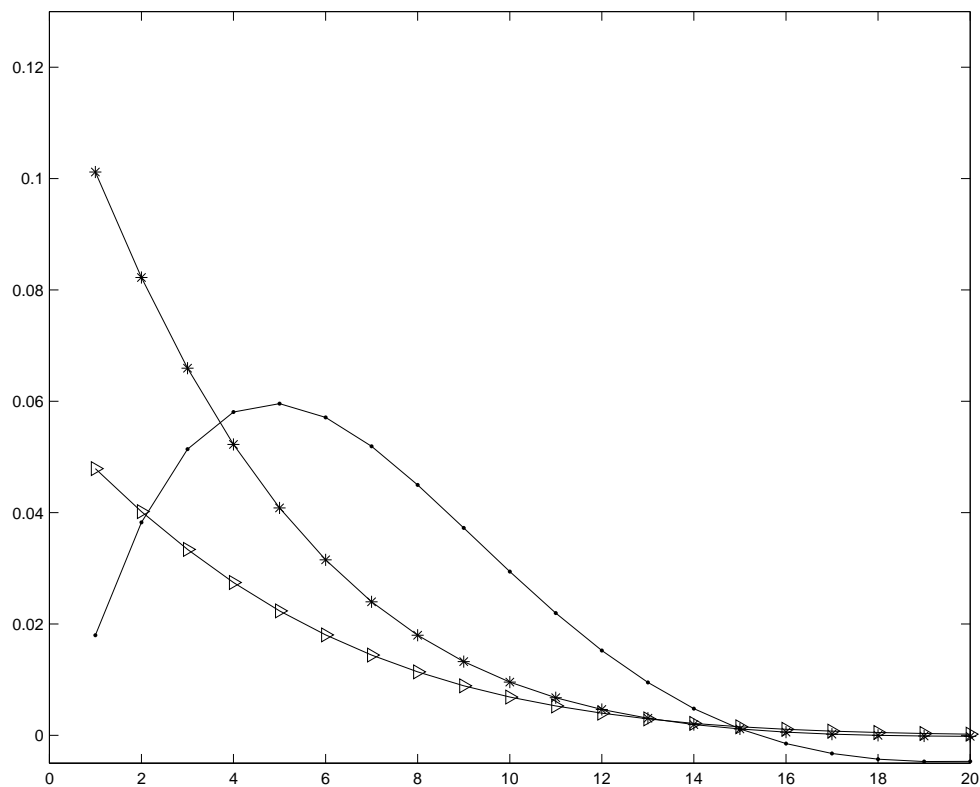
—▷— $\lambda = 1$
—∗— $\lambda = 0.4$ Model Specification i
—●— $\lambda = 0.4$ Model Specification ii

The remaining parameters are calibrated as follows: β=0.99, $\alpha_n = 0.985$, $\alpha_m = 0.015$, $\chi = 0.023$, $\phi = 1$, $\sigma = 0.3$, $\epsilon = 6$, $h = 0.9$, $\gamma = 0.9$, $\theta = 0.7$, $\phi_\pi = 2.5$.

Figure 3a. Estimated and Implied IRFs. Specification (i)

Pre−1983:04 (left column) and Post−1984:01 (right column). Rows from top to bottom: CPI, GDP Deflator, Nominal Wage, Value Added, Employment.
