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Technology, Employment, and the Oil-Countries' Business Cycle

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Abstract

On the ground of the significance and potential dual-nature of oil-price shocks— they may act simultaneously like pure technology and pure expenditure shocks—in the context of the oil-countries—net oil-exporters with a substantial share of oil-income on their total export- and/or fiscal-income—, the paper questions the validity in such context of Gal'ı (1999)'s influential methodology for evaluating—so far, negatively— the empirical merits of the standard Real Business Cycle Model, and introduces an oil-price extended version of it aimed to restore such validity by disentangling oil-price shocks from the rest of shocks. The comparison of the results from the application of both methodologies to Norway, Mexico, Russia, Trinidad&Tobago and Venezuela, besides supporting the dual-nature hypothesis and the necessity of such disentangling, proves the latter to be instrumental to get results consistent with Gal'ı (1999)'s. Additionally, the paper unveils some startling facts about the effects of oil-price shocks in this context—remarkably, the prevalence of their technological-nature when oil-income has a higher weight on export— than on fiscal-income, and of their expenditure-nature otherwise—and shed some light on the influence of institutional reform on such effects.

Keywords: SVAR; identifying restrictions; small open economies; oil economies; dutch disease; resource curse.

JEL: C32, E32, F41, F44, Q33.

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Probably the most suggestive and influential contribution to the field of Business-Cycle scientific study in the last decade has been Galí's 1999 article "Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?" (see Galí, 1999). In this paper the author introduced a new approach to the evaluation of the empirical merits of the standard Real Business Cycle(RBC) model¹—and specially of its central tenet, the prevalence of technology shocks as the cause of Business-Cycle aggregate fluctuations—and by extension of any theory about the Business-Cycle phenomenon.

The central innovation of the approach, lies in its focus on the conditional-correlations between macroeconomic variables associated with each particular business-cycle-driving shock, in contrast with the traditional focus on the unconditional-correlations. Specifically the core of the approach is the contrasting of the standard RBC model prediction of a strong positive employment-productivity (contemporaneous) correlation conditional on technology-shocks² against the empirical estimate of such correlation derived from a bivariate Structural Vector Autoregressive (SVAR) model identified through the single a priori economic assumption that only technology shocks have permanent or long-run effects on average labour productivity.

The application of the approach in that paper to the analysis of the G7 country-members, produced results at conflict with the standard RBC-model³ but, as the author exposes and illustrates, which do are consistent with some specific New-Keynesian-style models. Such empirical findings have produced a wide, lively, and ongoing reaction among Business-Cycle students, reflected in a long series of papers whose contribution can be grouped in four main categories.

First, and by far the most extensive category, those who evaluate the robustness of Galí's findings to variations in model specification—e.g, Christiano et al. (2003), Francis and Ramey (2004), Fernald (2004), and Galí (2005) analyze the sensitivity of the findings to different assumptions and treatments of labor time-series or the use of alternatives measures of it (the first article, raising doubts about the robustness of Galí's original findings, the others reassuring it), whereas Francis and Ramey (2002) and Francis, Owyang and Theodorou (2003) evaluate their sensitivity to the extension of the number of variables and identification restrictions on the SVAR (with reassuring results); in turn, Canova et al. (2008) mixed both types of exercises, emphasizing the filtering of the long-cycles of employment and the inclusion of two types of technology shocks (also producing results at odds with Galí's).

Second, those who evaluate the possibility of a failure of the approach in empirically disentangling or identifying technology-shocks from other shocks—e.g, Galí and Rabanal (2004) and Francis and Ramey (2002) explore the correlation of the technology shocks recovered through the approach with some alternative measures of technology shocks and with some observable nontechnology shocks (in both cases, with reassuring results).

¹The RBC model was introduced by Kydland and Prescott (1982), while a rather simplified version of it, which has become the standard textbook representation of the model, was introduced by Hansen (1985)

²The broad term for all the exogenous forces that impinge randomly on the economy through their impact on the aggregate production function—i.e, on the technical quantitative relationship between the aggregate output of goods and services and the aggregate inputs (raw materials) and factors of production (labor and capital) used in its production.

³The same happened in what was the very first but less known application of the approach: the analysis of the spanish case in Galí(1996).

Third, those intended to account theoretically for Galí's findings. A first subgroup by trying to conciliate them with the standard RBC-Model, as Chari et al. (2005) and McGrattan (2004), who by applying Galí's approach to artificial data from standard RBC-models⁴ show that SVAR model misspecification could well account for Galí's findings⁵. Other subgroup, by pointing to or creating alternative model formulations consistent with these findings, as is done Francis and Ramey (2002) without even abandoning the characteristic perfect competition–price flexibility RBC's setting (notwithstanding, in the end the authors are sceptic about the chances for a so modified RBC–type model to achieve a satisfactory explanatory power over most Business–Cycle stylized facts); or by Galí (2002) and Galí and Rabanal (2004) by further developing sticky–price (i.e. New–Keynesian–type) models compatible with such findings.

Finally, and by far the scantiest group, those papers which check the consistency of Galí (1999)'s findings for the G7-countries (and by extension to the similar findings for Spain in Galí (1996)) with those obtained from applying Galí's methodology to additional cases. So far, only the European Union as an aggregate(see Galí, 2004) and (South) Korea(see Kim et al., 2008).

The contribution of this paper lies simultaneously in several of these categories. In the first place, it extends the application of Galí's methodology to the oil-countries, evaluating whether or not the results from this case are consistent with those obtained hitherto—constrained to a handful of highly industrialized net-oil-importers⁶—and whether they support, or not, the alleged conflict with the standard RBC-model's predictions.

In the second place, to make this application at least as reliable as the preceding ones, the paper needs to modify Galí's methodology by introducing oil-price and disentangling the effects of oil-price shocks, as a way to meet the challenge posed by the potential duality of oil-price shocks in this class of economies—oil-price shocks can potentially have direct effects on both the production function, like technology shocks, and the aggregate demand, like many nontechnology shocks, while Galí's methodology assumes the existence of only two type of shocks: pure technology shocks, whose direct effects on the economy concentrate exclusively on the production-function, and pure nontechnology shocks, whose direct effects on the economy concentrate exclusively in places different from the production function (mainly on the aggregate demand).

Finally, in those oil-countries where the technology-shock nature of oil-price shocks predominates, these shocks became a source of observable technology shocks whose analysis serves as a benchmark to pondering the robustness of the estimates concerning the nonobservable technology shocks identified through Galí's identification assumption—in line with McCallum (1988)'s suggestion of including explicitly oil-price shocks in RBC models as a way

⁴While Chari et al. (2005) restricts its models to satisfy Galí's key assumptions, McGrattan (2004) use a model whose parameters are fitted to the US data.

⁵This line of argument is embedded in the more general and ongoing debate about the scope and limitations for the use of SVAR models in the empirical evaluation of Dynamic Stochastic General Equilibrium models, discussed and analyzed in theoretical depth by Christiano et al. (2006) and Fernández–Villaverde et al. (2007), and under a more pragmatic perspective in Canova (2006)

⁶The only exceptions being (South) Korea, a developing net-oil-importer, and the United Kingdom, an industrialized country which from 1990 to 2005 was a net-oil-exporter, though just by a slim margin and with an almost insignificant weight of net oil-export proceeds in its external and fiscal income.

to count with an observable category of technology shocks whose analysis may allow more reliable conclusions about the role of technology shocks on the Business-Cycles.

Section 1 describes briefly Galí’s methodology—emphizing its dependence on the assumption of orthogonality between technology and nontechnology shocks—and also motivates and describes the oil-price extended version of the methodology introduced in this paper⁷. Section 2 sets out the criteria for the selection of the sample of oil-countries subsequently analyzed. Section 3 describe and analyze the results from the application of the original and extended versions of the methodology to the oil-countries selected, and Section 4 summarizes the main results and concludes. An Appendix closes the article—it starts by describing the data, and ends with an evaluation of the robustness of the main results in the paper.

1 Empirical methodology

1.1 The gist of Galí’s original methodology

The starting point of Galí (1999) are the predictions⁸ of the standard RBC model concerning the response of productivity⁹, employment and output to technology and nontechnology shocks. There exists an extensive literature which rigorously explore and discuss the implications of the standard RBC model and its variations under different sets of parameter values (Christiano and Eichenbaum (1992) analyze the aspects and variations of the standard RBC model most relevant for the forthcoming discussion, McCandless (2008) is a good recent summary of standard methods and results, while the contributions in Cooley (1995) explore many important departures from the standard model.), thereby this section opts for presenting instead an informal, heuristic and schematic exposition of the essential insights from this literature underlying Galí’s methodology (and our extension of it) with the help of the textbook-static representation of the (aggregate)labour–market (under the perfect competition setting characteristic of the RBC-model) that is shown in Figures 1 and 2¹⁰.

As usual, the vertical axis measure simultaneously real wages, S , and productivity, Q/L , which equate in equilibrium, while the horizontal axis measures labour (in hours), L ; the curve denoted L_t^s represents the (aggregate) supply of labour services by the people in the labour force at period t , and L_t^d represents the (aggregate) demand of these services by the firms at the same period—which coincides under perfect competition with the curve of marginal-productivity of labour (or the derivative respect to L of the production function, i.e, of the function expressing the technical relation between inputs and output for a given technology). Galí’s starting point is the observation that the original sigle-shock Real Business Cycle Model introduced by Kydland and Prescott (1982), and its many versions, predicts a strong positive unconditional correlation¹¹ between (the equilibrium values of) employment

⁷The exposition of the estimation procedures is left to the Appendix

⁸For the sets of parameters’ values considered reasonable by most students on the ground of microeconomic and cross-section data.

⁹Hereafter, the term productivity refers to average-labor-productivity, as measure by the ratio between GDP and number of people in the labor-force employed.

¹⁰However, in the Appendix these insights are illustrated in a more formal, though yet very stylized, way by calibrating and simulating a vanilla version of the Standard RBC model

¹¹Hereafter, the term correlation (unconditional or conditional) refers specifically to the contemporaneous

an productivity, which arise from the fact that technology-shocks, the single Business-Cycle driving shock in these models, by concentrating its direct effects on the economy exclusively on the production-function, specifically it causes random shifts of labor-demand¹²—as illustrated in Figure 1, a shift of labour-demand, say, from L_1^d to L_2^d moves the equilibrium level of employment (L) and productivity (Q/L) (i.e, the coordinates of the intersection point of the curves), in the same direction, generating a positive correlation between these two variables in absence of other shocks.

In contrast with this theoretical prediction, the empirical evidence, at least for the industrialized countries¹³, shows an unconditional correlation next to zero or even negative in some cases (see Table 1 below, which report Galí (1999)' unconditional correlation estimates for the G7-countries). . To cope with this contradiction, some authors have modified the basic RBC-model by including a second category of shocks, nontechnology shocks, which have direct effects exclusively on the supply side of the labour-market, i.e, they causes random shifts of the labour-supply¹⁴, such as public expenditure-shocks(as in Christiano and Eichenbaum, 1992), or preference-shocks(as in Bencivenga, 1992)—as illustrated in Figure 2, a shift of labour-supply, say, from L_1^s to L_2^s moves the equilibrium level of employment (L) and productivity (Q/L) (i.e, the coordinates of the intersection point of the curves) in opposite direction, generating a negative correlation between these two variables in absence of other shocks. Therefore, in the context of this multiple-shocks version of the standard RBC model, the positive employment-productivity correlation associated with technology shocks may be counteracted by the negative correlation produced by nontechnology shocks, giving rise to a null or even negative unconditional correlation between these variables, as it is observed in the data.

Galí's contribution starts by noticing that this way of reconciling the RBC model unconditional correlation predictions with the facts, generates a fresh supply of conditional-correlation predictions—remarkably, a positive employment-productivity correlation conditional on technology shocks and a negative one conditional on nontechnology shocks—whose contrasting with the facts offers in turn an additional and allegedly more conclusive test of the empirical merits of the standard RBC-model—now in its single and multiple-shocks versions alike. To perform such a test, the author proposes estimating the empirical counterpart of these productivity-employment conditional correlations through a two-steps procedure. In the first step, it is performed a dichotomous empirical decomposition of the observed variations of productivity and employment in two components each, namely the component associated or produced by “permanent” shocks (any shocks capable of producing permanent effects on average labor-productivity) and the one associated or produced by “transitory” shocks (those shocks incapable of producing permanent effects on average labor productivity). In the second step, there are computed the correlations between the resulting

correlation.

¹²Sometimes, we are going to refer to these shocks as ‘pure technology shocks, to emphasize the concentration of all their direct effects on the production-function and the labor-demand.

¹³The existing studies documenting the stylized facts characterizing the business-cycles of developing countries of which we are knowledgeable(see ?), contain no estimates or considerations at all about the patterns of correlations between employment and productivity.

¹⁴Sometimes, we are going to refer to these shocks as pure nontechnology shocks, to emphasize their lack of direct effects on the production-function and the labor-demand.

Figure 1: Labor-Demand shift

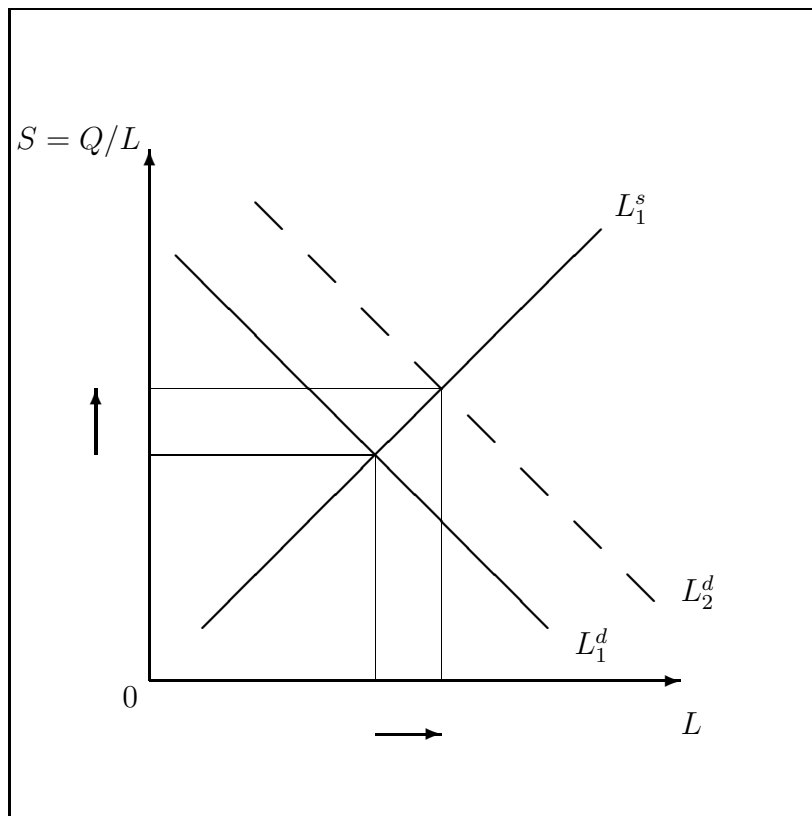
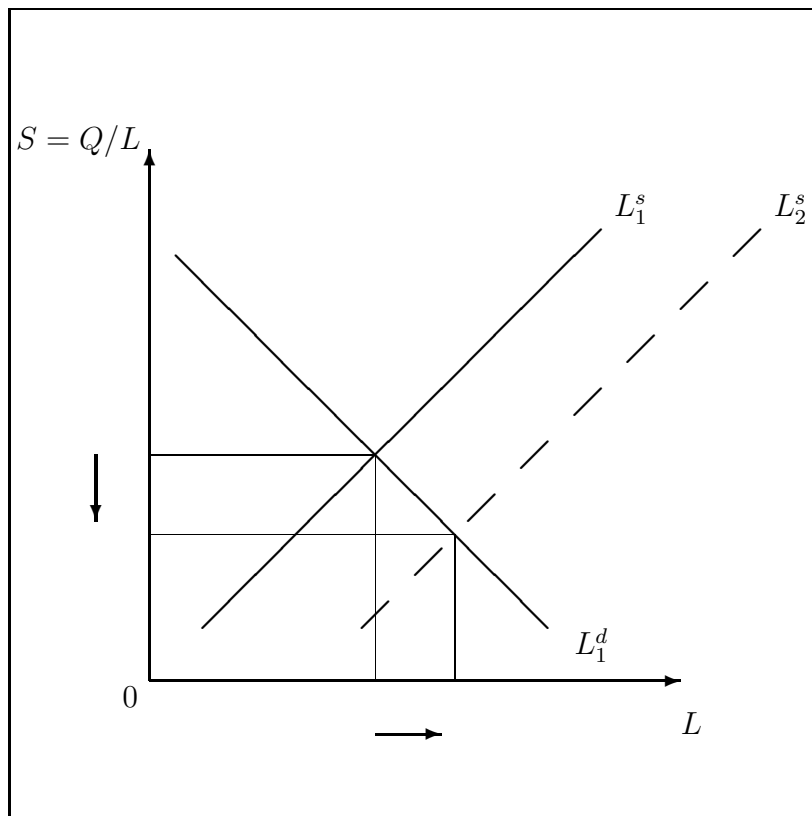


Figure 2: Labor-Supply shift



components of employment and productivity associated to permanent shocks, on one side, and between the ones associated to transitory shocks, on the other. Galí argues that under very general conditions it is valid equates permanent shocks with pure technology shocks (and, hence, transitory shocks with nontechnology shocks), and by doing so, it is also valid contrasting the theoretical employment-productivity correlation conditional on (pure) technology (nontechnology) shocks against the corresponding empirical correlation conditional on permanent (transitory) shocks.

Specifically, Galí's decomposition method is derived from the rather popular Structural Vector Autoregressive (SVAR) approach devised by Blanchard and Quah (1989) and applied originally in the decomposition of the US historical path of GDP growth rates and unemployment in their technology ("supply") and nontechnology ("demand") components. The most distinguishing feature of such decomposition is its reliance on the assumption of the existence of some specific difference between the long-run or permanent effect of technology and nontechnology shocks on the different observed variables being decomposed—i.e, statistical identification relies on an a priori restrictions over the long-run effects of shocks.

The essential departure of Galí's approach from Blanchard and Quah's, lies on the specific a priori identification assumption used to distinguish the shocks: whereas Blanchard and Quah based its identification on the assumption that only technology shocks can produce long-run effects on output, Galí's base his on the assumption that only technology shocks can produce long-run effects on average labour-productivity (hence, his readiness to equate permanent shocks with pure technology shocks), leaving open the possibility that nontechnology shocks may produce long-run effects on output. Galí justifies his abandonment of Blanchard and Quah's assumption alleging that a great many of the models of the Business-Cycle in competition at present, as much of the RBC type as of the New Keynesian type, violate such assumption—in fact, Blanchard and Quah already recognized in their 1989's paper the theoretical weakness of their identification assumption¹⁵. On the contrary, Galí argues that his alternative assumption is consistent with most Business-Cycle models provided they exhibit the standard property of balanced growth, as most of them do—see section II of (Galí, 1999).

Formally, the methodology start by postulating the following multivariate moving average representation of the stochastic process responsible for generating the observed variations of (log) employment, n_t , and (log) average labor-productivity, x_t ¹⁶ under the assumption that x_t and n_t are first-order integrated variables, $I(1)$. The latter assumption is essential to the methodology in the case of x_t (for it is assumed a priori that some shocks have permanent effects on it), while Galí's methodology gives room for the alternative possibility of n_t being trend-stationary instead of $I(1)$, in which case Δn_t is substituted by the deviations of n_t

¹⁵ "...one may argue that even demand disturbances have a long-run impact on output: changes in the subjective discount rate, or changes in fiscal policy may well affect the saving rate, and subsequently the long-run capital stock and output. The presence of increasing returns, and of learning by doing, also raise the possibility that demand disturbances may have some long-run effects...We agree that demand disturbances may well have such long-run effects on output. However, we also believe that if so, those long-run effects are small... (pp.659)

¹⁶This representation can be justified by Wold's representation theorem (see Canova, 2007, ,chapter 4, and the references there.)

from its deterministic trend.,

$$\begin{bmatrix} \Delta x_t \\ \Delta n_t \end{bmatrix} = \sum_{i=0}^{+\infty} \begin{bmatrix} c_{11i} & c_{12i} \\ c_{22i} & c_{23i} \end{bmatrix} \begin{bmatrix} \varepsilon_{t-i}^z \\ \varepsilon_{t-i}^m \end{bmatrix} \equiv \sum_{i=0}^{+\infty} C_i \varepsilon_{t-i} \equiv C(L) \varepsilon_t \quad (1)$$

$$\text{Such that, } \varepsilon_t \equiv \begin{bmatrix} \varepsilon_t^z \\ \varepsilon_t^m \end{bmatrix} \sim N[0, I].$$

Where ε_t^z and ε_t^m represent technology and nontechnology shocks, respectively, which in this context comprehend the only two categories of shocks responsible for producing the dynamic path of employment, average-labor productivity, and output¹⁷. Notice the orthogonality of ε_t^z and ε_t^m .

It is from the estimated values of the parameters of this model—i.e, of the matrices C_i for $i = 1, 2, 3, \dots$ —that Galí compute his estimates of the empirical conditional correlations wanted—to be contrasted with the predictions of the standard RBC model. However, in order to make possible such estimation an a priori restriction on these parameters is required, otherwise the model would be underidentified, and it is just here where Galí introduce his assumption that only pure technology shocks produce long-run effects on x_t (i.e, that permanent shocks and pure technology shocks are equivalent), which translate on the following restriction,

$$\sum_{k=0}^{+\infty} c_{12k} = 0$$

Notice that this restriction implies that the matrix $C(1)$ (the long-run impact matrix) have to be lower-triangular.

To estimate these parameters Galí's relies on the already standard bayesian procedure popularized by Tom Doan (see Doan, 2007) through its automatization and distribution with his proprietary software RATS since the beginning of the 1990s¹⁸. The starting point of the procedure is the bayesian estimation of the parameters of reduced-from Vector Autoregressive Representation (VAR) of the stochastic process for Δx_t and Δn_t , imposing a Jeffrey's prior on them, and afterwards exploit the exact identification of the SVAR to estimate the coefficients of the latter from the estimated parameters of the former through conventional Monte Carlo simulation. The details of the procedure are described in the Appendix.