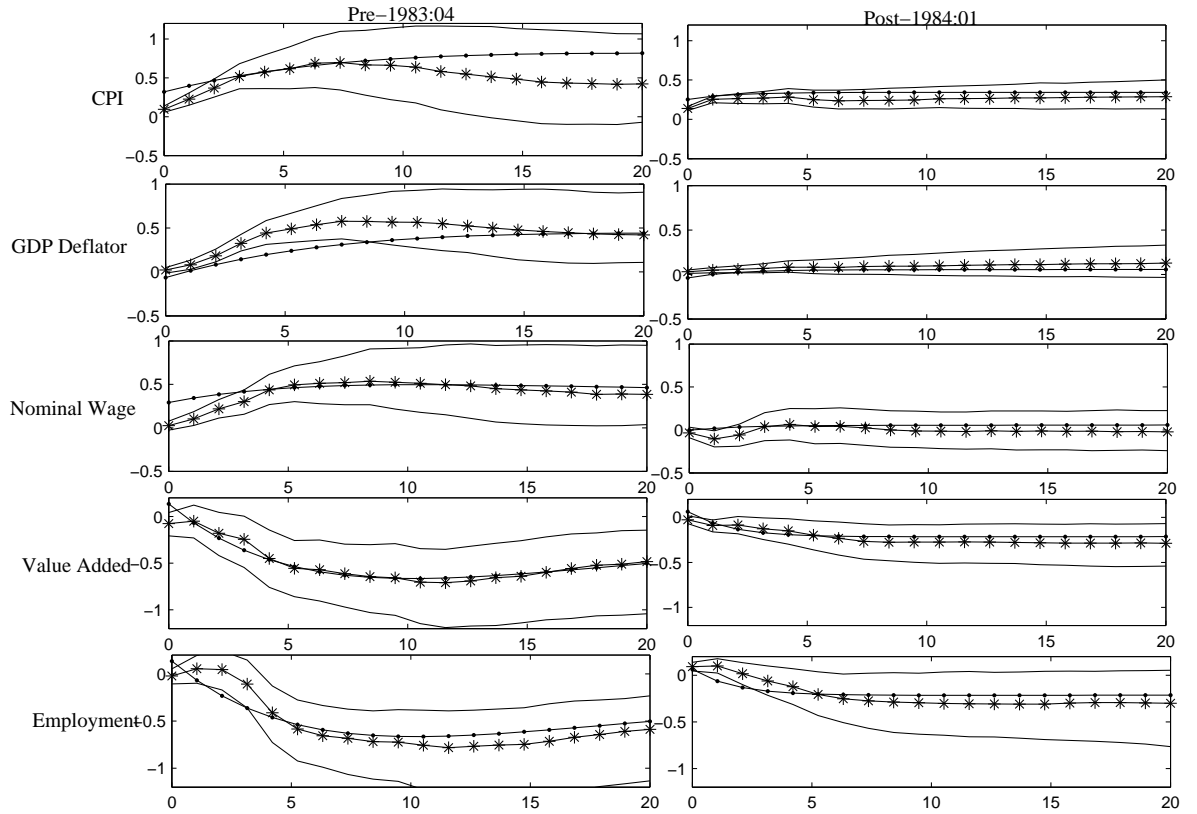
Figure 3b. Estimated and Implied IRFs. Specification (ii)
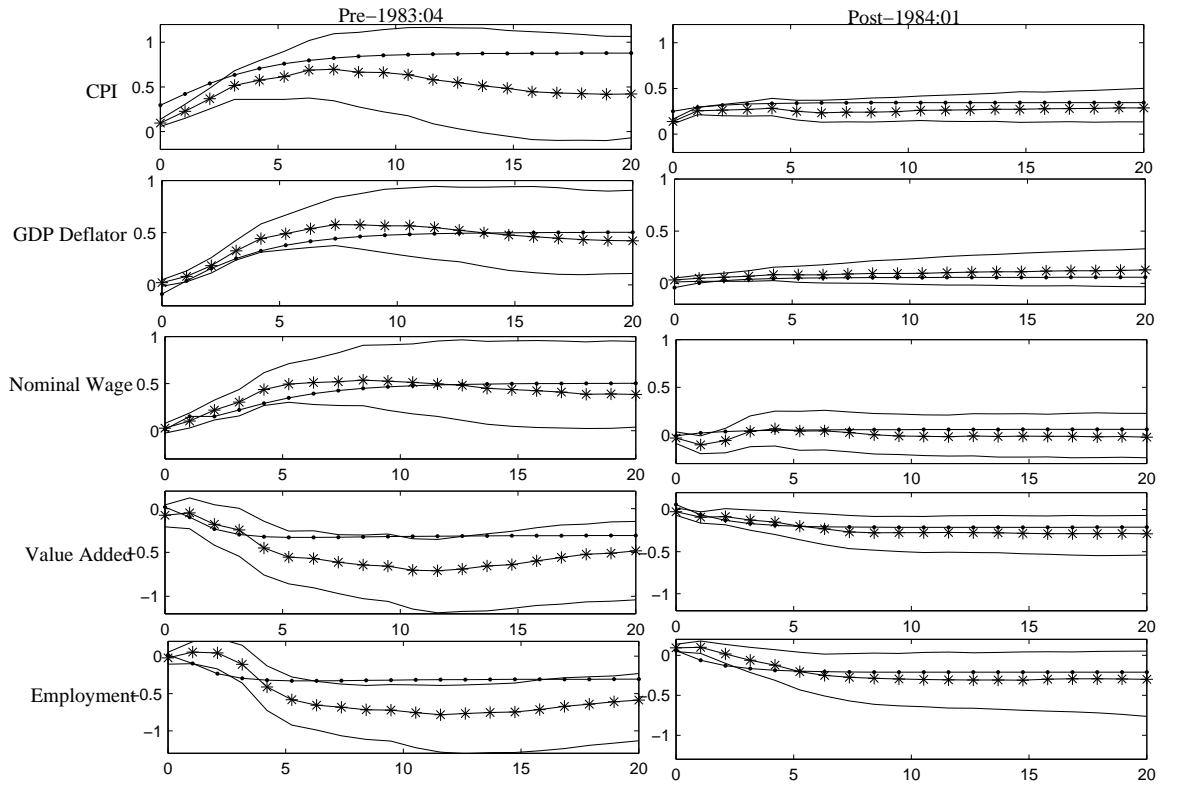
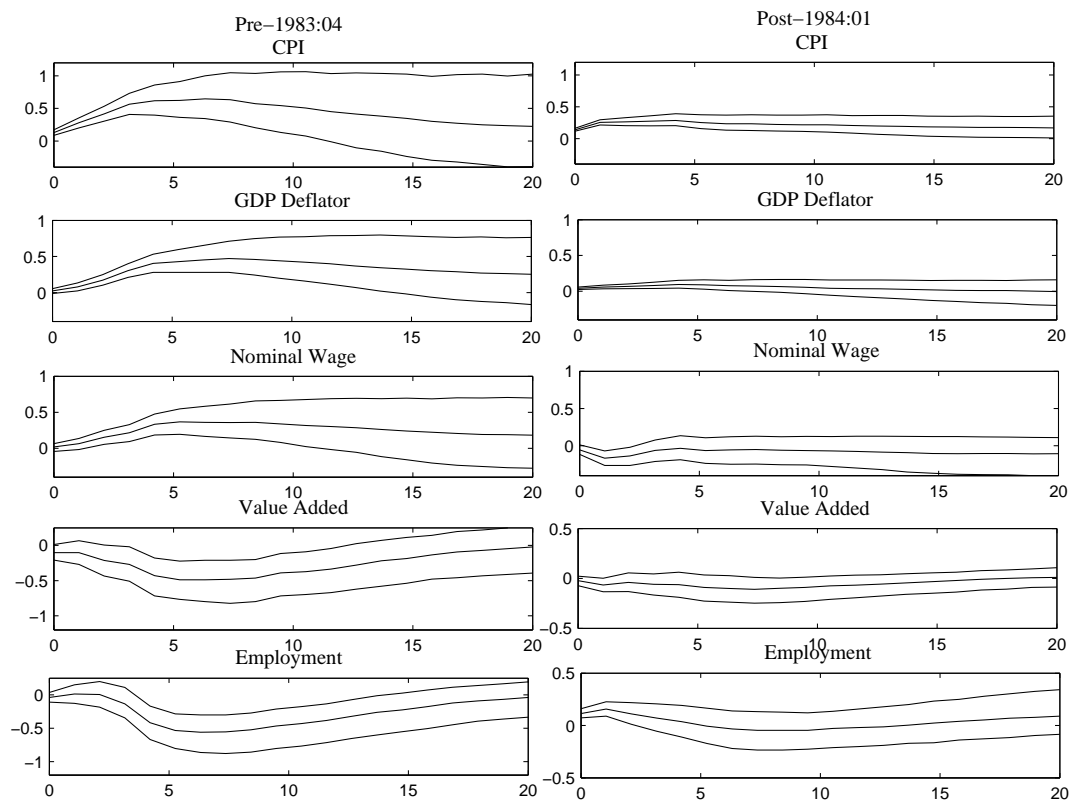# Figure 