¹⁷Given that average productivity is measured here by the ratio between output and employment, the logarithm of output, y_t , is no more than the sum of n_t and x_t , i.e, $y_t \equiv n_t + x_t$

¹⁸As a matter of fact, Galí's computations were performed using RATS, and we have benefited by the analysis of his original codes and some recodification of it by Thomas Doan which are available at the webpage of RATS, www.estima.com

1.2 Galí's empirical findings

Table 1, and Figures 3 and 4, replicate the main empirical findings reported in Galí (1999) resulting from the application of the methodology outlined before to the United States (baseline case) and the rest of the G7 industrialized countries¹⁹. Galí starts by highlighting the fact motivating the whole exercise: the unconditional correlation between employment and average labor-productivity is in most cases (see Table 1, first column) statistically indistinguishable from zero (i.e, not statistically significant) and negative otherwise—findings whose stark contrast with the strongly positive unconditional correlation predicted by the standard single-shock RBC model has motivated the development of multiple-shocks versions of the model able to account for them.

Then, Galí proceeds to present the core results of the exercise: primarily, the statistical significance and negative sign of the G7-countries' empirical estimates for the conditional correlation between employment and productivity associated to technology shocks (see Table 1, second column), and, secondarily, the statistical significance and positive sign of the one associated to nontechnology shocks—Japan is an exception, because in its case the estimates lack statistical significance. These findings, Galí emphasizes, are at odds with the theoretical conditional correlations implied by the multiple-shocks versions of the standard RBC model—and provided that Galí's conditional correlation's estimates are good approximations of the true empirical conditional correlations, such contradiction shed doubts on the empirical merits of the multiple-shocks version of the standard RBC model in the same way that the estimate of the unconditional correlation does in the case of the basic single-shock version of the model.

Subsequently, Galí expands upon these findings by analyzing the estimates for the impulse-response functions underlying them. On the one hand, the author highlights the consistency of the point estimates (i.e, the mean dynamic response of the variables to each shock) with the results for the conditional correlations: a positive technology shock²⁰ produces, in the short-term at the least, a drop in employment in all countries but Japan, while a positive nontechnology shock produces a persistent raise in the same variable in all cases. In the other hand, the author evaluates the uncertainty associated to these results, as synthesized in the confidence intervals, emphasizing the relative certainty (except in the case of Japan) about the aforementioned direction of the employment response to each type of shocks in the short term—the confidence bands for the short-term include only the possibility of an employment reduction in response to a positive technology shocks, and of an employment increase in response to a positive nontechnology shocks, while the wide amplitude of the bands in the medium and long-term impede to assess with any certainty the direction of the employment's response in those horizons.

Finally, Galí points out some findings derived from his estimates of the components of the historical fluctuations of employment and output growth rates in the business-cycle frequencies associated, respectively, to technology and nontechnology shocks (Galí only shows

¹⁹The analysis of the Spanish and European economies in Galí (1996) and Galí (2004) gives rise to similar findings.

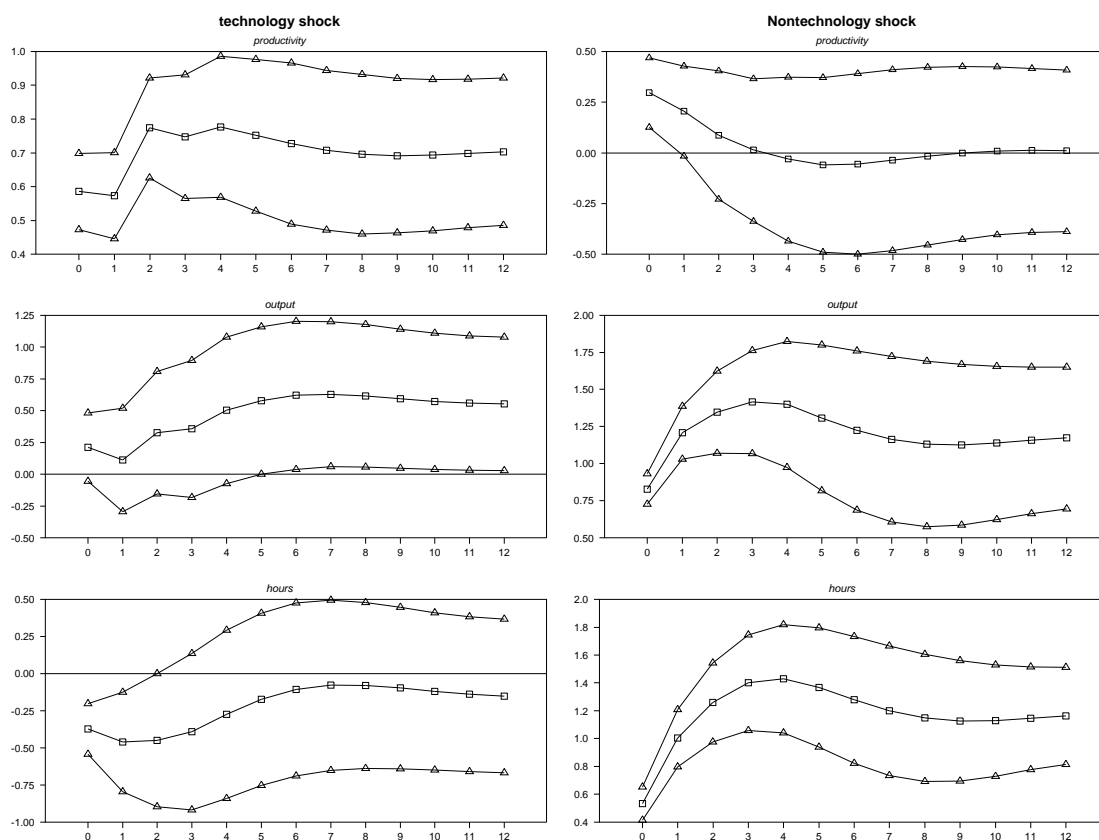
²⁰Hereafter, we use the expression positive (negative) technology-shock to refer to a technology shocks which causes a contemporaneous increase (decrease) in labor-productivity, and the expression positive (negative) nontechnology shock to refer a nontechnology shock which causes an increase (decrease) in output.

Table 1: **Correlation Estimates**

	Unconditional	Conditional	
		Tech	Nontech
USA (hours)	-0.8559** (0.3853)	0.9877 (0.8312)	-0.7434** (0.3305)
USA (employment)	-0.8559** (0.3853)	0.9877 (0.8312)	-0.7434** (0.3305)
Canada	-0.8559** (0.3853)	0.9877 (0.8312)	-0.7434** (0.3305)
United Kingdom	-0.8715 (0.6796)	-0.9963*** (0.3147)	-0.9235*** (0.1743)
Germany	-0.9686 (0.7008)	-0.9890 (0.8806)	-0.9582** (0.4497)
France	-0.7699 (0.6023)	-0.4254 (0.4413)	-0.7051** (0.3511)
Italy	-0.7699 (0.6023)	-0.4254 (0.4413)	-0.7051** (0.3511)
Japan	-0.7699 (0.6023)	-0.4254 (0.4413)	-0.7051** (0.3511)
Average(2)	-0.8693	-0.7072	-0.8317

Notes: See Notes to Table 1

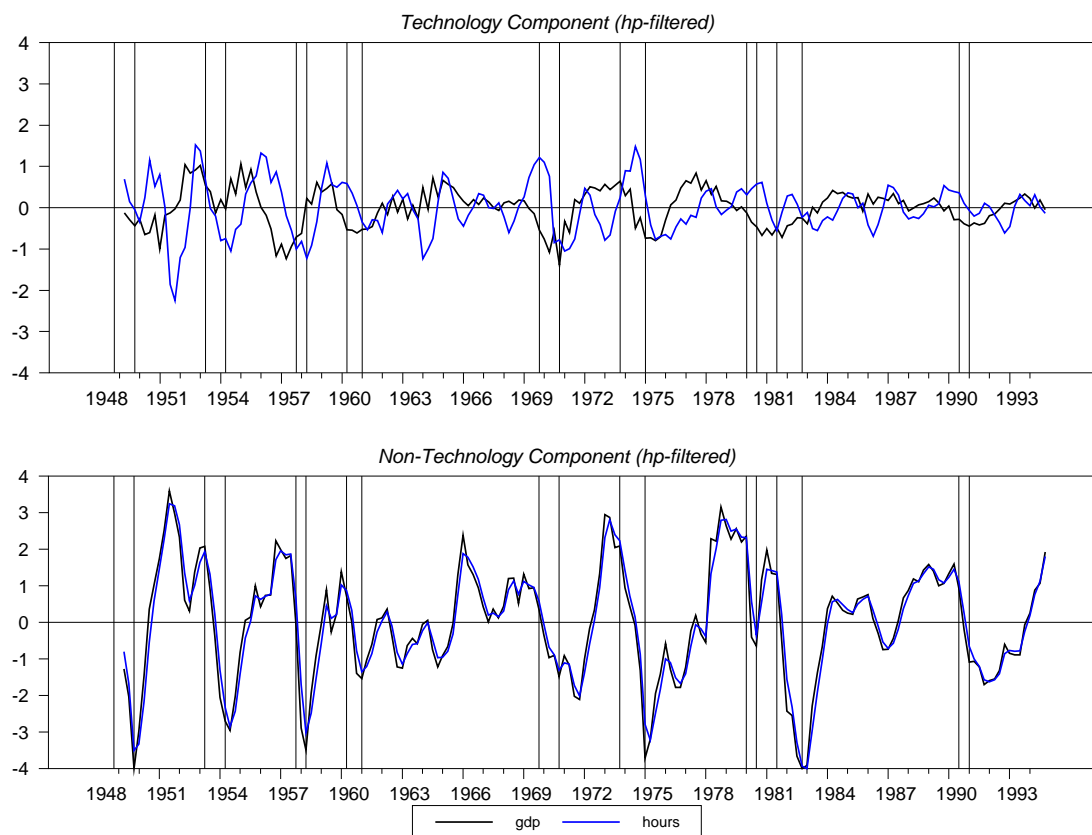
Figure 3: Response to a Technology-Shock: *Original Approach*



Notes: See Note 1 to Figure 5 and Note 4 to Figure 1.

the results for the baseline case that we reproduce as Figure 1, but he reports to have found similar results for the rest of cases). In the first place, according these estimates, only nontechnology shocks are able to account for the positive correlation between employment and output which has been traditionally considered a central feature of the business-cycle phenomenon²¹, although it is a generalization grounded so far only on the industrialized economies. In the second place, in the specific case of the US economy, the same evidence points out nontechnology shocks as responsible of the business-cycle turning-points reported by the National Bureau of Economic Research (the institution officially in charge of dating such turning-points).

Figure 4: **Technology and Nontechnology Components of US Output and Employment**



Notes: Figure 6 from Galí (1999).

²¹So, Zarnowitz 1991's authoritative survey (see Zarnowitz, 1991) about the theory and empirics of the business-cycle phenomenon, states: "...in each cycle, whether long or short, large or small, production, employment, real incomes and real sales tend to expand and contract together..."

1.3 The potential duality of oil-price shocks

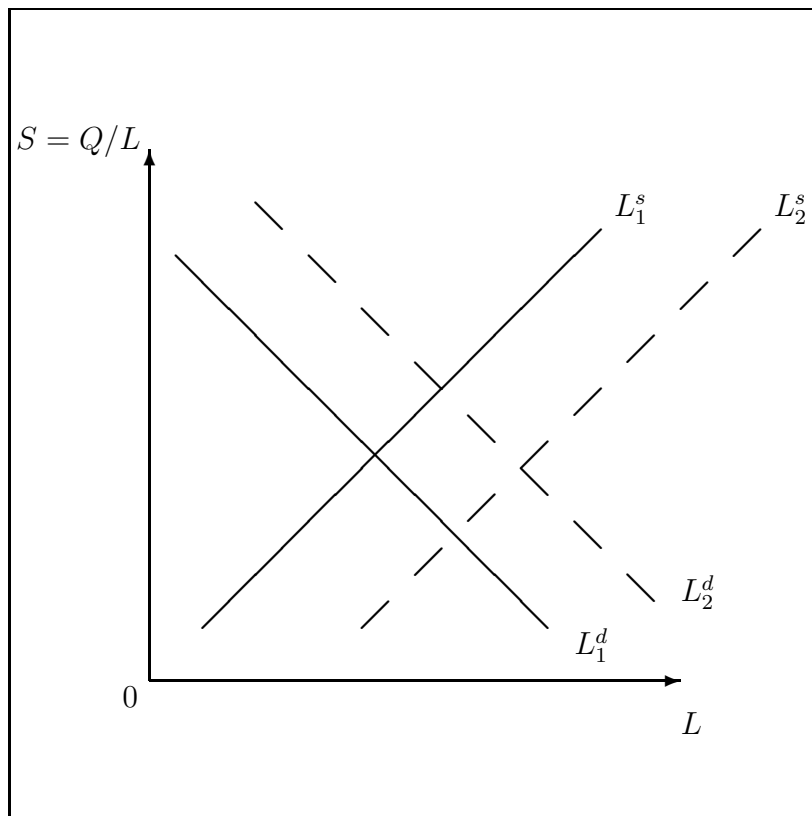
Notice, however, that the possibility of performing this neat dichotomous and exhaustive decomposition of shocks in pure technology and pure nontechnology shocks, stands on the assumption that, these two categories of shocks are actually orthogonal or uncorrelated; for one thing, otherwise at least some portion of the observed variations of employment and productivity could not be attributed to one single of these categories. In fact, McGrattan (2004) shows, on the one hand, that a multiple-shocks version of the standard RBC with parameters estimated using data for the United States do not satisfy this orthogonality assumption and, on the other, that such finding contributes to explain the misleading results produced by Galí’s methodology when applied to artificial data samples drawn by simulation from this model—notably, though by construction the model implies a positive employment-productivity correlation conditional on technology shocks, the corresponding estimate of the empirical employment-productivity correlation conditional on permanent shocks resulting from Galí’s methodology is negative.

Specifically, let’s place us in the setting of ?, and suppose there exists a third type of business-cycle-driving shock—in addition to pure technology and public-expenditure shocks—, whose nature is “dual”, in the sense that they are capable of producing simultaneously direct effects on the production-function (and, hence, on labor-demand) and on public expenditure (and, hence, on labor-supply). It follows from the results in that paper—as the introduction of these dual shocks is equivalent to make technology shocks correlates with public expenditure shocks in such setting—that the correlation between employment and productivity induced by these dual shocks (or by the category of shocks subsuming them) can be as well positive as negative, depending on the relative magnitude of their direct effects on labor-demand and labor-supply—to see it, just superimpose Figures

The central tenet of this paper is that oil-price shocks may embodying just this sort of dual shocks in the context of the oil-countries and that in front of such possibility it becomes necessary modifying Galí’s methodology by including oil-price and disentangling oil-price shocks—in the way introduced in the next section—to retain its ability to produce relevant implications against to contrast RBC-model’s predictions. On the one hand, the sizable weight of oil-income on total fiscal income in these countries, makes of each oil-price fluctuation²² a potential public expenditure shock—being the extent of materialization of this potentiality related to elements like the cyclical behavior of fiscal policy, the existence and effectiveness of oil-income saving or stabilization funds, etc. On the other hand, its sizable weight on total export income, make of each oil-price fluctuation a potential technology shock due to its potential effect on the availability of some imported input and capital goods irreplaceable or imperfectly substitutable by domestic goods—being the extent of this effect related to the degree of industrialization, the exchange policy regime, and, again, on the existence and effectiveness of oil-funds.

²²The bulk of the variance of the oil-income in US\$ is explained by the fluctuations of the oil-price in US\$.

Figure 5: **Simultaneous Labor-Supply and Demand shift**



1.4 Oil-price extended methodology

Formally, our proposal extent Galí's framework in the following way. It is assumed that the observed variations of the (log) international oil-price (expressed in US\$), p_t , (log) employment, n_t , and (log) average labor-productivity, x_t , are generated by the following multivariate moving average stochastic process,

$$\begin{bmatrix} \Delta p_t \\ \Delta x_t \\ \Delta n_{tg} \end{bmatrix} = \begin{bmatrix} r_{11k} & r_{12k} & r_{13k} \\ r_{21k} & r_{22k} & r_{23k} \\ r_{31k} & r_{32k} & r_{33k} \end{bmatrix} \begin{bmatrix} \varepsilon_{t-k}^o \\ \varepsilon_{t-k}^z \\ \varepsilon_{t-k}^m \end{bmatrix} \equiv \sum_{i=0}^{+\infty} R_i \varepsilon_t \quad (2)$$

$$\text{Such that, } \varepsilon_\tau \equiv \begin{bmatrix} \varepsilon_\tau^o \\ \varepsilon_\tau^z \\ \varepsilon_\tau^m \end{bmatrix} \sim N[0, I].$$

Where ε_τ^o represents the oil-price shocks, while ε_τ^z and ε_τ^m are redefined as to designate the oil-price-dissentangled technology and nontechnology shocks. Now the parameters to be estimated are the elements of the matrices R_i for $i = 1, 2, 3, \dots$. But having these extended model more parameters to estimate than the original Galí's model, it also requires additional restrictions to overcome underidentification, namely a minimum of two restrictions instead of one.

The natural first restriction is provided by Galí's assumption about the null long-run effects on productivity of nontechnology shocks, but now applied just to the restricted category of oil-price-disentangled nontechnology shocks. Formally,

$$\sum_{k=0}^{+\infty} r_{23k} = 0$$

On the other hand, as it is discussed below (and supported by the results of the exogeneity tests in the Appendix), we derive the additional restriction required for exact identification (and many more) from the assumption of oil-price exogeneity, i.e, from assuming that the international price of the standard bundle of oil-products (measure in US\$) is not affected in any way by the movements of the domestic level of employment or output of any of the oil-countries analyzed in this paper. This assumption translates in the following specific restrictions,

$$r_{12k} = r_{13k} = 0 \text{ for } k = 1, 2, 3, \dots, +\infty$$

As it is explained in the Appendix the resulting excess of restrictions makes the extended model overidentified, what precludes the use of the standard and straightforward estimation method employed by Galí (1999), forcing us, instead, to resort to the strategies developed by Zha (1999) to coping with the bayesian estimation of SVAR models with exclusion restrictions. The details of the estimation procedure are left once again to the Appendix.

2 Country sample selection and data issues

This section outline the criteria used to select the sample of “oil-countries” which are the focus of this paper. We define an “oil-country” as any country for which the proceeds of its oil-products-exports are a fundamental source of external and/or fiscal income.

In the first place, this definition rule out from our sample any country which is not a clear net oil-products exporter, i.e, any country whose oil-product-imports value exceeds or is just barely outweighed by their oil-product-exports value, what we do by focusing in those countries for whom the latter exceeds the former by more than 10% of the value of their total exports, namely those shown in Table 2, excepting the last nine²³.

In the second place, because the analysis to be performed consist in the decomposition of the historical variations of employment and average-labor-productivity, we must pick from Table 2 only those countries for whom employment time series data is available²⁴—namely, Colombia, Norway, Mexico, Russia, Trinidad&Tobago, and Venezuela²⁵. Finally, we must further tighten our selection to only those countries for which the net proceeds from oil-product exports have a sizable share in their total exports income and/or their total fiscal incomes, what we do by picking only those cases where one or both of these shares exceeds 25%—Table 3 shows both shares for the six countries selected so far.

All in all, the definitive sample of “oil-countries” to be analyzed comprises just five economies: Norway, Mexico, Russia, Trinidad&Tobago, and Venezuela. Figure 6 illustrates the marked differences in the oil-dependence pattern among these countries, highlighting through the bisectrix (blue line) the most remarkable and relevant of these differences for the analysis to come. For Norway, Russia and Venezuela—i.e, the countries above the line—the external dependence is much higher than the fiscal dependence, whereas for México and Trinidad & Tobago—i.e, the countries below the blue line—the opposite is true. As we’ll see this neat distinction is very convenient for the main end of our analysis, which is to unveil the potential dual nature of the effects of oil-price shocks over the business cycle.

However, there are also marked differences in the quantity and quality of the employment and output data available for these five countries²⁶, which are worth to take into account at the moment of pondering the findings for the different cases. In particular, the data for Norway is by far which better compare with the data used in Galí (1999): Norway has the most developed economy in the sample, it counts with the longest time series, and it is the only for which aggregate hours worked is available (and not only the number of people employed as in the rest of our sample), what allows a more rich and robust analysis. Therefore, we will consider Norway as our baseline case—as the United States is in Galí’s study—, hence analyzing it separately and in greater depth.

²³Table 2 includes all the countries in World Trade’s database COMTRADE, which were net exporter as of 2005—for later years the availability of country data is much reduced—plus the countries without oil-products trade data available at this source for 2005, but which are reported by the International Energy Agency’s Monthly Oil Survey among the country origins of OCDE oil-product imports in 2005.

²⁴Output data is relatively more abundant, and average-labor-productivity is obtained just by dividing output by employment.

²⁵We rely on the employment time series data available on the International Labor Organization’s database—LABORSTA—or alternatively on the central national public statistical agency.

²⁶A detailed description and analysis of the employment and output for theses five countries used in the analysis forthcoming is shown in the Appendix

Table 2: Net Oil Export by Country in 2005

Country	Share in country export,%	Share on world import,%
Lybia	97.12 ^a	2.69
Angola	94.79 ^b	2.02
Kuwait	90.27 ^c	3.75
Nigeria	88.78	1.89
Venezuela*	87.93	4.30
Saudi Arabia	86.16	13.75
Iraq	84.66 ^d	1.48
Gabon	83.11	0.37
Sudan	76.93	0.30
Iran	75.49	4.00
Yemen	72.53	0.36
Azerbaijan	72.44	0.28
Syria	65.63	0.37
Oman	64.30	1.16
Kazakhstan	61.17	1.49
Algeria	60.50	2.46
Ecuador	56.00	0.49
Qatar	49.76	1.13
Brunei Durassalam	48.91	0.18
Norway*	47.67	4.37
Russian Federation*	46.60	9.94
United Arab Emirates	43.95	4.37
Bahrain	33.56	0.30
Trinidad & Tobago*	25.10	0.21
Colombia*	24.26	0.44
Cameroon	20.35	0.04
Egypt	19.19	0.18
Netherlans Antilles & Aruba	12.76	0.01
Argentina	11.01	0.39
Mexico*	11.01	2.08
Cape Verde	8.32	0.00
Vietnam	7.92	0.23
Bulgaria	6.06	0.06
Belarus	6.03	0.09
Côte d'Ivoire	5.10	0.03
Bolivia	4.04	0.01
Denmark*	3.79	0.28
Canada*	3.20	1.01
Malaysia	2.79	0.35

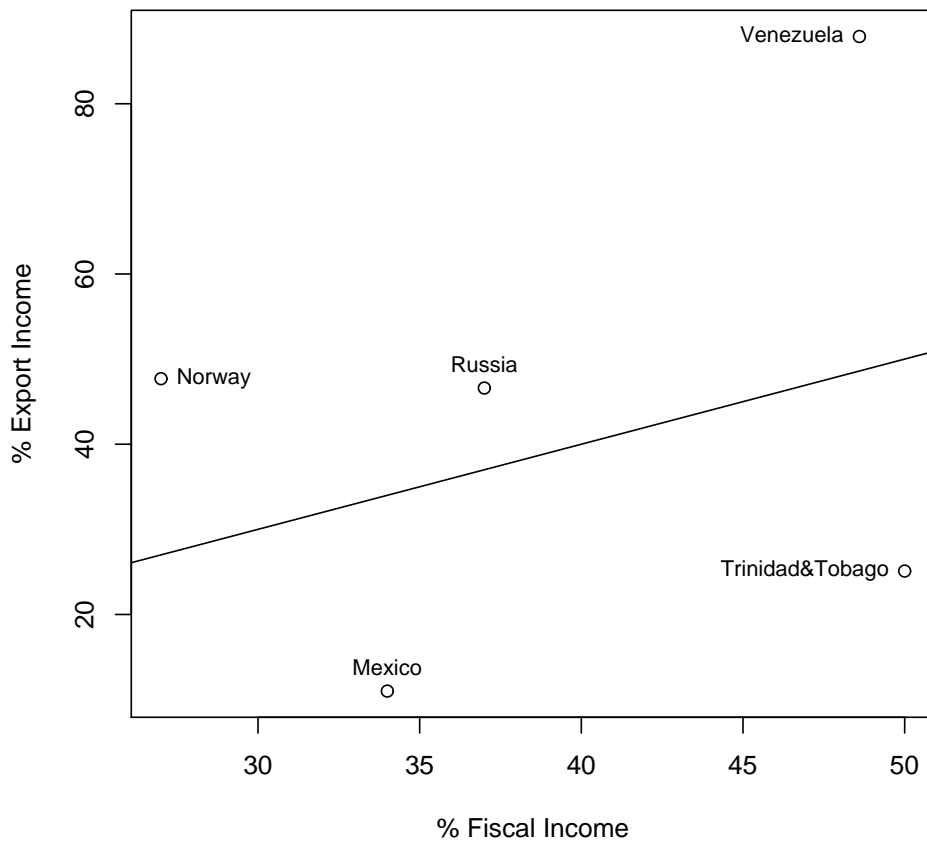
Notes: (1) The source is UN Comtrade, except by *b*, *c* and *d* that come from IMF's Country Reports, and *a* that come from the IMF Staff Visit Conclusions Report;(2) All data correspond to the year 2005, except by Nigeria (2003),Brunei Durassalam (2003),and Netherland Antilles & Aruba (1987)

Table 3: Oil-income share, 2005

Country	%Total Export Income	%Total Fiscal Income
Colombia	24.3	14.2 ^e
Norway	47.7	27.0 ^a
Mexico	11.0	34.0 ^f
Rusia	46.6	37.0 ^b
Trinidad & Tobago	25.1	50.0 ^d
Venezuela	87.9	48.6 ^c

Sources:(a) Norway Oljedirektorate, Statistics Norway; (b) IMF; (c) Exposición de Motivos, Ley de Presupuesto 2008; (d) Central Bank of Trinidad & Tobago; (e) Consejo Superior de Polifca Fiscal de Colombia, Cierre Fiscal 2005 (f) Informe Primer Trimestre 2006, Secretaria de Hacienda y Crédito Público de Mexico.

Figure 6: Importance of Oil-income



3 Empirical results for the Oil-countries

This section presents and discuss the results from the application of Galí’s methodology both in its original and oil-price extended versions to the selected sample of oil-countries²⁷. In the following analysis, based on the criteria described in the Appendix, in all the cases, excepting Mexico, (log)employment is treated as a trend-stationary series, hence the corresponding bivariate-SVAR includes the first-difference of (log)productivity and the deviations of (log)employment respect to a linear-trend. In the case of Mexico, (log)employment is treated as a I(1) series instead, therefore the corresponding SVAR includes the first-difference of both (log)productivity and (log)employment.

However, in the robustness analysis included in the Appendix, there are reported the results from applying Galí’s methodology with an alternative treatment of employment (namely, assuming employment as trend-stationary in the case of Mexico, and as I(1) in the rest of cases), or in the case of Norway using hours instead of employment (treating them alternatively as trend-stationary and I(1)). In all cases, the results from these alternative specifications turn to confirm the main findings of this section.

The analysis starts by analyzing Norway (our baseline case) and then proceeds to compare its results with that from the rest of the oil-countries in the sample.

3.1 Baseline case

3.1.1 Original methodology

Norway is not an exception to Galí (1999)’s central findings about the unconditional and conditional correlation between employment and productivity—though, in one case, the norwegian findings are a bit less conclusive. On the one hand, as shown by the first row of Table 4, the unconditional correlation is negative and statistically significant, in contrast with the standard single-shock standard RBC model’s prediction. On the other hand, as shown in the second and third rows from the first column, the conditional correlation estimates resulting from the application of Galí’s methodology to the norwegian case are negative and statistically significant conditional on technology shocks and positive (though, unlike Galí’s findings, not statistically significant) conditional on nontechnology shocks.

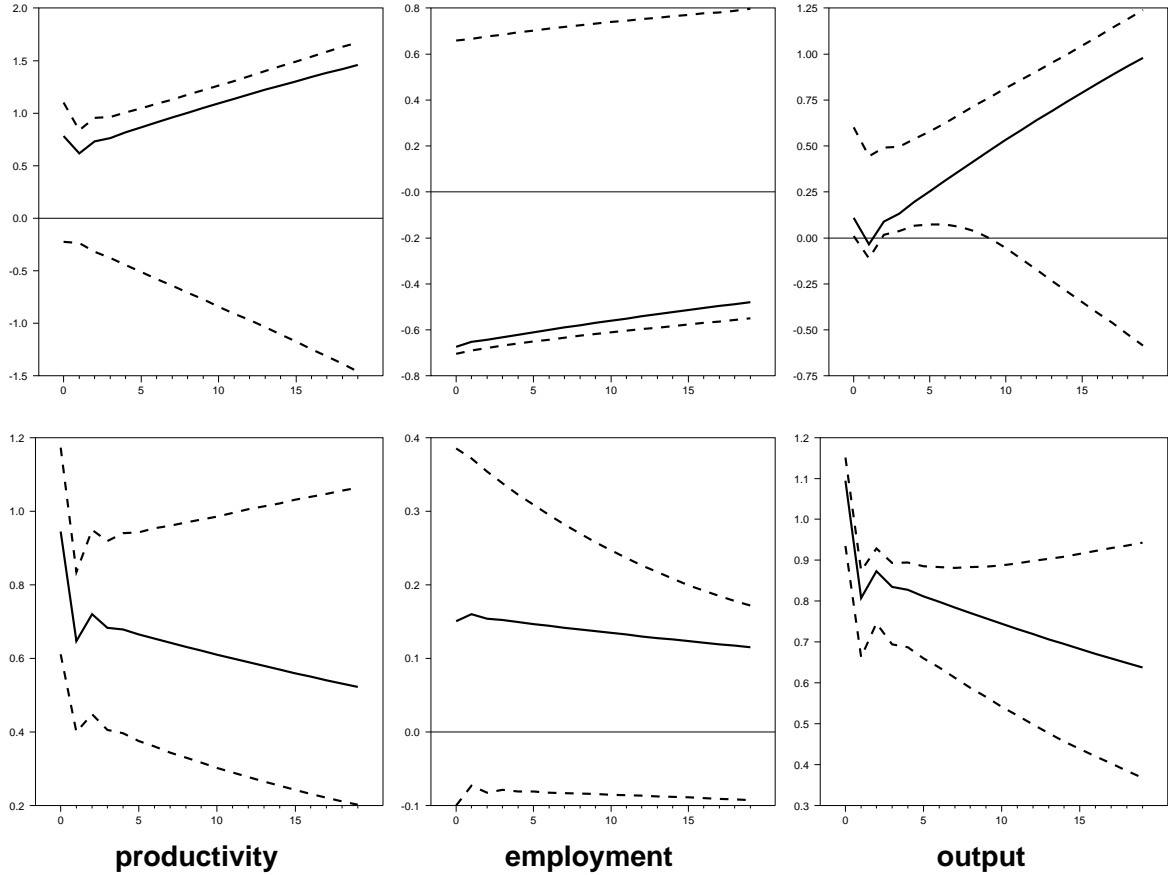
In the same way, findings about impulse-response functions are roughly consistent with Galí’s findings, but they are much more uncertain. The point estimates for the impulse-response functions—i.e, the estimates of the mean response of each variable to each shock—, as shown in Figure 7, reflect well the sign of the conditional correlation point estimates, being in this sense equally consistent with Galí’s findings—in particular, they show that a positive technology shock produces on average a reduction of the norwegian employment, whereas a positive nontechnology shock produces on average a increase of the norwegian employment. However, these results are not only, as in Galí study-cases, inconclusive about the long-run responses, but they are also inconclusive about the short-run ones, for the uncertainty associated to them is so big at all horizons—i.e, the width of the confidence intervals shown is so large—that they don’t exclude the possibility of a short-run increase of

²⁷The results from an early similar application to the Venezuelan economy appear in Manzano et. al. (2008)

employment in response to a particular positive technology shock or a short-run reduction of employment in response to a particular positive nontechnology shock.

Finally, Figure 8 focuses on the kind of evidence used by Galí to discern which, between technology and nontechnology shocks, is the main source of the output fluctuations in the business cycle frequencies, namely: to check which of them appears to be responsible for the positive correlation between the cyclical components of the historical path of output and employment that is conventionally held as a definitional feature of the business-cycle phenomenon. Clearly, in the case of Norway, as in the cases analyzed by Galí, the responsibility is borne by the nontechnology shocks.

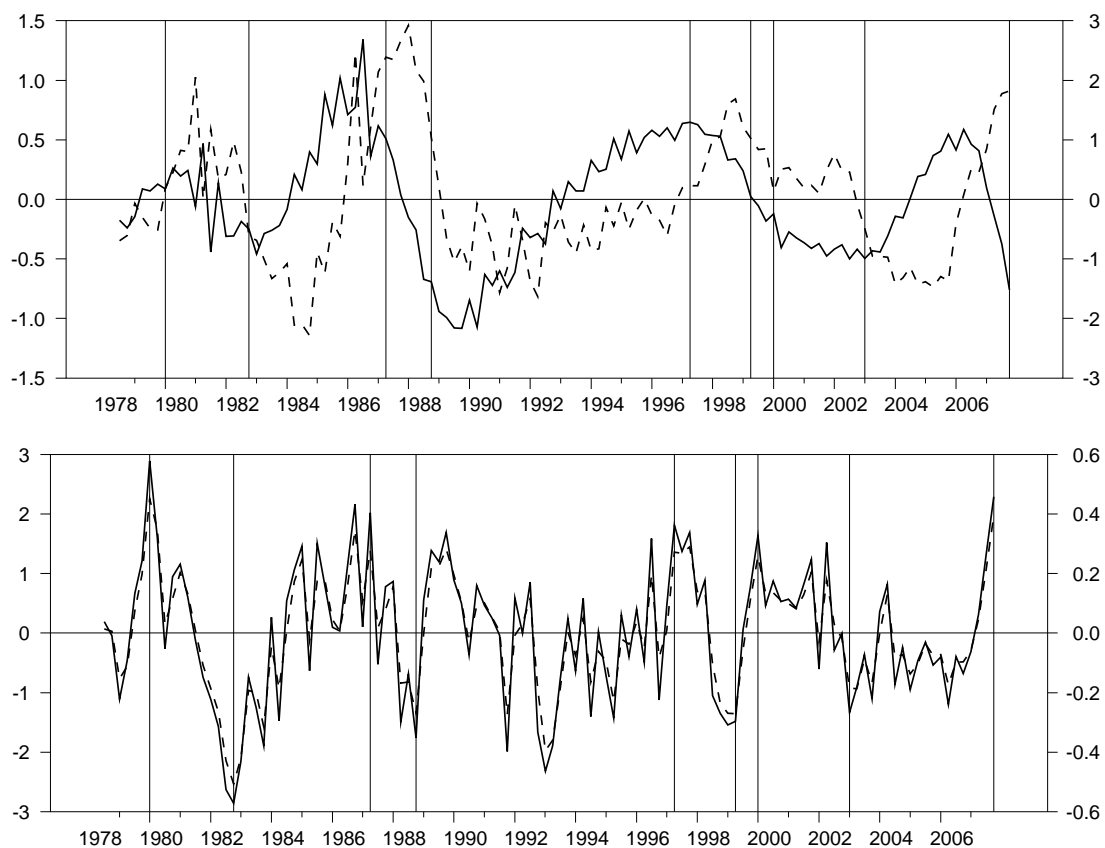
Figure 7: Norway's IRFs with Bands: *Original Approach*



Notes:

1. The first row shows the responses to a technology-shock, and the second, to a nontechnology-shock.
2. The continuous line in the middle of each graph correspond to the (posterior)mean response of the endogenous variable at the top of the column to the corresponding shock—Which, in our context, is identical to the usual maximum likelihood point estimate of the response.
3. The broken lines correspond to the fractiles 16 % and 84 % of the posterior distribution of the responses at each horizon(which would correspond—roughly— to an interval of \pm one-standard-deviation around the mean if the distribution were—approximately— Gaussian).
4. Each shock size is normalized to produce a one-standard deviation impact at the first period on a particular endogenous variable (technology-shock on average labor-productivity, and nontechnology-shock on employment).

Figure 8: Norway's Output & Labor: *Original Approach*



Notes:

1. The graph show the technology(first row) and nontechnology(second row) components of the historical fluctuations of output(continuous line) and employment(broken line) at Business Cycle frequencies(extracted with the standard Hodrick–Prescott Filter).
 2. The vertical lines are the turning–points(peaks and troughs) of output fluctuations at Business Cycle frequencies estimated using the algorithm of Bry and Boschan(1971), which tries to approximate–in an aothomatic fashion– the Business Cycle dating procedure used by the National Bureau of Economic Research in the case of the United States.
-

3.1.2 Extended methodology

The second column (last two rows) of Table 5, shows the conditional correlation estimates resulting from the application to the norwegian case of the oil-extended version of Galí’s methodology. The first thing to remark is that the extended methodology, like the original one, produces results similar but a bit less certain than Galí’s findings—though we must keep in mind that in the extended methodology technology and nontechnology shocks are cleanse out from oil-price shocks and hence they are narrower categories of shocks. On the one hand, the norwegian employment-productivity correlation is negative and statistically significant conditional on technology shocks and positive (though, unlike Galí’s finding, not statistically significant) conditional on nontechnology shocks. The second thing remarkable, is that the estimate for the employment-productivity correlation conditional on oil-price shocks is starkingly similar to the one conditional on technology shocks—not only these correlations are both negative and statistically significant but they are of a similar magnitude too. When it comes to compare impulse-response functions estimates(see Figure 9), the results from the application to Norway of the original and extended methodology are also very similar: while mean responses to technology and nontechnology shocks reflect the sign of the conditional correlations point estimates, their confidence bands are so wide that the results cannot be considered any conclusive not only in the long-run, as in Galí’s cases, but also in the short-run. However, results do are conclusive about the short, medium and long-run responses to an oil-price shock: the confidence bands only give room for a persistent increase in productivity and a persistent reduction in employment in response to a positive oil-price shock.²⁸

Finally, Figure 10 shows that the business-cycle components of the historical path of output and employment resulting from the extended methodology also support the hypothesis that nontechnology shocks (now oil-price disentangled) are responsible for the positive correlation between output and employment in the business-cycle frequencies. However, there is a puzzling difference with the results from the original methodology: while the business-cycle component of employment driven by technology shocks is fairly similar under both methodologies (second row of Figure 4), the business-cycle component of output is rather different—fairly fluctuating under the original methodology, but extremely smooth under the extended methodology—, what seems a direct consequence of disentangling the components associated to oil-price shocks (first row of Figure 4), specifically: oil-price shocks account, under the extended methodology, for most of the variability of output which technology shocks explain under the original methodology, leaving (oil-price disentangled) technology shocks accounting now only for the ouput fluctuations in the lowest business-cycle frequencies.

This seemingly puzzling finding is probably the consequence of narrowing the set of technology-shocks in such a way that the category becomes closer to the subset of shocks more properly technological²⁹ and as such, following the traditional view of business-cycle

²⁸Hereafter, we use the expression positive (negative) oil-price shock to refer to a persistent increase (decrease) of the oil price.

²⁹Literally speaking the label “technology shocks” should refer to changes in the productivity derived from the diffusion of the advances in scientific knowledge and its applicatios, however in the business cycle literature its meaning is much broader, including any external forces inducing changes in the productivity of the available quantities of capital and labor, as it can be the case of fluctuations in the terms of trade given their potential effects on the affordability of some irreplaceable imported industrial inputs.

Table 4: **Norway's Labor and Productivity: *Original approach***

	<i>Correlation</i>
Unconditional	−0.4264*** (0.1457)
Conditional on Technology shocks	−0.9354*** (0.2864)
Conditional on Nontechnology shocks	0.9256 (0.8051)

Notes:

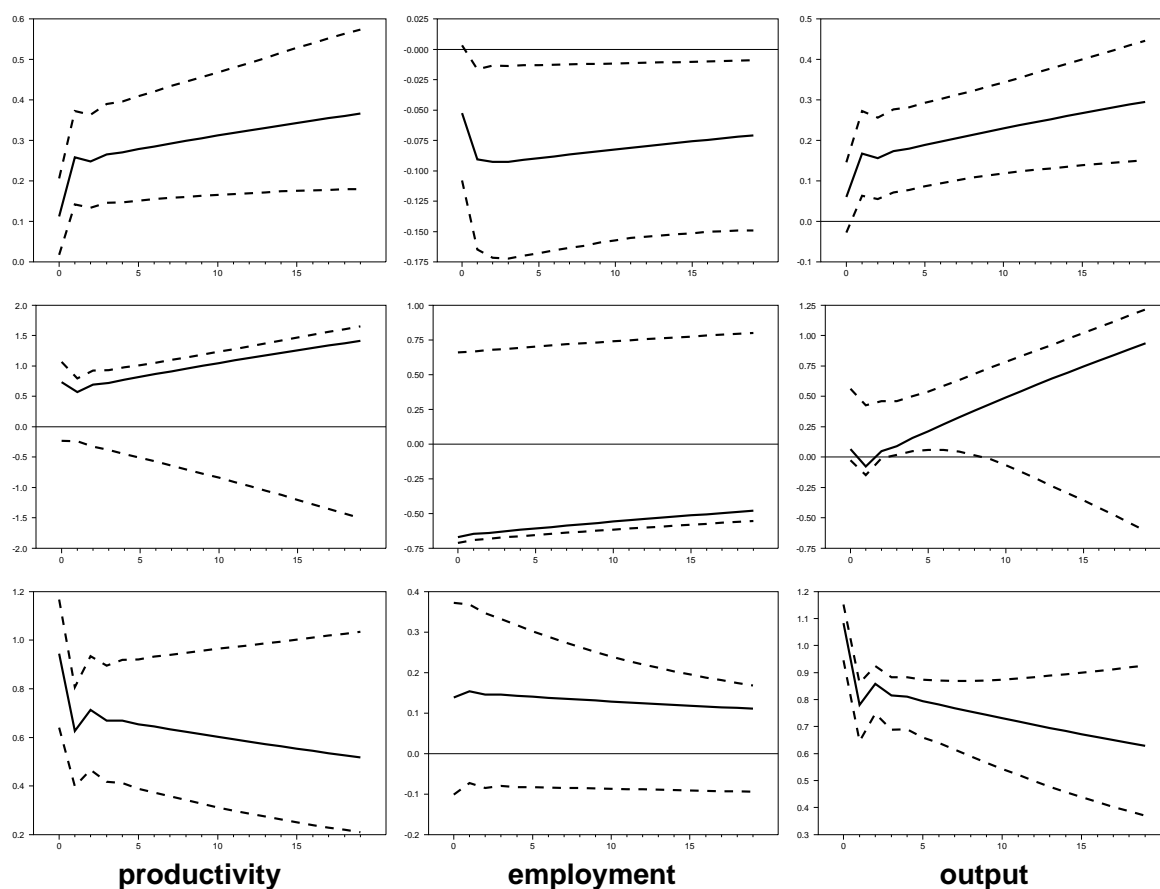
- The table shows the correlation between the growth rates of output and employment.
- In parenthesis, standard errors.
- The marks ***, **, and * indicates a 1%, 5% and a 10% significance levels respectively.

Table 5: **Norway's Labor and Productivity: *Oil-shocks disentangled***

	<i>Correlation</i>	
	Original approach	Oil-shocks disentangled
Unconditional	−0.4264*** (0.1457)	−0.4264*** (0.1457)
Conditional on Technology shocks	−0.9354*** (0.2864)	−0.9292*** (0.2872)
Conditional on Nontechnology shocks	0.9256 (0.8051)	0.8926 (0.8104)
Conditional on Oil-price shocks	— —	−0.9279** (0.4412)

Notas: See Notes to Table 1.