4. Impulse responses to an oil price shock. Level/Growth specification of the VAR

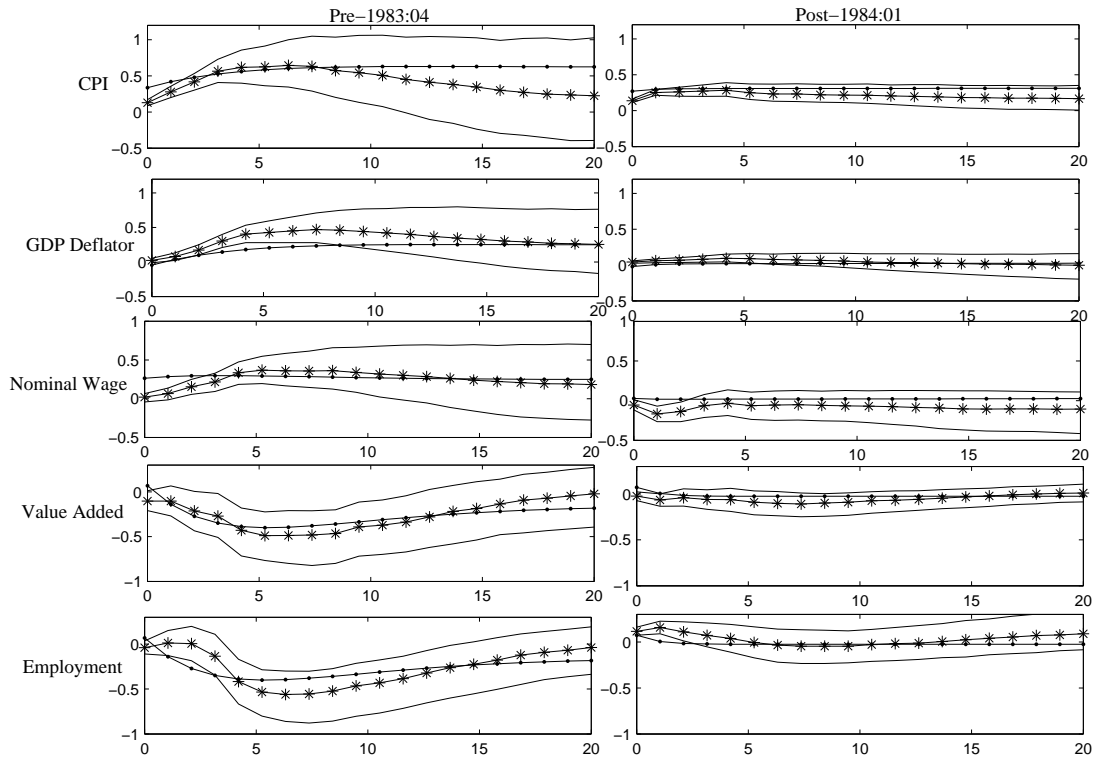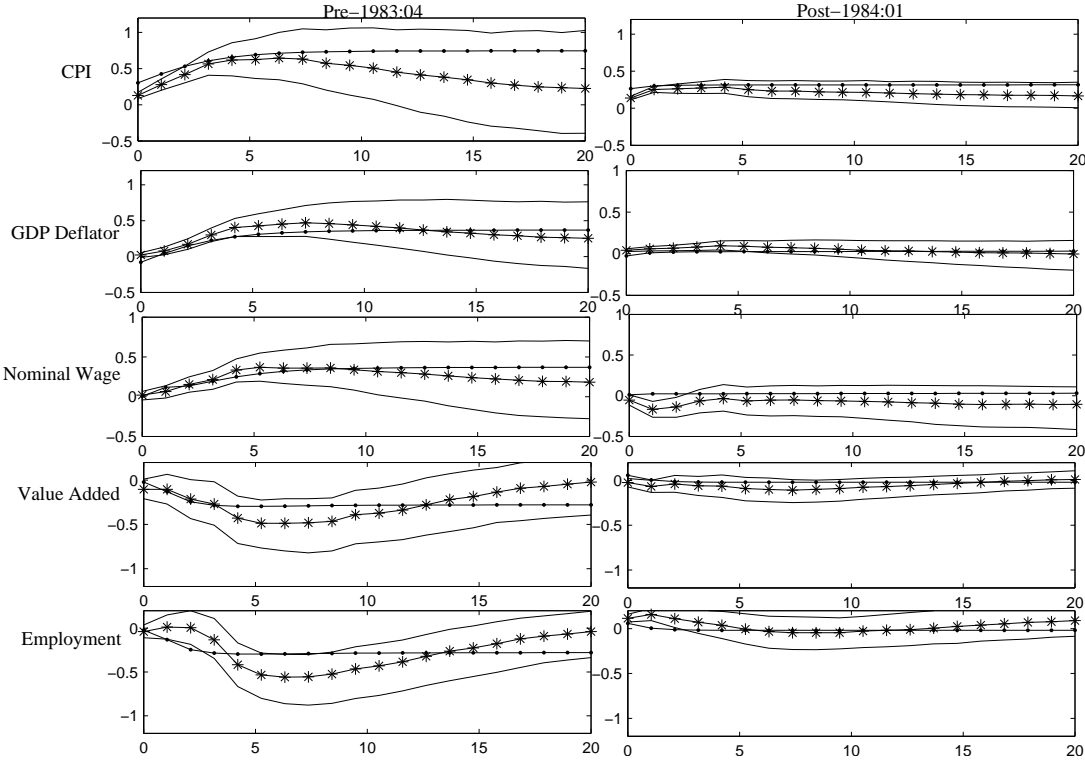# Figure 