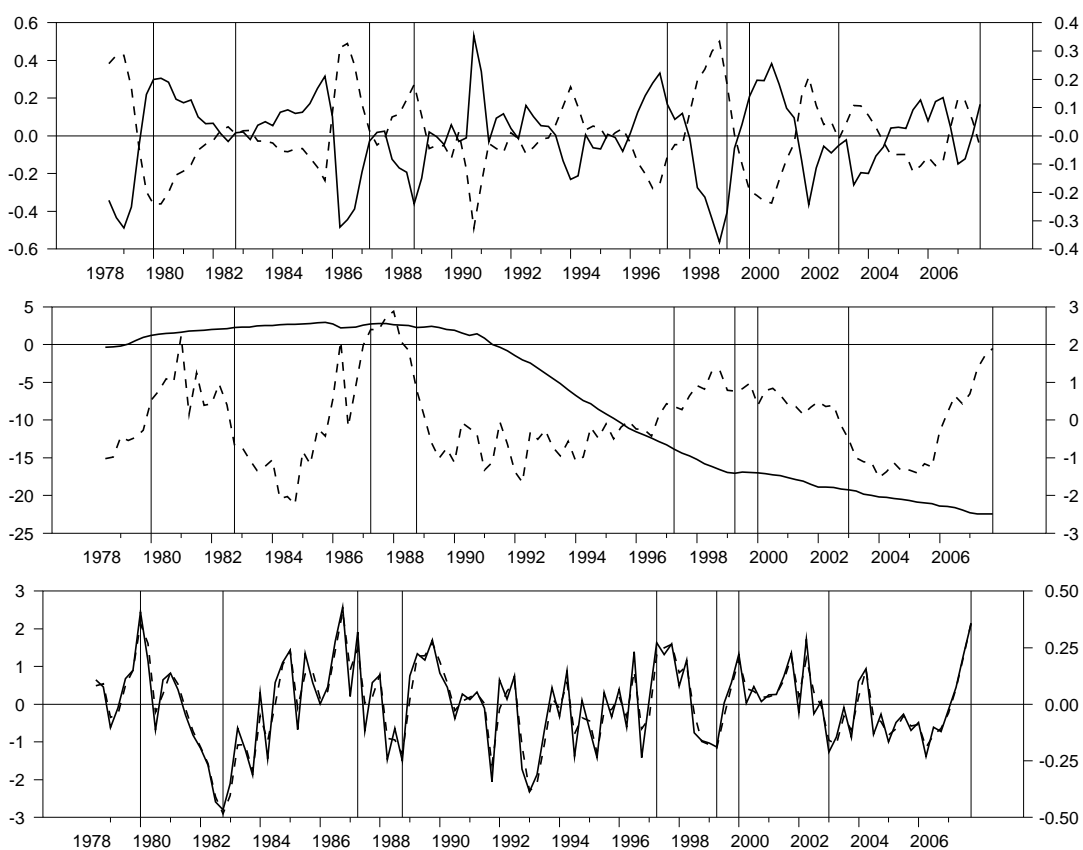
Figure 9: Norway's IRFs with Bands: *Oil-shocks disentangled*



Notes:

1. The first row show the responses to an oil shock; the second, to a technology-shock; and the third, to a nontechnology-shock.
 2. The continuous line in the middle of each graph correspond to the (posterior)mean response of the endogenous variable at the top of the column to the corresponding shock—Which, in our context, is identical to the usual maximum likelihood point estimate of the response.
 3. The broken lines correspond to the fractiles 16 % and 84 % of the posterior distribution of the responses at each horizon(which would correspond—roughly— to an interval of \pm one-standard-deviation around the mean if the distribution were—approximately— Gaussian).
 4. Each shock size is normalized to produce a one-standard deviation impact at the first period on a particular endogenous variable (oil-shock on oil-price, technology-shock on average labor-productivity, and nontechnology-shock on employment)
-

Figure 10: Norway's Output & Labor: *Oil-Shocks disentangled*



Notes:

1. The graph shows the oil (first row), technology (second row) and nontechnology (third row) components of the historical fluctuations of output (continuous line) and employment (broken line) at Business Cycle (BC) frequencies (extracted with the standard Hodrick–Prescott Filter).
 2. See Note 2 to Figure 2.
-

and growth students, these are shocks more associated to the long-run behavior of output than with the business-cycle fluctuations—even less with the high frequency fluctuations. As we'll see in the next subsection this interpretation would take even more force when we consider the structural change associated to the introduction of the norwegian oil-fund: then the fluctuations of employment associated to technology shocks become, like the fluctuations of output, much smoother after disentangling oil-price shocks. All in all, the findings for Norway resulting from both versions of Galí's methodology have several implications. In the first place, they justify the concerns that motivates our oil-price extension of Galí's methodology: the original methodology would tangle oil-price shocks and pure technology shocks when applied to oil-countries because in such context both shocks share what the methodology assumed to be the distinguishing feature of pure technology shocks: their permanent effect on productivity. In the second place, the fact that even after disentangling oil-price shocks, a positive technology shock keeps producing, at least on average, a reducing effect on employment and a positive nontechnology shock keep producing an increasing effect on employment—both effects in line with the previous empirical findings by Galí—not only rule out the possibility of conciliating such effects with the multiple-shocks standard RBC model's predictions by arguing that it can be explained by the tangled direct effects of oil-price shocks on public expenditure, but also suggests that the effects produced by a positive oil-price shock—i.e, an increase of productivity and a reduction in employment—cannot arise from their impact on aggregate demand (most likely through their impact on public expenditure) but instead they should arise from their impact on the production function (most likely through their effect on the affordability of imported inputs and capital goods), i.e, the oil-price shocks effects on Norway's Business-Cycle, seems to be dominated by those arising from the technology-shock nature of oil-price fluctuations. Additionally, the latest suggestion has the implication of making of oil-price-shocks, in the context of Norway's economy, an example of an observable type of technology shock, whose analysis serves to contrast and assess the robustness—favorably, as it came to be—of the results about the effects of the non-observable technology shocks which are the main focus of Galí's methodology.

3.1.3 Norway's *Oljefond*

The application of the extended methodology above, neglect the commonly alleged structural changes presumably produced by the introduction of the Norway's Oil Fund (the *Oljefond*) in 1990³⁰ on the effects of oil-price shocks on the norwegian macroeconomic variables³¹. To account for and explore the consequences of this potential structural change, this subsection analyze the results from splitting Norway's data in two subsamples—1978Q1-1989Q4 and 1990Q1-2007Q4—corresponding to the periods before and after the introduction of the *Oljefond* (hereafter, labeled the pre-*Oljefond* and post-*Oljefond* periods, respectively), and apply the oil-price extended Galí's methodology to each subsample in turn³², producing two new models and set of results.

The results concerning the conditional correlation between employment and productivity from both sub-sample models are shown in Table 6. The only remarkable difference with the results from the whole-sample model is the lost of statistical significance of the negative correlation between employment and productivity conditional on oil-price shocks after the introduction of the *Oljefond*—what gives some support to the assertion that the fund, and perhaps other concurrent institutional reforms, has reduced the vulnerability of Norway's economy to oil-price fluctuations. However, we must be cautious about this interpretation; for one thing, oil-price's volatility has been substantially different in both subperiods.

Table 6: **Norway's Labor and Productivity**, and the *Oljefond*

	<i>Correlation</i>	
	Before <i>Oljefond</i>	After <i>Oljefond</i>
Conditional on Technology shocks	−0.9354*** (0.2864)	−0.9292*** (0.2872)
Conditional on Nontechnology shocks	0.9256 (0.8051)	0.8926 (0.8104)
Conditional on Oil-price shocks	— —	−0.9279** (0.4412)

Notes: See Notes to Table 1

As shown in Figure 11, the point estimates of the impulse responses from each sub-sample model are also qualitatively similar to those resulting from the whole-sample model—i.e, they show patterns consistent with the sign of the conditional correlations—, except for the contemporaneous response to a positive oil-price shock from the post-³³ model, which approaches

³⁰The fund experienced a reform in 2006, evolving in an oil-income financed pensions fund (the *Staten Pensjonsfond*), however, hereafter the change of label is neglected.

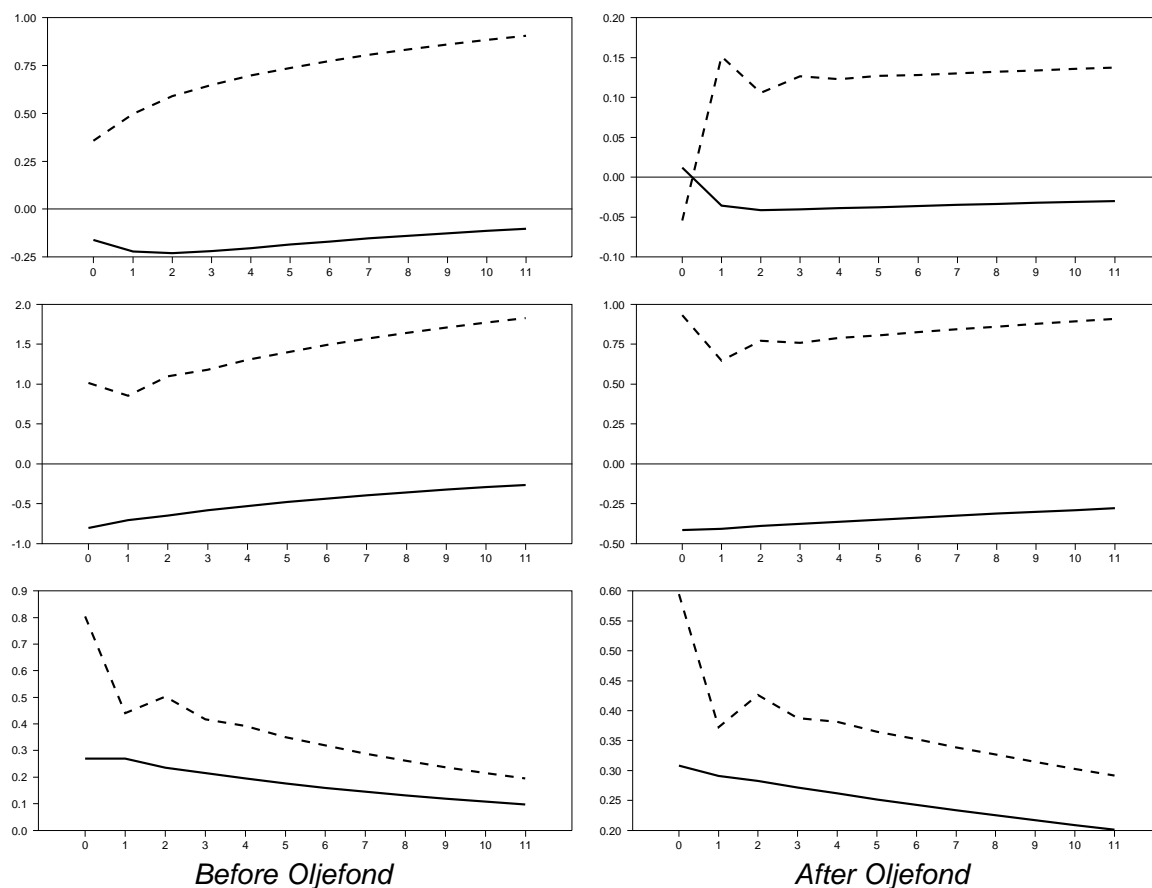
³¹As a matter of fact, most studies about the role of institutions in the optimal management of nonrenewable resources highlight Norway's last-decades institutional reforms, and specially its Oil fund, as the most successful and paradigmatic case. See for example Davis et al. (2001) and IMF (2007).

³²The results being similar in all the remarkable aspects discussed below, to the unreported results from applying instead the original version of the methodology to each subsample

³³Oljefond

to zero and shows a pattern inconsistent with the sign of the employment-productivity correlation conditional in oil-price shocks, namely, on average employment slightly increase and productivity slightly decrease immediately (i.e, in the same quarter) after a positive oil-price shock. But where the most remarkable difference arises is in the uncertainty around these

Figure 11: Norway's Labor & Productivity response



Notes:

1. The broken line is the (posterior)mean response of labor productivity, and the continuous one the (posterior)mean response of employment.
2. See Notes 1 and 4 to 3.

impulse-response point estimates (see Figures 12 and 13): while the results for the post-³⁴ model are as ambiguous as those for the whole-sample model and even more in the case of the response to oil-price shocks (i.e, the confidence bands are so wide that do not allow discharge almost any pattern of responses to whatever shock), the results for the pre-³⁵ model

³⁴Oljefond

³⁵Oljefond

are unambiguous—namely, the confidence bands only include the possibility of a (persistent) drop in employment and a persistent rise in productivity and output in response to both a positive technology-shock and a positive oil-price shock, and only include the possibility of a (persistent) increase in employment and a persistent rise in productivity and output in response to a positive nontechnology-shock.

Finally, Figures 14 and 15 show the historical business-cycle components of output and employment associated to each shock from the pre-*Oljefond* model and post-³⁶ model. As for the whole-sample model, nontechnology shocks appear very clearly as the cause of the positive correlation between output and employment in the context of both sub-sample models, in agreement with Galí’s finding. Besides this coincidence, several remarkable differences arise respecting the behaviour of the business-cycle components associated to technology and nontechnology shocks.

While the results from the post-*Oljefond* model do not show noticeable differences with those from the whole-sample model apart from the substantial reduction of the magnitude of the fluctuations of output and employment associated to oil-price shocks (in line with the lost of significance of the corresponding conditional correlation); the pre-*Oljefond* model produce, in the one hand, much smoother output and employment fluctuations in association with oil-price shocks (more in line with technology shocks), and, in the second hand, it also produce much smoother employment fluctuations in association to technology-shocks which match better with the even smoother output fluctuations associated with these shocks according to both the whole-sample and before-*Oljefond* models.

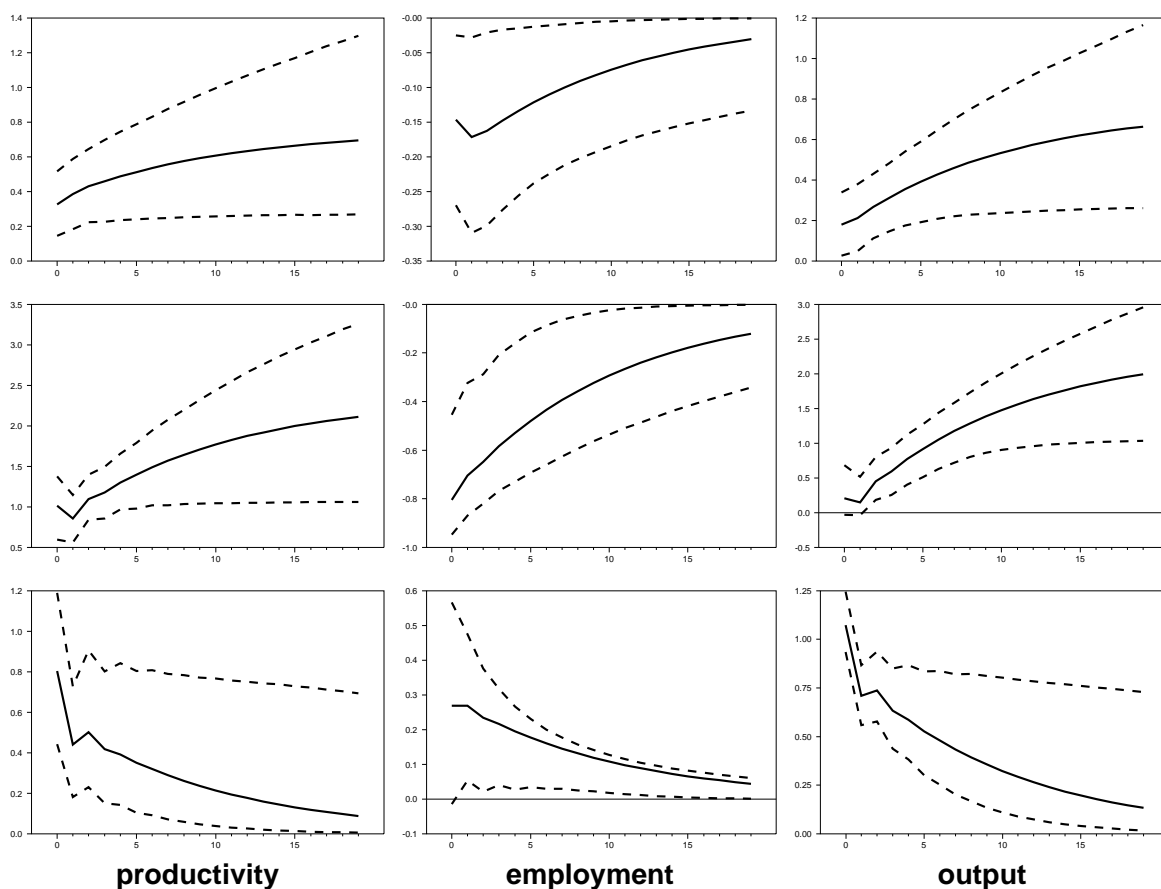
The results from the sub-sample models reassert and expand the implications derived at the end of the previous subsection. In the first place, they show the robustness to the potential structural change of the economy caused by the introduction of the *Oljefond* of the main findings underlying such implications—the negative (positive) employment-productivity correlation conditional on technology (nontechnology) shocks, the concomitant decreasing (increasing) average-response of employment and increasing average-response of productivity to a positive technology (nontechnology) shock, and the absolutely dominant role of nontechnology shocks in producing the positive correlation between employment and output in the business-cycle frequencies. In the second place, by smoothing out the business-cycle historical fluctuations of employment associated to technology-shocks in line with those of output, these results increase the support for the hypothesis that the resulting oil-price disentangled technology shocks, are really a good estimate of the narrow-category of technology shocks associated with the advance of science and technology that business-cycle and growth students have traditionally associated mainly with the medium and long-term evolution of the economy.

Besides, these results help to delineate better the previous findings about the role of oil-price fluctuations in Norway’s business cycle and, additionally, shed some light on the influence of institutions on that role. In the first place, as already noted, the lost of statistical significance suffered by the oil-price-shocks conditional employment-productivity correlation when the estimation-sample is change from the pre-*Oljefond* period to the post-*Oljefond* period, gives support to experts’ common belief in the short-run insulation experienced by the norwegian economy with respect to oil-price shocks. In the second place, the much increased

³⁶Oljefond

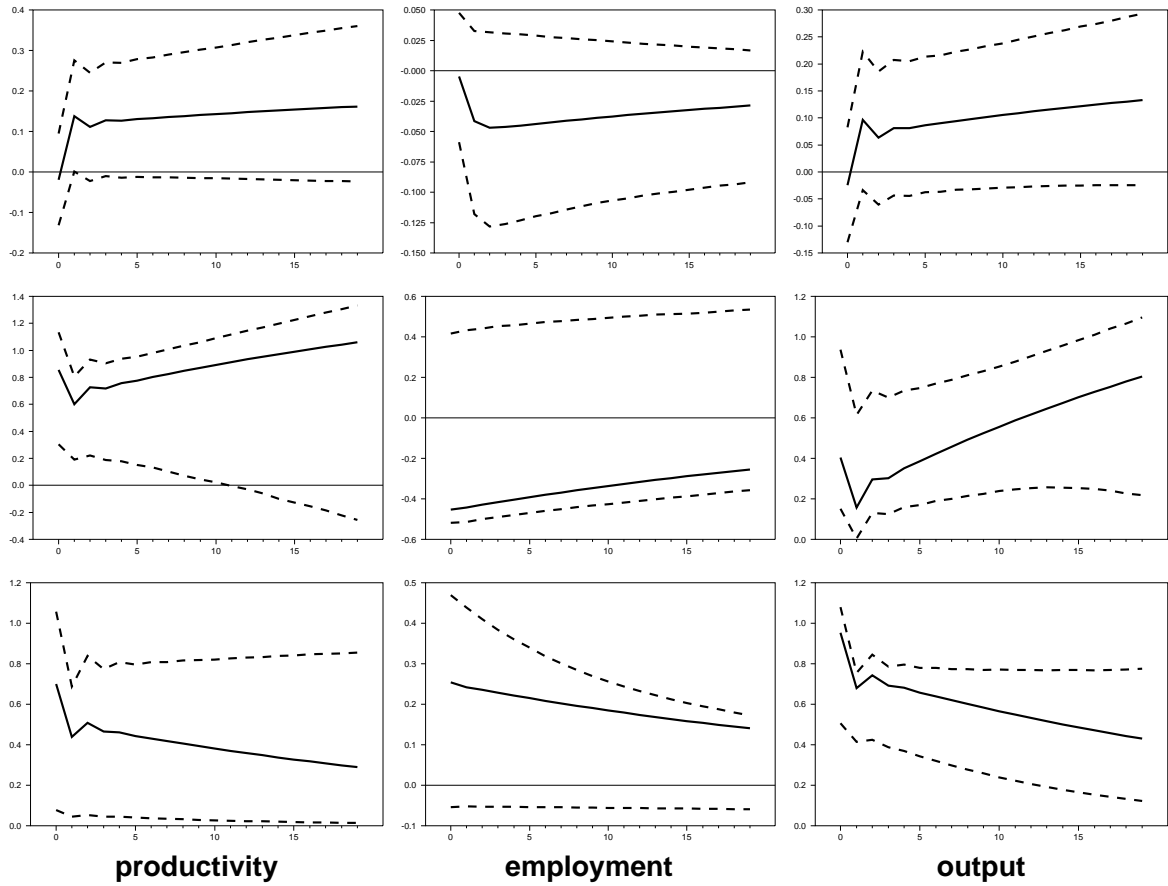
smoothness shown by the business-cycle components of output and employment associated with oil-price shocks in the pre-*Oljefond* period (i.e, in the only subperiod where oil-price shocks appear to have any significant role on Norway’s Business-Cycle), added to the even higher smoothness of the cyclical components associated with the (oil-price disentangle) technology shocks (in the context of both sub-sample models), draw a picture highly consistent with the common (New-keynesian) view of nontechnology shocks explaining the bulk of Business-Cycle fluctuations at the lowest frequencies, at the same time that technology-shocks in the narrow sense (i.e, those shocks closely linked to the advance of knowledge) would explain only, if any, just the lowest frequencies of the Business-Cycle—leaving oil-price shocks only a significant role in the middle frequency business-cycle fluctuations.

Figure 12: Norway’s IRFs with Bands: Before *Oljefond*



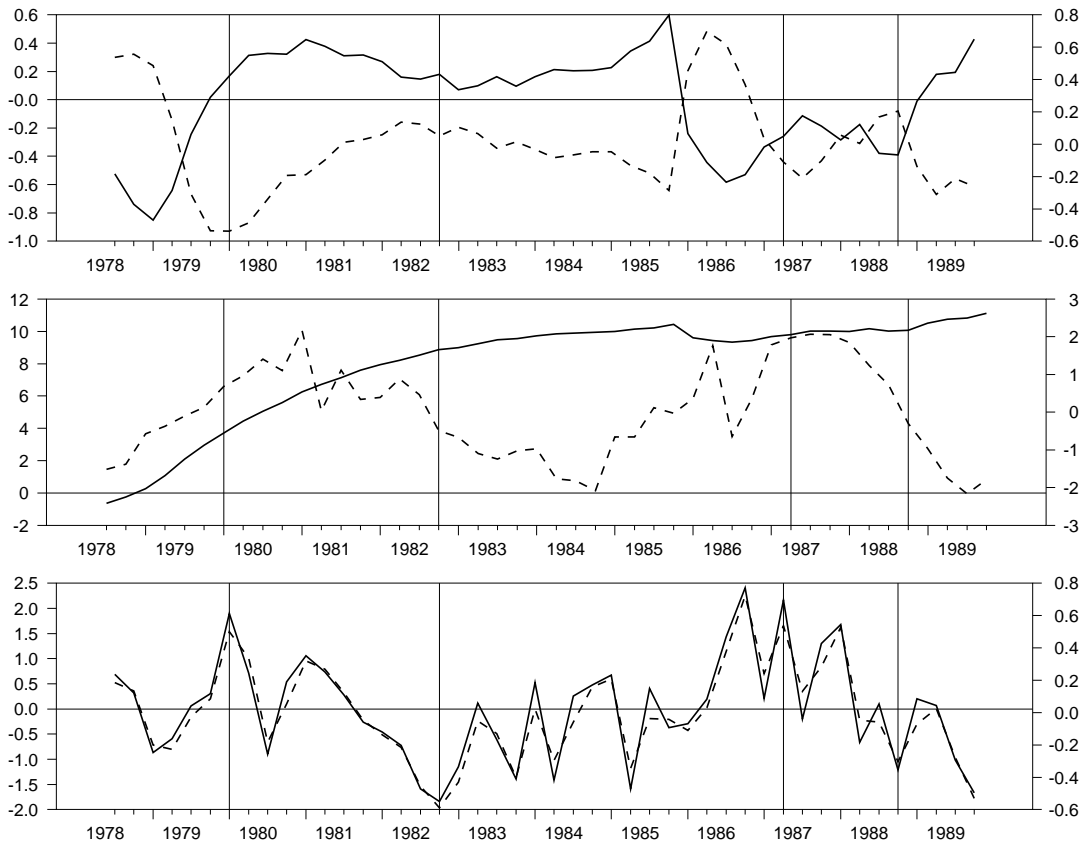
Notes: See Notes to Figure 3.

Figure 13: Norway's IRFs with Bands: After *Oljefond*



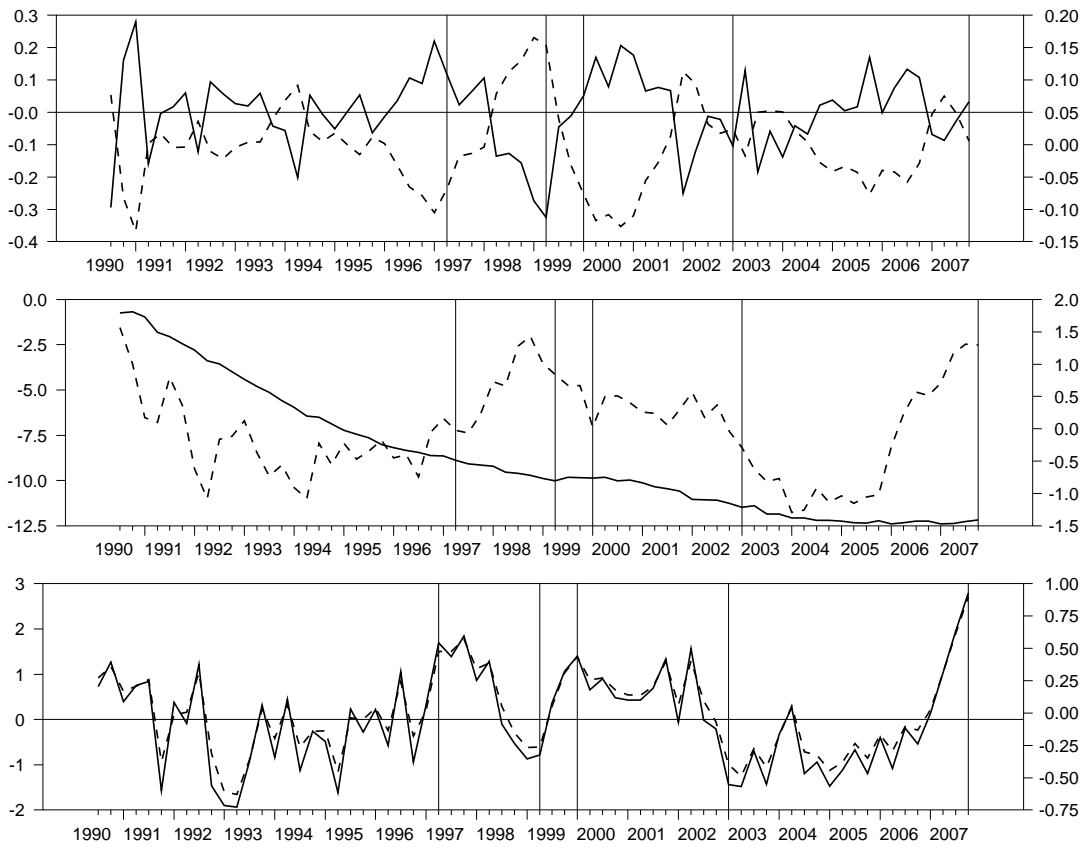
Notes: See Notes to Figure 3.

Figure 14: Norway's Output & Labor: Before *Oljefond*



Notes: See Note 1 to Figure 4 and Note 2 to Figure 2

Figure 15: Norway's Output & Labor: After *Oljefond*



Notes: See Note 1 to Figure 4 and Note 2 to Figure 2.

3.2 Comparison with other Oil–countries

In this section, the previous analysis is extended to the whole set of oil-countries in our sample (see Subsection X)³⁷, comparing the new results with those got for Norway and by Galí. It is convenient to state from the outset, that in the forthcoming analysis it will be of great help to recall the dichotomic classification of these oil-countries according to the nature of their oil-dependence, namely: while for Norway, Russia and Venezuela the oil-income share on total export-income is much bigger than its share on total fiscal-income (i.e, they are chiefly externally oil-dependent countries), the opposite happens in the cases of Mexico and Trinidad & Tobago (i.e, they are chiefly fiscally oil-dependent countries).

Let's start once again by the core of Galí's approach: the analysis of the unconditional and conditional correlation estimates. In the first place, Table 7 shows that the estimates for the employment-productivity unconditional correlation are in all cases consistent with Galí's findings in that they are either statistically significant and negative (Norway, Russia, and Trinidad & Tobago) or not statistically significant (Mexico and Venezuela), hence these caes are also at odds with the predictions of the basic (i.e, single-shock) standard RBC model. In the second place, the first and third columns of Table 8 shows that, while the estimates for the employment-productivity correlation conditional on technology shocks from the original and extended methodology coincide in all cases, in line with Galí's findings, in their negative sign; only under the extended methodology these estimates became, as in Galí's analysis, statistically significant.

In turn, the second and fourth columns of the same table shows that the estimates for the productivity-employment correlation conditional on nontechnology shocks, unlike Galí's empirical findings, are under both methodologies mostly statistically not significant and just in one case—under the original methodology— statistically significant but negative. Finally, the last column of the table shows that there exists a marked contrast among oil-countries respect the estimates of the employment-productivity correlation conditional on oil-price shocks: in the one hand, for Norway, Russian and Venezuela—i.e, the chiefly externally-oil-dependent countries—these estimates are significant and negative; in the other, for Mxico and Trinidad & Tobago—i.e, the chiefly fiscally-oil-dependent countries—these estimates are positive and in the case of Mexico, also statistically significant.

As expected, the impulse-responses point-estimates reflect the sign of the conditional-correlations estimates underlied by them. Firstly, in line with Galí's findings, Figures 16 and 17, shows that for all countries, under both the original and extended methodology, productivity and employment move on average in opposite directions in response to a technology shock—though in some cases the effect on employment fades out quickly. Secondly, Figures 18 and 19, show mixed results about the direction of the responses to a nontechnology shocks: while, under the original methodology, only for one country the employment and productivity move clearly, in line with Galí's findings, in the same direction; under the extended methodology this result generalized to the bulk of countries, leaving Russia as the only exception.

Finally, Figure 20, shows heterogenous results concerning the direction of responses of employment and productivity to an oil-price shock: while in the countries which are mainly externally oil-dependent employment and productivity move in the opposite direction (though

³⁷That is, besides Norway: Mexico, Russia, Trinidad & Tobago, and Venezuela.

Table 7: Unconditional Correlations

<i>Country</i>	<i>Correlation</i>
Norway:	
• Whole sample	−0.4264*** (0.1457)
• Pre- <i>Oljefond</i>	−0.5060*** (0.1644)
• Post- <i>Oljefond</i>	−0.3350 (0.2615)
Venezuela	0.1322 (0.2572)
Russia	−0.6126** (0.2454)
Average(1)	−0.3023
Trinidad&Tobago	−0.4446** (0.1819)
Mexico	−0.2611 (0.1805)
Average(2)	−0.3529

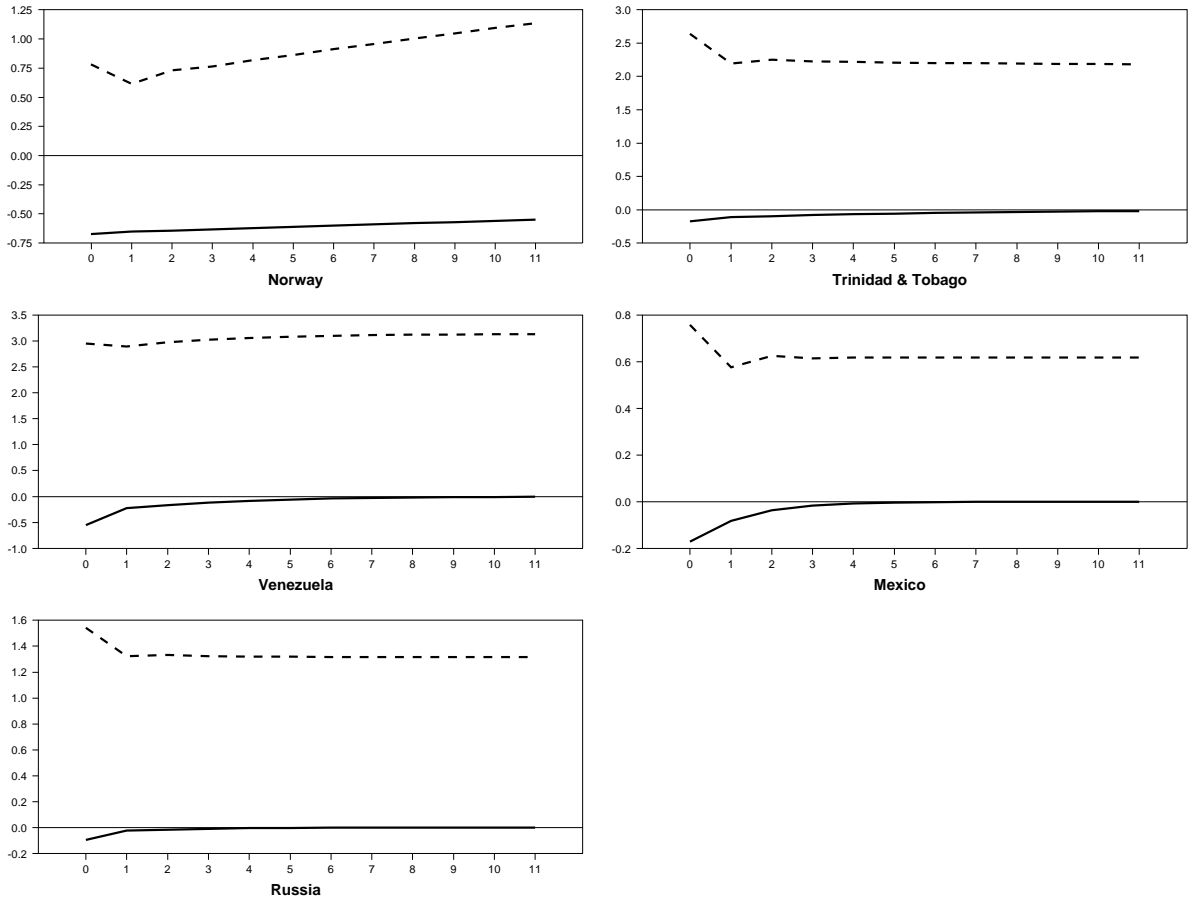
Notes: See Notes to Table 1

Table 8: **Conditional Correlations**

	Bivariate-SVAR		Oil-augmented-SVAR		
	Tech	Nontech	Tech	Nontech	Oil
Norway:					
• Whole sample	-0.9354*** (0.2864)	0.9256 (0.8051)	-0.9292*** (0.2872)	0.8926 (0.8104)	-0.9279** (0.4412)
• Pre- <i>Oljefond</i>	-0.8607*** (0.1734)	0.9465 (0.7395)	-0.8685*** (0.1873)	0.8928 (0.7273)	-0.8859** (0.3977)
• Post- <i>Oljefond</i>	-0.9327* (0.5042)	0.9459 (0.8321)	-0.9322* (0.5113)	0.9453 (0.8329)	-0.8993 (0.5672)
Venezuela	-0.8559** (0.3853)	0.9877 (0.8312)	-0.7434** (0.3305)	0.9969 (0.7630)	-0.6793* (0.3640)
Russia	-0.8715 (0.6796)	-0.9963*** (0.3147)	-0.9235*** (0.1743)	-0.9836 (0.6778)	-0.4907* (0.2510)
Average(1)	-0.8876	0.3057	-0.8654	0.3020	-0.6993
Trinidad&Tobago	-0.9686 (0.7008)	-0.9890 (0.8806)	-0.9582** (0.4497)	0.9838 (0.9273)	0.7171 (0.4952)
Mexico	-0.7699 (0.6023)	-0.4254 (0.4413)	-0.7051** (0.3511)	0.3733 (0.3648)	0.9815* (0.5395)
Average(2)	-0.8693	-0.7072	-0.8317	0.6786	0.8493

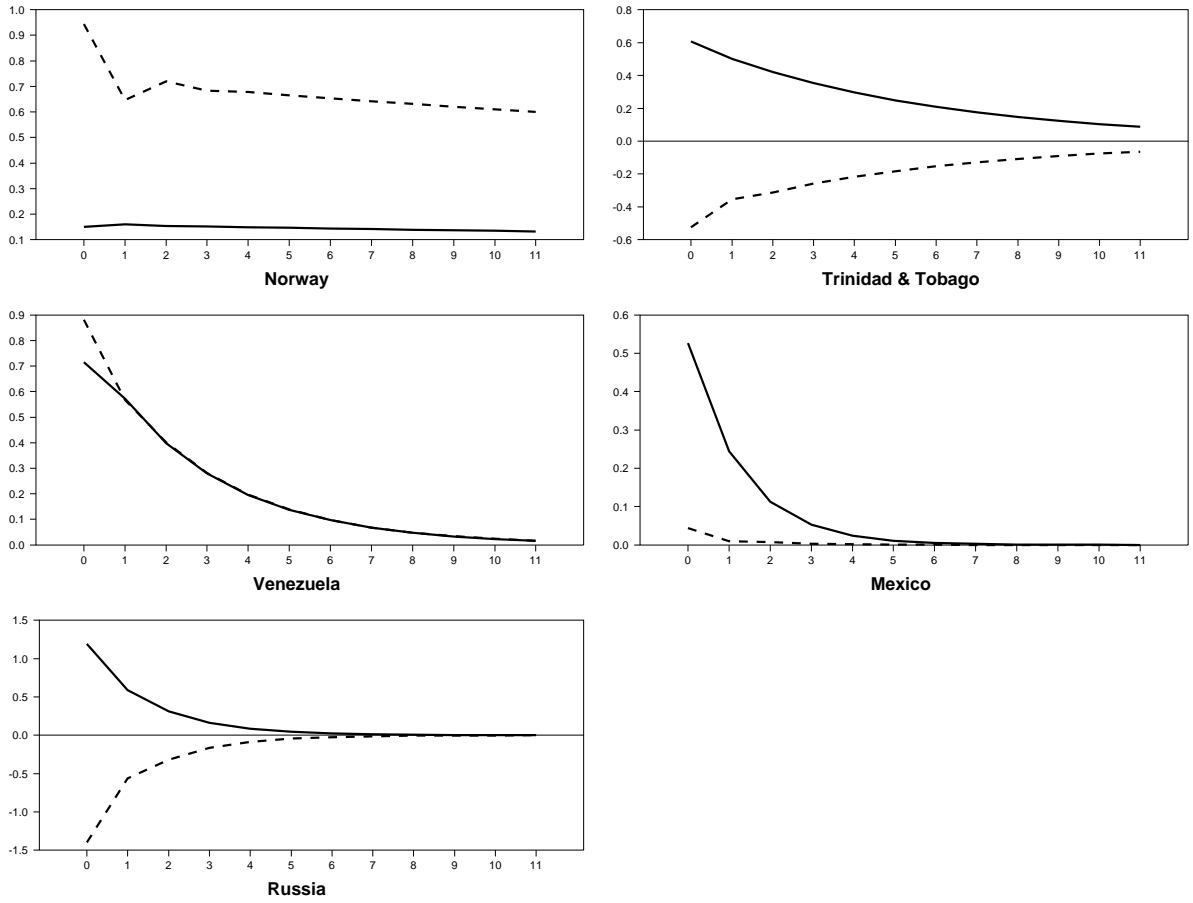
Notes: See Notes to Table 1

Figure 16: Response to a Technology-Shock: *Original Approach*



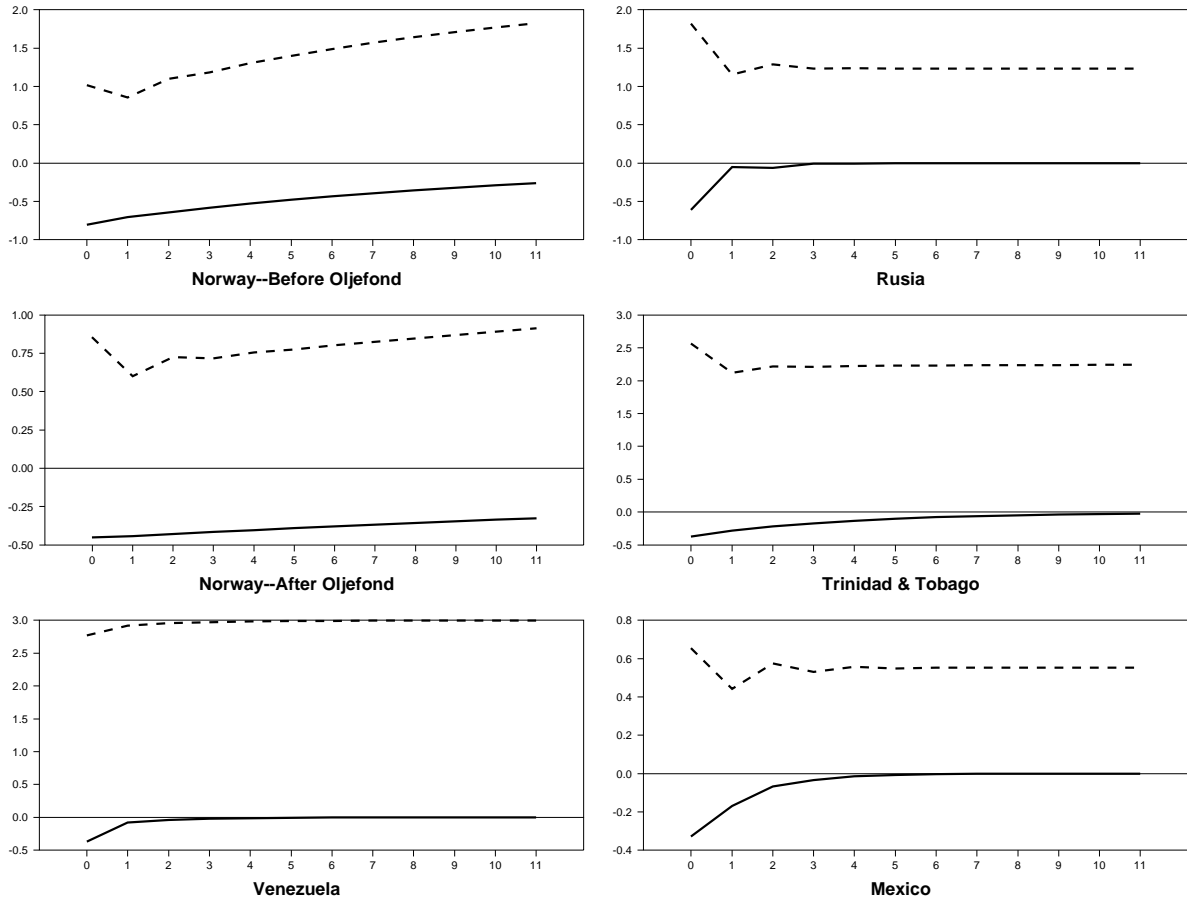
Notes: See Note 1 to Figure 5 and Note 4 to Figure 1.