5a. Estimated and Implied IRFs. Level/growth VAR. Model specification (i)

Figure 5b. Estimated and Implied IRFs. Level/growth VAR. Model specification (ii)

Figure 6a. Estimated and Implied IRFs. Leontief technology. Model specification (i)
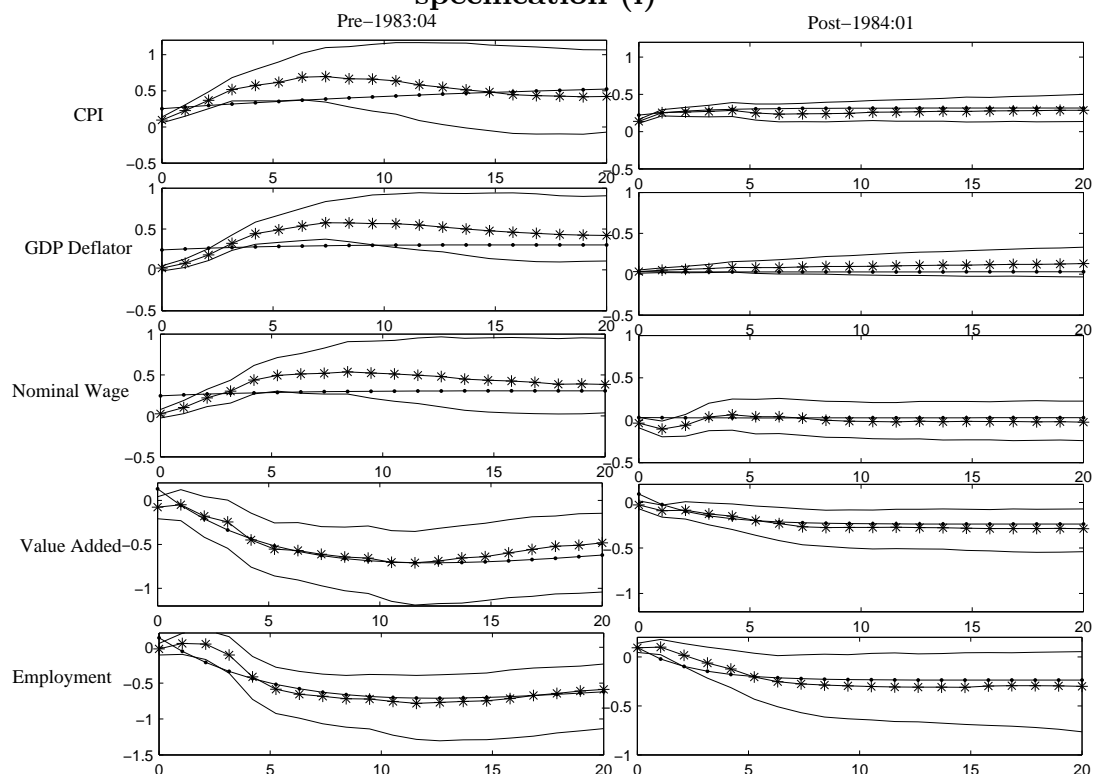
Figure 6b. Estimated and Implied IRFs. Leontief technology. Model specification (ii)