Figure 17: Response to a Nontechnology-Shock: *Original Approach*



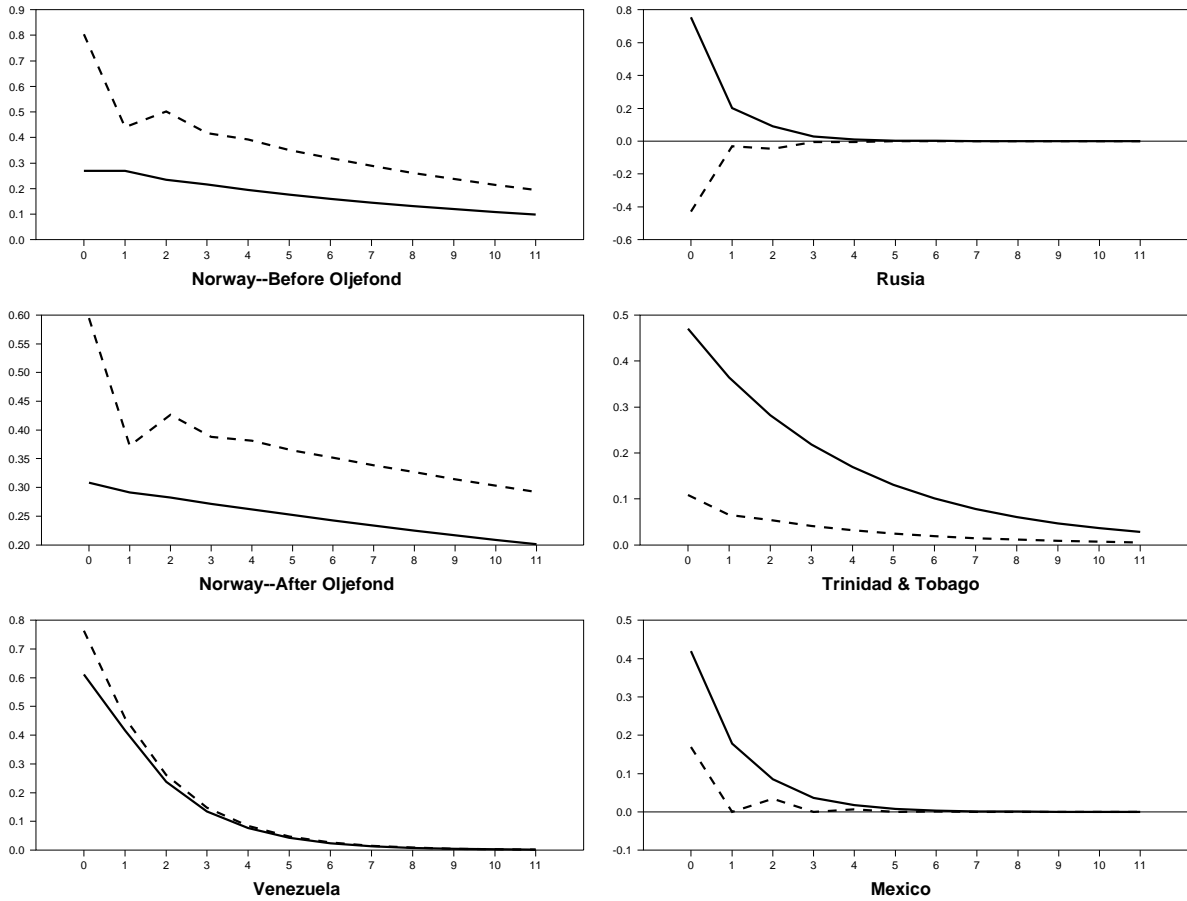
Notes: See Note 1 to Figure 5 and Note 4 to Figure 1.

Figure 18: **Response to a Technology-shock: *Oil-shocks disentangled***



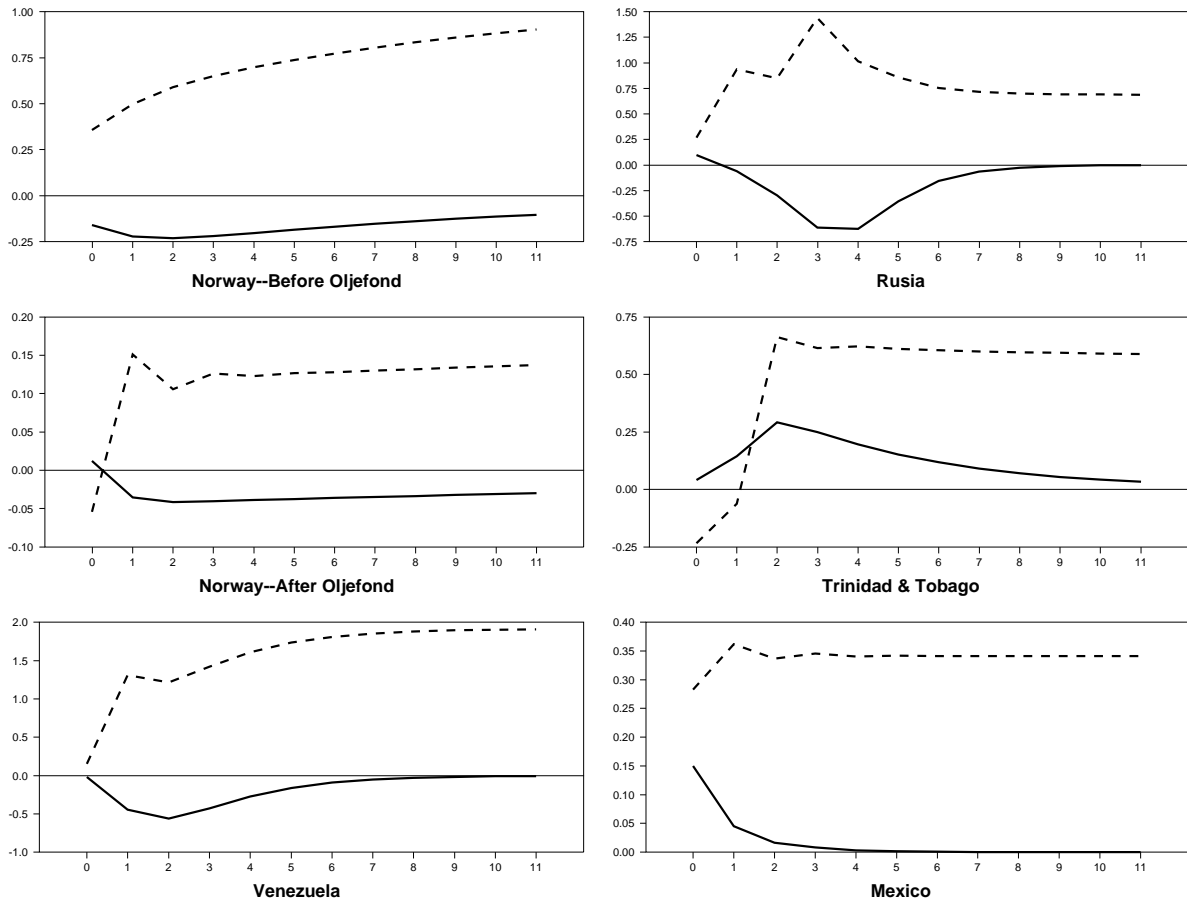
Notes: See Note 1 to Figure 5 and Note 4 to Figure 3.

Figure 19: Response to a Nontechnology shock: *Oil-shocks disentangled*



Notes: See Note 1 to Figure 5 and Note 4 to Figure 3.

Figure 20: Response to an Oil-shock: *Oil-shocks disentangled*



Notes: See Note 1 to Figure 5 and Note 4 to Figure 3.

in some cases the initial or instantaneous response may seem to contradict this assertion, its magnitude, as the confidence bands will confirm, is essentially null); in the countries mainly fiscally oil-dependent, these variables move in the same direction (again, in one case, the initial response may seem not supporting the corresponding assertion, but once again, as the confidence bands will confirm, its magnitude is indistinguishable from zero). Notice that the latter case, is an instance of the type of situations that the oil-price extension of Galí's methodology was meant to cope with: when applying Galí's original methodology to these chiefly fiscally-dependent countries—hence, tangling oil-price shocks with the other shocks with permanent effects on productivity—, we could be tangling expenditure shocks with technology shocks, rising doubts about the interpretation of the results from the whole exercise—e.g, it cannot be rule out the possibility that the negative correlation between employment and productivity conditional on permanent shocks would be mainly the consequence of the impact of oil-price fluctuations on aggregate demand—remember that in the context of the standard RBC model, expenditure shocks can well be associated to a negative employment-productivity correlation(see [?])op.cit]chistetal05.

As for the uncertainty around these impulse-response point-estimates, while under the original methodology (Figures 21 to 28) confidence bands are in most cases too wide as to allow assess with any certainty the true relative direction of the responses of employment and productivity to the different shocks in most cases; under the extended methodology the uncertainty reduces up to point of allowing to establish with relative certainty (confidence bands barely give room for a different possibility): that employment and productivity move (possibly after one quarter lag), in all cases, in opposite direction in response to a technology shocks; that the same happen, in the case of the mainly externally-oil-dependent countries, in response to an oil-price shock; that in the case of the mainly fiscally-oil-dependent countries both variables increase in response to a positive oil-price shock; finally, that in all cases employment increase in response to a positive nontechnology shock, and that such increase is accompanied by an increase of productivity in Norway (at least in the pre-*Oljefond* period) and Venezuela.

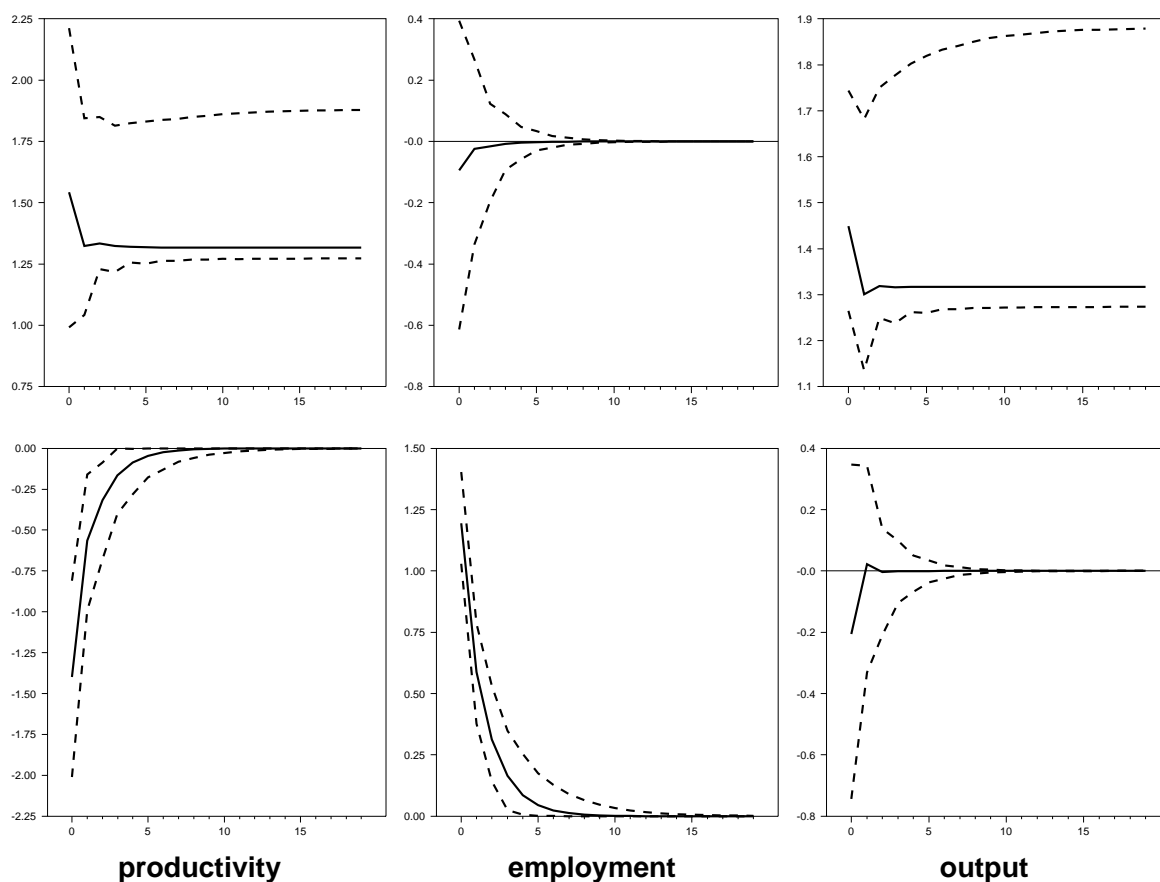
Finally, let's turn to the business-cycle components of output and employment historical evolution associated with each specific category of shock (see Figures 29 and 30) , as a way, once again, of pondering the weight of each shock in the Business-Cycle. As in all previous cases, clearly nontechnology shocks constitutes the fundamental source of positive correlation between output and employment which is supposed to characterized the Business-Cycle in all cases—only under the original version arises one exception—namely, Russia.

Whereas the components resulting from applying the extended methodology show that, without exception, nontechnology shocks constitutes the source of the positive correlation between output and employment that it is supposed to characterized the Business-Cycle phenomenon in general (while technology shocks produce a negative correlation between these variables in all the cases); the components resulting from the original methodology leave one exception, Russia, for whom both shocks produce a negative correlation between employment and productivity.

In summary, the results for the whole sample of oil-countries turn out to be roughly consistent with Galí's main findings, but the degree of consistency is much higher when oil-price shocks are disentangled, specially because then the results became much less ambiguous, approximating better the relative conclusiveness of Galí's findings. Besides, the results as a

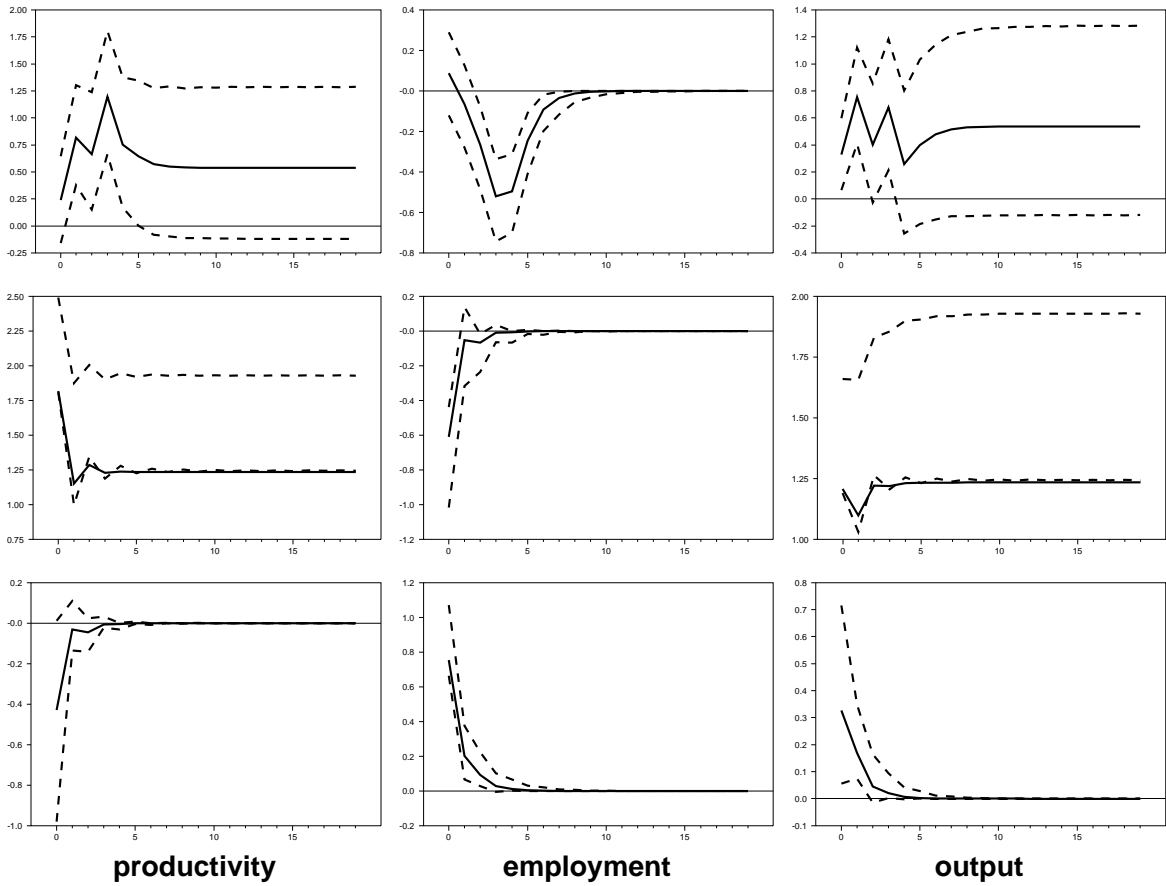
whole, reassert strongly the whole set of implications which were derived from the analysis of the baseline case, Norway. In particular, the differences in the response of employment and productivity to an oil-price-shocks between the chiefly fiscally-oil-dependent and chiefly externally-oil-dependent countries, support the hypothesis of the dual-nature of oil-price shocks effects on the Oil-countries's Business-Cycle. On the one hand, oil-price persistent movements—possibly through their impact on the availability of imported inputs and capital goods—had, like (oil-price disentangled) technology shocks, permanent effects on productivity; on the other hand, these movements—probably through their impact on fiscal income and expenditure—affect, like (oil-price disentangled) nontechnology shocks, aggregate demand

Figure 21: **Russia IRFs with Bands: *Original Approach***



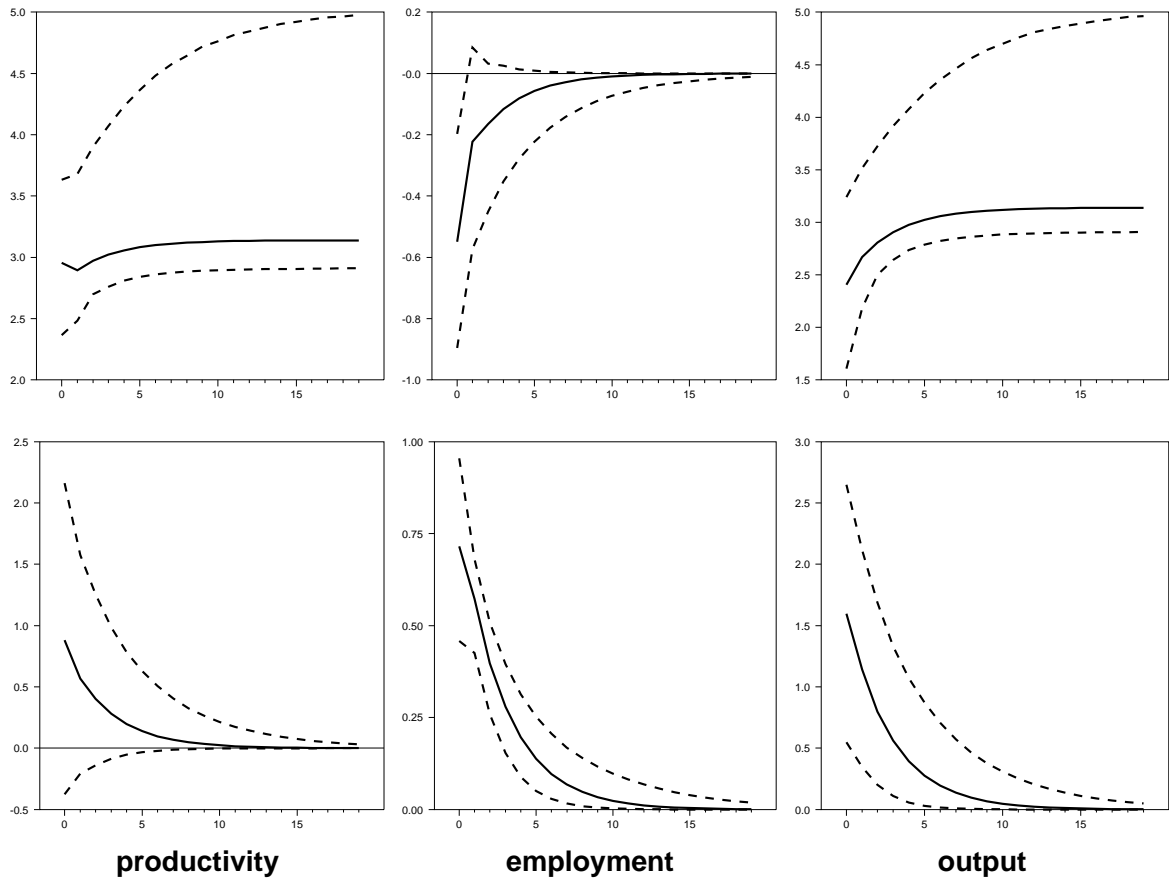
Notes: See Notes to Figure 1.

Figure 22: Russia IRFs with Bands: *Oil-shocks disentangled*



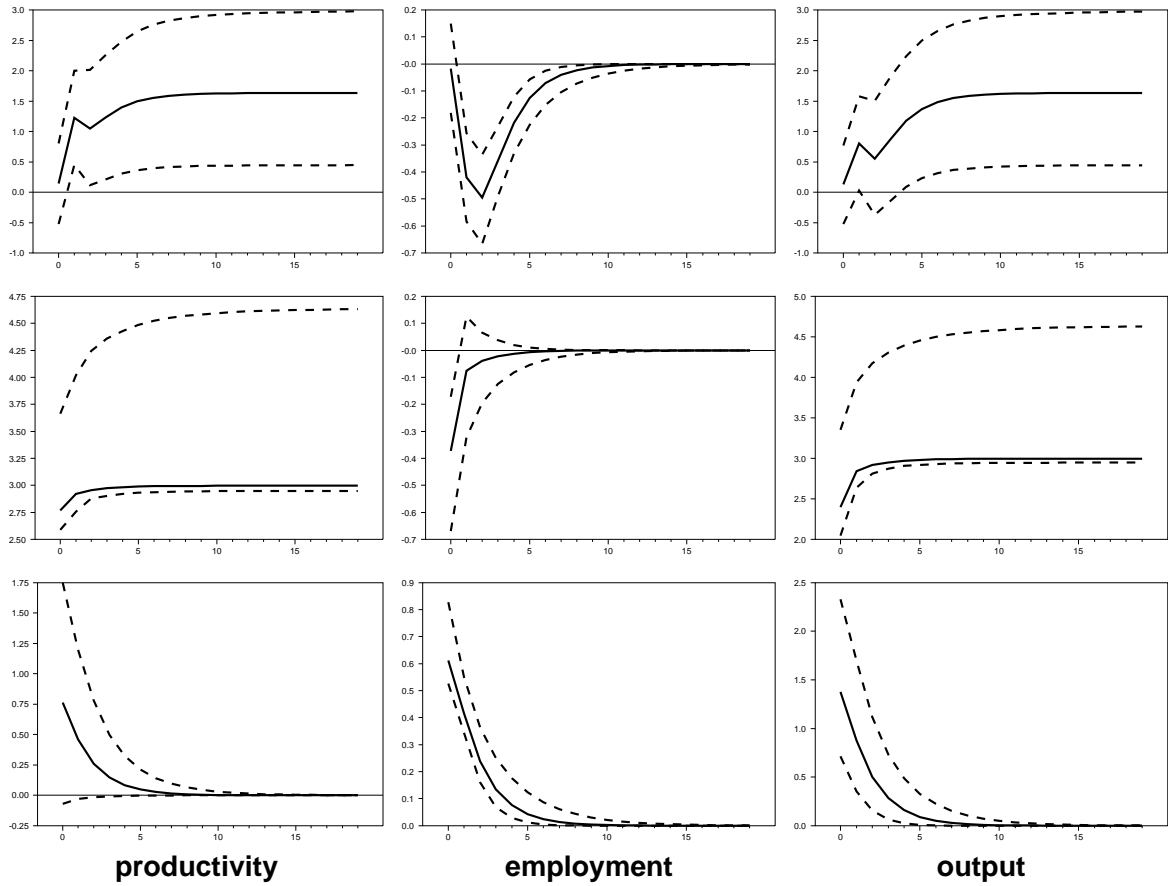
Notes: See Notes to Figure 3.

Figure 23: Venezuela IRFs with Bands: *Original Approach*



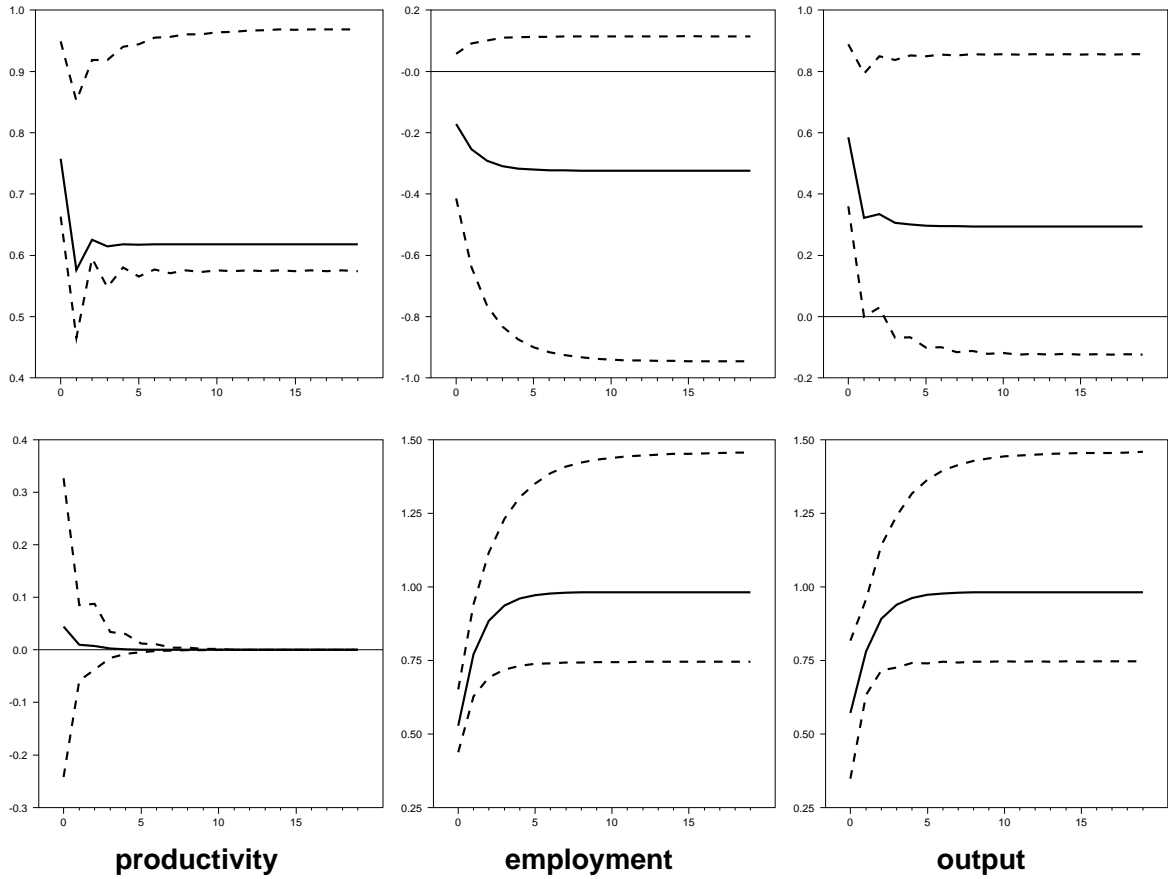
Notes: See Notes to Figure 1.

Figure 24: Venezuela IRFs with Bands: *Oil-shocks disentangled*



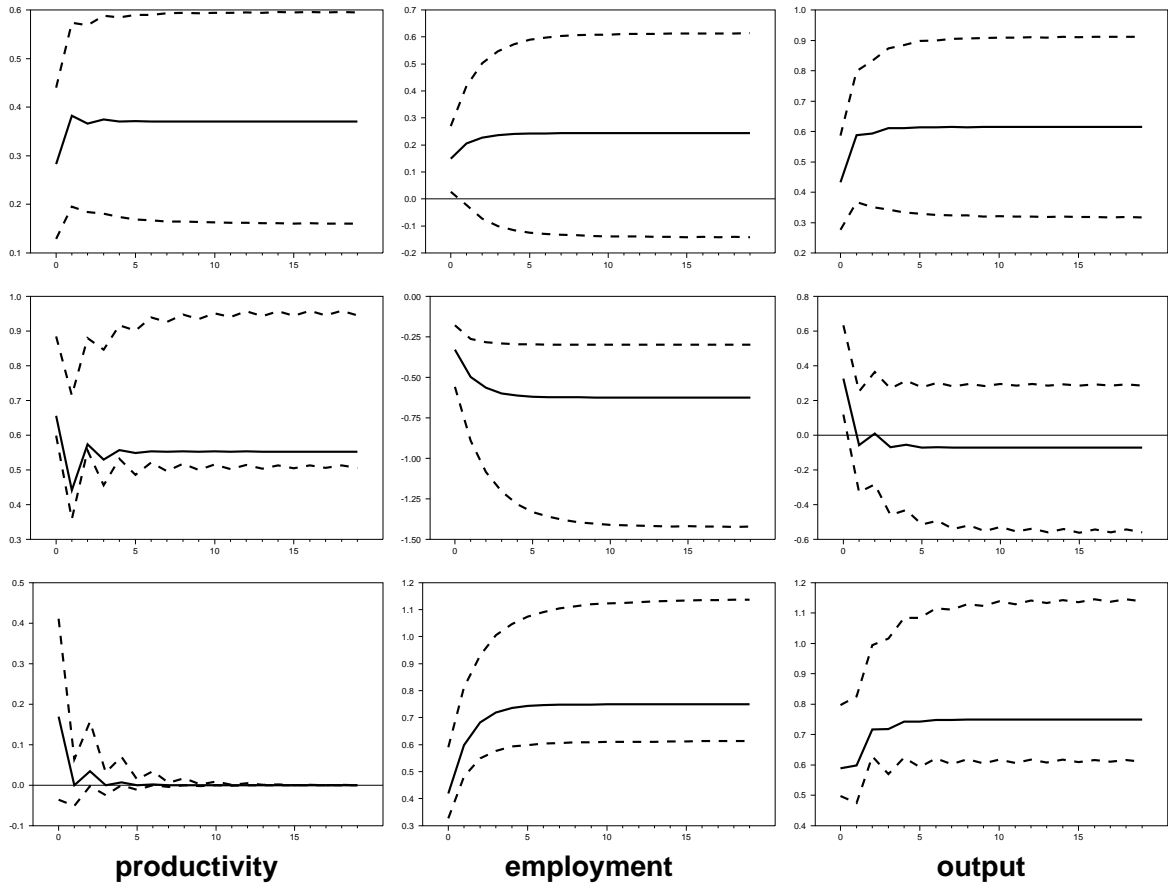
Notes: See Notes to Figure 3.

Figure 25: Mexico IRFs with Bands: *Original Approach*



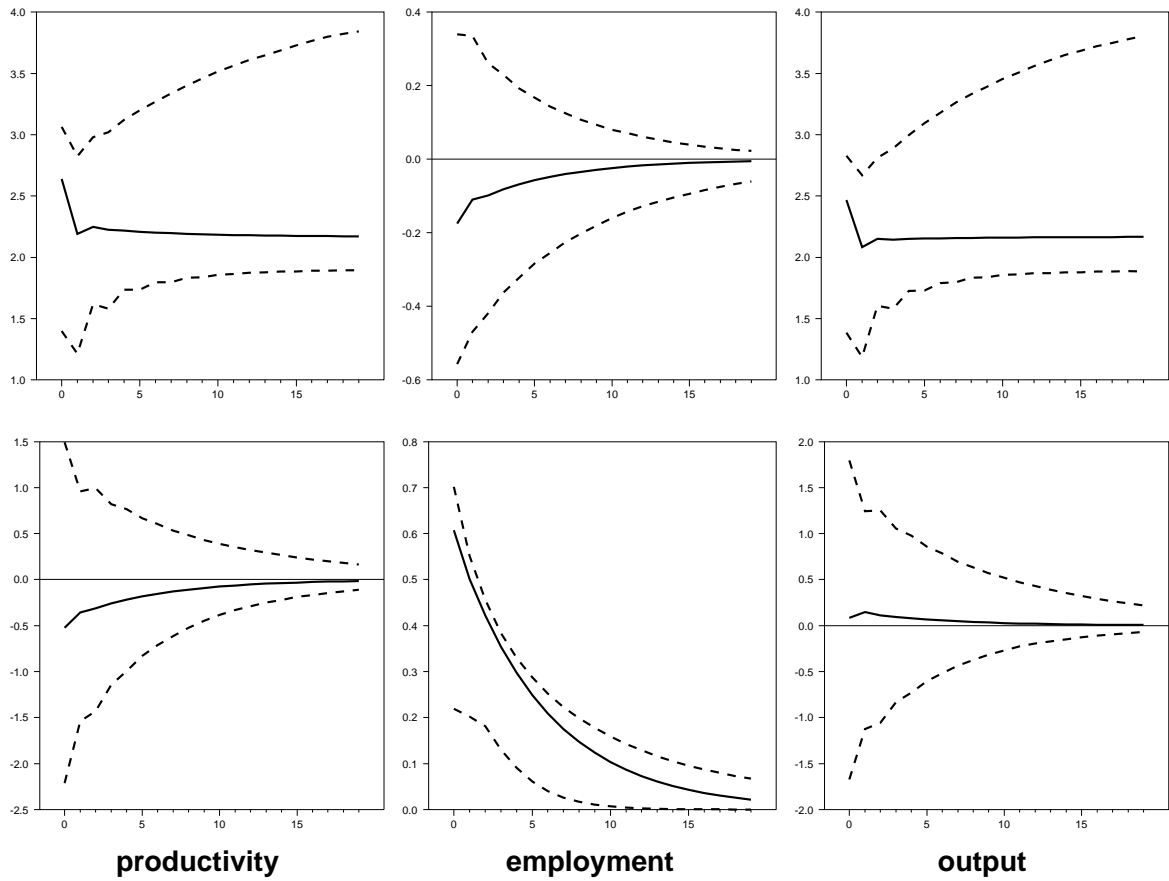
Notes: See Notes to Figure 1.

Figure 26: Mexico IRFs with Bands: *Oil-shocks disentangled*



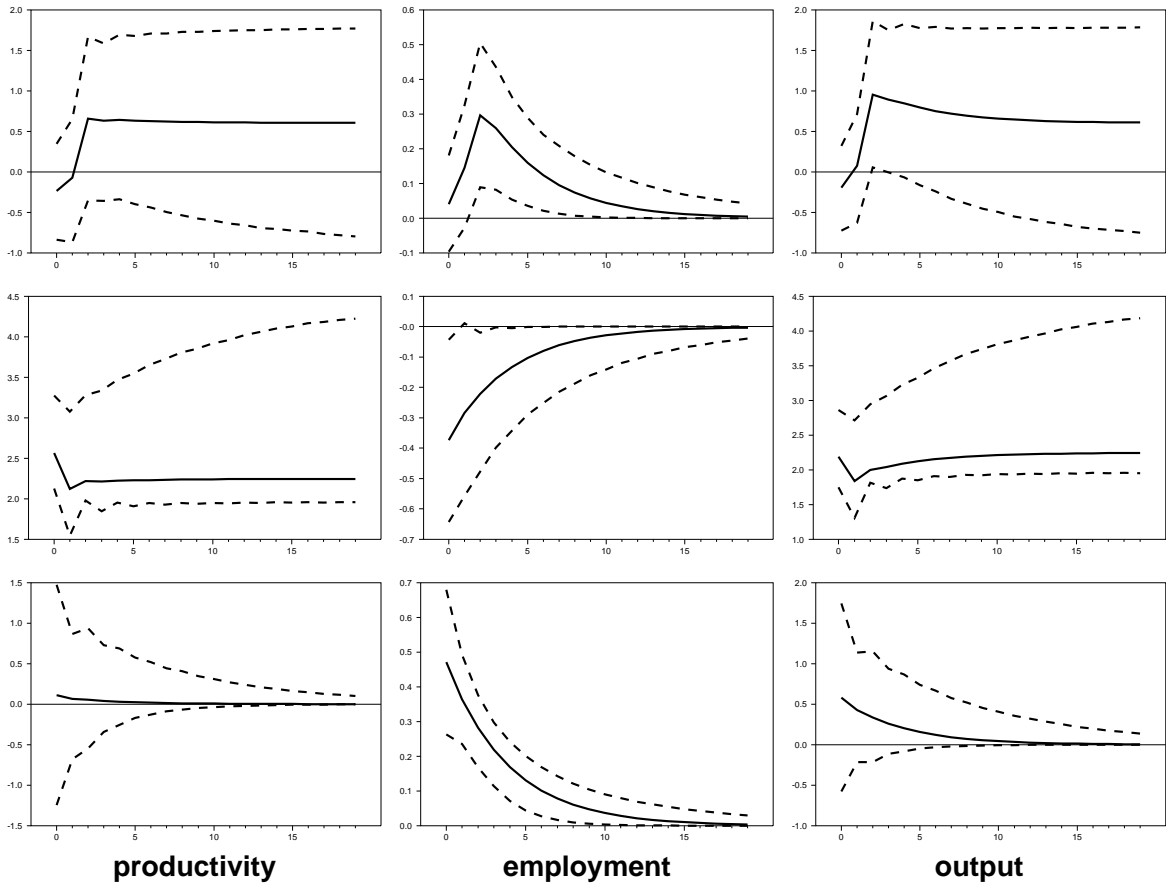
Notes: See Notes to Figure 3.

Figure 27: Trinidad&Tobago IRFs with Bands: *Original Approach*



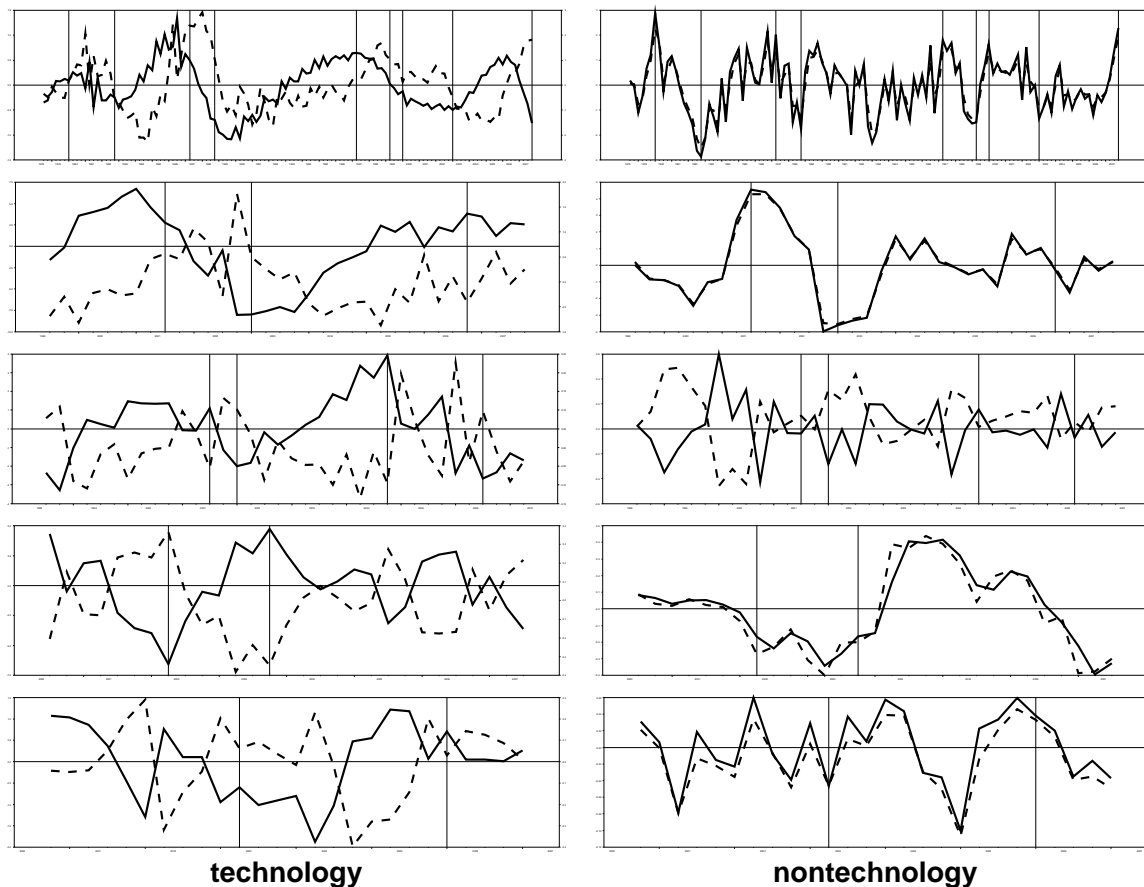
Notes: See Notes to Figure 1.

Figure 28: Trinidad&Tobago IRFs with Bands: *Oil-shocks disentangled*



Notes: See Notes to Figure 3.

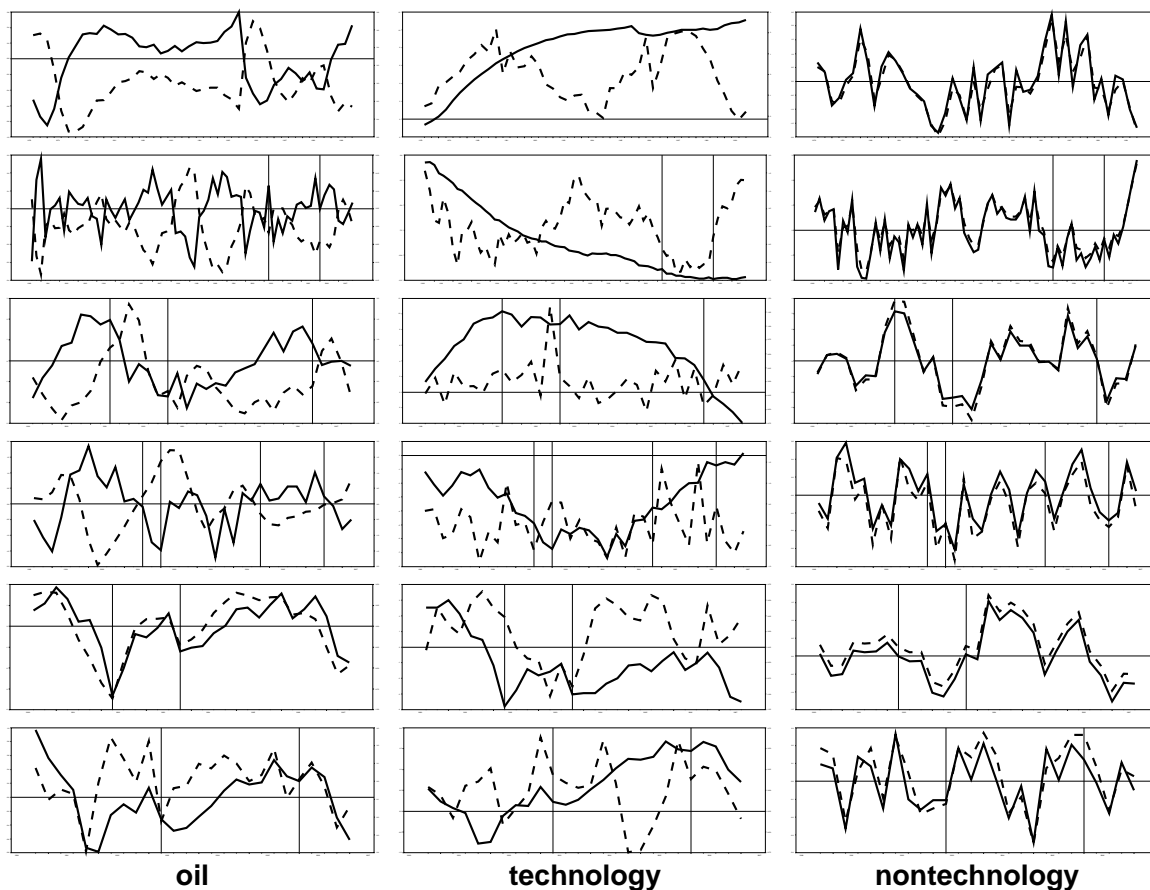
Figure 29: Output & Labor: *Original Approach*



Notes:

1. From top, first row graphs belong to Norway, second to Venezuela, third to Russia, fourth to Trinidad & Tobago, and fifth to Mexico.
 2. Each graph show the technology(first column) and nontechnology(second column) components of the historical fluctuations of output(continuous line) and employment(broken line) at Business Cycle frequencies(extracted with the standard Hodrick–Prescott Filter).
 3. The vertical lines are the turning–points(peaks and troughs) of output fluctuations at Business Cycle frequencies estimated using the algorithm of Bry and Boschan(1971), which tries to approximate–in an authomatic fashion– the Business Cycle dating procedure used by the National Bureau of Economic Research in the case of the United States.
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Figure 30: Output & Labor: *Oil-shocks disentangled*



Notes:

1. From top, first row graphs belong to Norway before *Oljefond* creation, second to Norway after *Oljefond* creation, third to Venezuela, fourth to Russia, fifth to Trinidad & Tobago, and sixth to Mexico.
 2. Each graph show the oil(first column), technology(second column) and nontechnology(third column) components of the historical fluctuations of output(continuous line) and employment(broken line) at Business Cycle frequencies(extracted with the standard Hodrick–Prescott Filter).
 3. The vertical lines are the turning–points(peaks and troughs) of output fluctuations at Business Cycle frequencies estimated using the algorithm of Bry and Boschan(1971), which tries to approximate–in an authomatic fashion– the Business Cycle dating procedure used by the National Bureau of Economic Research in the case of the United States.
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4 Summary and Conclusions

This paper analyzes and compares the results from applying to oil-countries—those net oil-exporting countries whose export- and/or fiscal-income depends significantly on oil-income—two versions of Galí (1999)’s SVAR-based methodology for assessing the empirical merits of the standard Real Business Cycle (RBC) model, namely, the original version and the oil-price-extended version introduced in this paper. After recapitulating briefly both methodologies, the section proceeds to summarize the main findings and conclusions from the exercise.

In its original version, Galí’s methodology characterizes by grouping all business-cycle-driving shocks on two exhaustive and orthogonal empirical categories—those shocks that produce permanent effects on average labor-productivity (let’s call them “permanent shocks”), and those which do not (let’s call them “transitory shocks”). The methodology interprets the first category of shocks as the empirical counterpart of the usual “technology shocks” of the RBC model’s textbook presentation, that is, those shocks whose immediate impact on the economy concentrate on the production function, having only indirect effects on other elements of the economy (as aggregate demand, labor-supply, etc). In fact, the ultimate goal of the methodology is comparing the estimated effects of permanent shocks with the theoretical predictions of the standard RBC model concerning the effects of technology shocks, just as a way to assess the empirical merits of such model. Specifically, the methodology focuses mainly in contrasting the strong and positive employment-productivity correlation conditional on technology shocks predicted by the standard RBC model against the estimated employment-productivity correlation conditional on permanent shocks—a contrast, which in the country-cases analyzed in ? and other precedent studies, has been adverse to the predictions of the standard RBC model.

In turn, the oil-extended version of Galí’s methodology, introduced in this paper, characterizes by adding oil-price to the bivariate SVAR model of the original methodology as a way of disentangling the permanent and transitory shocks—estimated with the original methodology—from oil-price shocks, grouping the latter in a separated third category of shocks. The disentangling relies (in addition to the assumptions of the original version of the methodology) on the assumption of exogeneity of oil-price with respect to domestic employment and average labor-productivity in the context of the oil-countries in our sample (namely, the only five oil-countries with availability of the data required to apply Galí’s methodology: México, Norway, Russia, Venezuela, and Trinidad & Tobago)—an assumption justified among other things by the results of standard exogeneity tests.

First of all, the results from the exercise shows that oil-price shocks have permanent effects on average labor-productivity, implying that oil-price-shocks are tangled by the original version of Galí’s methodology in the group of permanent shocks—those interpreted by the methodology as technology shocks.

Secondly, it is found that the effects of oil-price shocks mimic the effect of the (oil-price disentangled) permanent shocks (those meant to capture technology shocks) in the “chiefly externally oil-dependent countries”—those oil-countries where oil-income matters mainly for external payments (being then an important determinant of the availability of imported inputs and capital goods and, hence, affecting the production function); while their effects mimic that of the (oil-price disentangled) transitory shocks (those meant to capture nontechnology shocks) in the “chiefly fiscally oil-dependent countries”—those oil-countries

where oil-income matters mainly for funding public spending (being then an important determinant of aggregate demand). What gives support to the hypothesis that in the context of the oil-country economies, oil-price shocks have a dual nature: they are able to have direct effects on the production function, as the usual technology shocks, and, simultaneously, on other elements of the economy (mainly, aggregate expenditure) as nontechnology shocks.

These two findings cast serious doubts, in the context of the oil-countries, on the interpretation that Galí's methodology make of the estimated empirical permanent shocks as the counterpart of the usual type of RBC's theoretical technology shocks. For one reason, the latter are supposed not to have direct effects anywhere else than on the production function, while, by the contrary, the previous findings suggest that permanent shocks, by including oil-price shocks, may have simultaneous direct effects on both the production function and the aggregate demand—suggesting also that the former effect dominates on the chiefly externally oil-dependent countries and the latter does in the chiefly fiscally oil-dependent countries.

Therefore, even when the results from the application of Galí's methodology to Oil-countries are, as a matter of fact, fairly consistent with (though more uncertain than) Galí's main empirical findings—notably, also in the Oil-countries a positive permanent (transitory) shock cause, at least on average, a drop (rise) in employment in the short-term, what expresses in a negative (positive) employment-productivity correlation conditional on such permanent (transitory) shocks—, it cannot be asserted on this ground, as presumed by the methodology, that these results are at odds with the standard RBC model predictions. For one reason, the RBC model's predictions concerning the effects of dual shocks—those which, like oil-price shocks seems to do, impinge directly as much on the production function as on the aggregate demand, or other elements of the economy—are ambiguous. In particular, as illustrated in the Appendix, a permanent shock which shift simultaneously and independently the production function (like technology shocks) and the aggregate public expenditure (like some nontechnology shocks) would produce, in the context of the standard RBC model, simultaneous shifts on labor-demand and labor-supply—hence, the direction and magnitude of its final effect on employment, as well as the the magnitude and sign of the induced employment-productivity correlation, would result highly sensitive to the relative magnitude of these shifts.

Given these facts, the disentangling of oil-price shocks from the rest of permanent shocks arises as a *sine qua non*, in the context of the oil-countries, for restoring to Galí's methodology its capacity to extract implications which could be unambiguously contrasted against the standard RBC model's predictions. Consequently, the fact that the results from the application of our oil-price extended version of Galí's methodology to the Oil-countries have resulted highly consistent (even more than those from the original methodology, in that they are more precise or certain) with Galí's empirical findings—a positive oil-price-disentangled permanent (transitory) shock cause an unambiguous short-term drop (rise) in employment, what expresses in a negative (positive) employment-productivity correlation conditional on such permanent (transitory) shocks—should not be seen as a mere robustness check of the presumably rebutting evidence against the RBC model's predictions arising from the original methodology, but as a pretty much firmer ground on which to question such predictions in the context of the Oil-countries.

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Appendix

A Data description

- **Oil Price:** US\$ per barrel of West Texas Intermediate at Cushing (quarterly averages from daily data) deflated by the US consumer price index seasonally adjusted (1982-1984=100). Period: 1947:1-2007:4. Sources: oil price data from **Energy Information Administration** (<http://www.eia.doe.gov>) ; US consumer price index data from **Bureau of Labor Statistics** (<http://www.bls.gov>).
- Norway:
 - **Employment** (people employed): Millions of people employed. Quarterly. Seasonally adjusted. Period: 1978:1–2007:4. Source: *Quarterly National Accounts, Statistics Norway* (www.ssb.no/english/).
 - **Hours** (hours employed): Millions of hours employed. Quarterly. Seasonally adjusted. Period: 1978:1–2007:4. Source: *Quarterly National Accounts, Statistics Norway* (www.ssb.no/english/).
 - **GDP:** Gross Domestic Product in millions of kroner at constant prices of 2005. Quarterly. Seasonally adjusted. Period: 1978:1–2007:4. Source: *Quarterly National Accounts, Statistics Norway* (www.ssb.no/english/).
- Venezuela:
 - **Employment** (people employed): Number of people employed. Quarterly. Period: 1999:1–2007:4. Source: **Instituto Nacional de Estadística** (www.ine.gob.ve). Seasonally adjusted using TRAMO–SEAT (outlier at 2003:1).
 - **Hours** (hours employed): Non–available.
 - **GDP:** Gross Domestic Product in millions of bolívares at constante prices of 2007. Quarterly. Seasonally adjusted. Period: 1997:1–2007:4. Source: **Banco Central de Venezuela** (www.bcv.org.ve).
- Russia (Russian Federation):
 - **Employment** (people employed): Thousands of people employed. Quarterly . Period: 1998:1–2007:4. Source: LABORSTA database, **International Labour Organization** (<http://laborsta.ilo.org/>). Seasonally adjusted using TRAMO/SEAT (<http://www.bde.es/servicio/software/econom.htm>).
 - **Hours** (hours employed): Non–available.
 - **GDP:** We link three measures of the real volume of aggregate output, namely,
 - * Real Volume of Gross Domestic Product in billions of rubles at annual average prices of 1995. Quarterly. Period: 1995:1–2000:4. Source: **Federal State Statistics Service** (<http://www.gks.ru/wps/portal/english>).

- * Real Volume of Gross Domestic Product in billions of rubles at annual average prices of 2000. Quaterly. Period: 2000:1–2007:4. Source: **Federal State Statistics Service** (<http://www.gks.ru/wps/portal/english>).
 - * Good and services output index at annual average prices of the previous year. Quaterly . Period: 2004:1–2007:4. Source: **Federal State Statistics Service** (<http://www.gks.ru/wps/portal/english>).
- Trinidad & Tobago:
 - **Employment** (people employed): Thousands of people employed. Quaterly . Period: 1991:1–2007:4. Source: **Central Statistics Office** (<http://www.cso.gov.tt/>). Seasonally adjusted using TRAMO/SEAT (<http://www.bde.es/servicio/software/econom.htm>).
 - **Hours** (hours employed): Non–available.
 - **GDP**: Quaterly Index constructed from Quaterly GDP Growth Rates (2000=100). Seasonally Adjusted. Period: 2000:1–2007:3. Source: **Central Bank of Trinidad and Tobago** (<http://www.central-bank.org.tt/>).
 - Mexico:
 - **Employment** (people employed): Thousands of people employed. Quaterly. Period: 2000:2–2007:1. Source: LABORSTA database, **International Labour Organization** (<http://laborsta.ilo.org/>). Seasonally adjusted using TRAMO/SEAT (<http://www.bde.es/servicio/software/econom.htm>).
 - **Hours** (hours employed): Non–available.
 - **GDP**: Gross Domestic Product in millions of pesos at constante prices of 1993. Quaterly. Period: 1980:1–2007:4. Source: **Banco de México** (<http://www.banxico.org.mx/>). Seasonally adjusted using TRAMO/SEAT (<http://www.bde.es/servicio/software/econom.htm>).

B Unit roots and Cointegration tests' results

Table 9: Employment Unit Root Test

Lag-selection criterion:	BIC			AIC		
Significance-level:	10%	5%	1%	10%	5%	1%
Norway(1)	<i>TS</i>	<i>I(1)</i>	<i>I(2)</i>	<i>TS</i>	<i>I(2)</i>	<i>I(2)</i>
Norway(2)	<i>I(1)</i>	<i>I(1)</i>	<i>I(1)</i>	<i>I(1)</i>	<i>I(1)</i>	<i>I(1)</i>
Venezuela	<i>TS</i>	<i>TS</i>	<i>I(1)</i>	<i>TS</i>	<i>TS</i>	<i>I(1)</i>
Russia	<i>TS</i>	<i>TS</i>	<i>I(1)</i>	<i>I(1)</i>	<i>I(1)</i>	<i>I(1)</i>
Trinidad & Tobago	<i>TS</i>	<i>TS</i>	<i>TS</i>	<i>TS</i>	<i>TS</i>	<i>TS</i>
Mexico	<i>I(1)</i>	<i>I(1)</i>	<i>I(1)</i>	<i>I(1)</i>	<i>I(1)</i>	<i>I(1)</i>

Notes: TS \equiv Trend-stationary, I(1) \equiv First-difference-stationary ;
 Norway(1) refers to people, Norway(2) refers to hours.

Table 10: Employment-Productivity Cointegration Test

	T-Statistic	
	BIC-Lags	AIC-Lags
Norway(1)	-1.11	-2.49
Norway(2)	-1.07	-1.98
Venezuela	-1.52	-1.52
Russia	-2.88	-2.88
Trinidad & Tobago	-2.67	-3.48
Mexico	-2.57	-2.57

Notes: Norway(1) uses people, Norway(2) uses hours.

C Oil-price exogeneity test

C.1 Results

Table 11: Oil-Price Exogeneity Tests

	Granger		Geweke–Meese–Dent			
	$N \sim TS$	$N \sim I(1)$	$N \sim TS$	X	$N \sim I(1)$	X
Norway(1)	0.55 (70%)	1.02 (40%)	1.00 (41%)	0.01 (99%)	0.58 (68%)	0.07 (99%)
Norway(2)	0.69 (60%)	0.76 (55%)	0.90 (47%)	0.45 (77%)	0.77 (54%)	0.50 (73%)
Venezuela	0.38 (82%)	0.88 (49%)	0.35 (84%)	1.47 (26%)	0.44 (78%)	1.09 (40%)
Russia	1.25 (31%)	0.62 (65%)	0.41 (80%)	0.58 (68%)	0.56 (70%)	0.71 (59%)
Trinidad & Tobago	1.84 (16%)	1.87 (15%)	0.36 (83%)	1.93 (18%)	0.41 (80%)	1.92 (18%)
Mexico	0.91 (48%)	0.77 (56%)	0.76 (57%)	3.36 (6%)	0.84 (53%)	1.17 (38%)

Notes: Norway(1) uses people, Norway(2) uses hours.

tab11

C.2 Description of the tests

C.2.1 Granger's Causality Test:

$$dp_t = b_0 + \sum_{k=1}^{+4} b_k dp_{t-k} + \sum_{h=1}^{+2} b_{4+h} dx_{t-h}^j + \sum_{h=1}^{+2} b_{6+h} \hat{n}_{t-h}^j + \varepsilon_t$$

Such that, the superindex j denote thye counrty, \hat{n}_t^j corresponds employment first difference (if it is regarded as $I(1)$) or detrended employment (if it is regarded trend-stationary), whereas dx_t^j and dp_t are, once again, the first difference of labor-productivity and oil-price respectively.

The null-hypothesis of oil-price exogeneity, corresponds to $b_5 = b_6 = b_7 = b_8 = b_9 = 0$, and the test reduces to an F-Test of the significance of this hypothesis. Results are shown in Table X.

C.2.2 Geweke, Meese and Dent's Causality Test:

$$\hat{n}_{it}^j = b_0 + \sum_{k=-4}^{+4} b_{5+k} dp_{t-k} + \sum_{h=1}^{+2} b_{9+h} dx_{t-h}^j + \sum_{h=1}^{+2} b_{11+h} \hat{n}_{t-h}^j + \varepsilon_t$$

$$dx_{it}^j = b_0 + \sum_{k=-4}^{+4} b_{5+k} dp_{t-k} + \sum_{h=1}^{+2} b_{9+h} dx_{t-h}^j + \sum_{h=1}^{+2} b_{11+h} \hat{n}_{t-h}^j + \varepsilon_t$$

Such that, the superindex j denote thye counrty, \hat{n}_t^j corresponds employment first difference (if it is regarded as I(1)) or detrended employment (if it is regarded trend-stationary), whereas dx_t^j and dp_t are, once again, the first difference of labor-productivity and oil-price respectively.

The null-hypothesis of oil-price exogeneity, corresponds to $b_1 = b_2 = b_3 = \dots = b_8 = b_9 = 0$ in both equations, and the test reduces to an F-Test of the significance of this hypothesis. Results are shown in Table X+1.

D Robustness Analysis

D.1 Alternative assumptions about employment

In the main text of this article (in line with results from Augmented Dickey–Fuller Test at 10%–significance level and BIC–based lag selection), employment was treated as a trend–stationary time series in the models for Norway, Russia, Venezuela, and Trinidad & Tobago; and as a difference–stationary or I(1) series in the models for Mexico. In the following, there are shown and analyzed the results from recomputing impulse–response functions and conditional correlations using models where employment is treated as a difference–stationary or I(1) series for all countries excepting Mexico, where is treated as a trend–stationary series.

Table 6 shows the resulting estimates of the conditional correlations between productivity and employment, for the Original Galí’s model (first two columns) as well as for the oil–augmented model (last three columns). In the baseline case, Norway, the new results are qualitatively similar to the previous ones: On the one hand, conditioned on technology shocks, the correlations are negative and statistically significant, even after disentangle the oil–shocks, and the same holds for the correlations conditioned on oil–price shocks—which, contrary to our previous results, is significant even for the post–*Oljefond* period. On the other hand, conditioned on nontechnology shocks, the correlations are again positive, but now also statistically significant—excepting for the pre–*Oljefond* period. However, there are some quantitative differences: while the correlations conditioned on technology–shocks and oil–price shocks increase slightly, the conditioned on non–technology shocks decreases substantially.

On the remaining country–cases, this qualitative similarity between the new and old results remain for the original model but it rather weakens after disentangling the oil shocks. On the one hand, the conditional correlations derived from the original model are again negative for all the countries when conditioned on technology shocks—but now statistically significant only for Russia and Trinidad & Tobago and not, as before, for Venezuela. On the other hand, the correlations conditioned on nontechnology shocks, are negative in all but the Venezuelan case, and statistically significant only in the case of Russia.

As for the correlations derived from the oil–price–augmented model, the most striking difference with previous results lies on the reversion of the negative sign, but also of the statistical significance, from the correlations conditioned on technology shocks for Venezuela and Mexico, but they remain negative and significant, as before, in the cases of Russia and Trinidad & Tobago. In turn, the correlations conditioned on nontechnology shocks change their sign only in the case of Mexico, but leaving it statistically insignificant, and became significant in one case, Russia. Finally, the correlations conditioned on oil–price shocks keep their sign—negative for Russia and Venezuela, positive for the rest—and became statistically significant in the only case when previously it was not, Trinidad & Tobago.

In the whole, we can consider the results derived from the new model specifications as fairly consistent with but less conclusive than—statistically speaking—the previous results of this article and with Galí’s findings.

Table 12: **Conditional Correlations, Alternative specifications**

	Original Approach		Augmented Model		
	Tech	Nontech	Tech	Nontech	Oil
Norway:					
• Whole sample	−0.9905*** (0.0262)	0.5476*** (0.1194)	−0.9897*** (0.0268)	0.5304*** (0.1263)	−0.9791** (0.4380)
• Before <i>Oljefond</i>	−1.0000*** (0.0757)	0.6857 (0.6151)	−1.0000*** (0.0860)	0.6375 (0.5264)	−1.0000** (0.4403)
• After <i>Oljefond</i>	−0.9496*** (0.0610)	0.3551*** (0.1268)	−0.9480*** (0.0646)	0.3553*** (0.1279)	−0.8767* (0.4887)
Venezuela	−0.8936 (0.5708)	0.5402 (0.4944)	0.3833 (0.6881)	0.6687 (0.6723)	−0.7978* (0.4075)
Russia	−0.9696** (0.3777)	−0.7711** (0.3497)	−0.9237** (0.4409)	−0.7184* (0.4243)	−0.9346*** (0.2547)
Trinidad&Tobago	−0.9930** (0.4087)	−0.6399 (0.6002)	−0.9977*** (0.3382)	0.6451 (0.5958)	0.8484* (0.5152)
Mexico	−0.3876 (0.7435)	−0.9659 (0.9030)	0.9683 (0.6923)	−0.8500 (0.7063)	0.8897* (0.5393)
Average	−0.8803	−0.0995	−0.8519	0.4526	−0.0799
Average(-Mex.)	−0.9079	−0.0180	−0.8886	0.4724	−0.3452
Average(-Mex,-insig)	−0.8957	−0.9963	−0.8886	—	−0.5245

tab12

Notes:

(a) See Notes to Table 1.

(b) All averages include Norway's whole sample estimates.

(c) Average(-Mex) excludes Mexico, and Average(-Mex,-insig) excludes Mexico and insignificant estimates.

D.2 Using hours instead of employment

Norway is the only Oil-Economy for which it is available an aggregate measure of labour-input different from the number of people employed, namely, the amount of hours worked—or, henceforth, simply “hours”. Then, as it was done by Galí(1999) in the case of the United States, in this section the results got for Norway using alternatively both measures of labour-input in the specification of the models, are compared.

Table 7 shows the estimates of Norway's conditional correlation between hours and productivity—GDP divided by hours—derived, in the first three rows, from the baseline model specification which treat hours—according with the results from the ADF test with a 10% significance level and BIC-selected lags—as a difference-stationary or $I(1)$ series and, in the last three rows, from the alternative one which treat it as a trend-stationary series. Both sets of results are fairly consistent with the ones got so far: Conditioned on tech-

nology shocks, the correlation estimates are negative and statistically significant—except, now, for one of the alternative cases, namely the post-*Oljefond* period. The same happen when correlation is conditioned on oil-price shocks—only that now became significant even in the post-*Oljefond* period. As for the non-technology conditioned correlation estimates, they keep their positive sign and remain statistically insignificant in all cases, with only one (different) exception for each attribute.

Table 13: **Conditional Correlations with Norwegian Employed Hours**

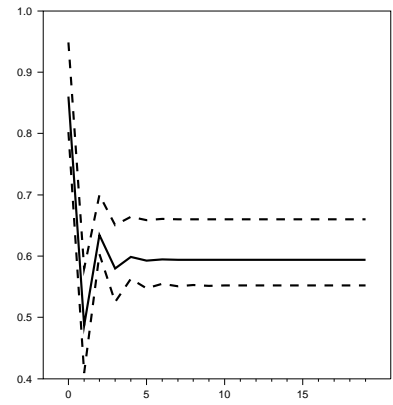
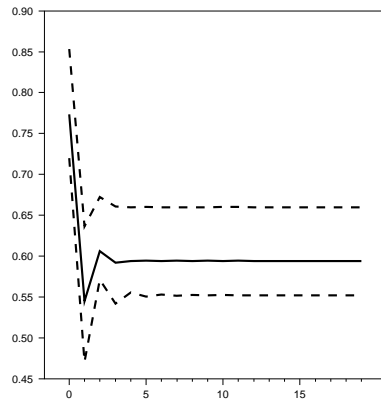
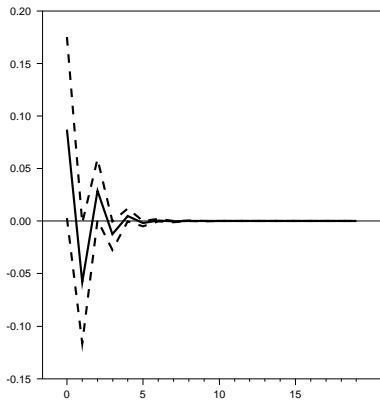
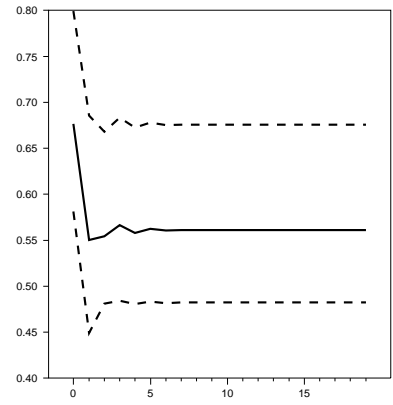
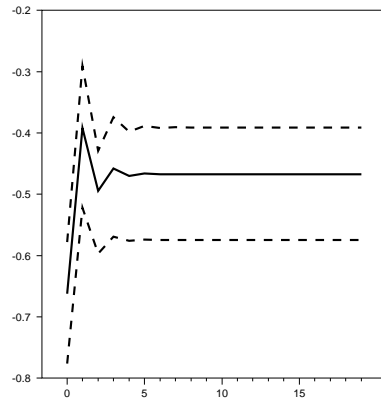
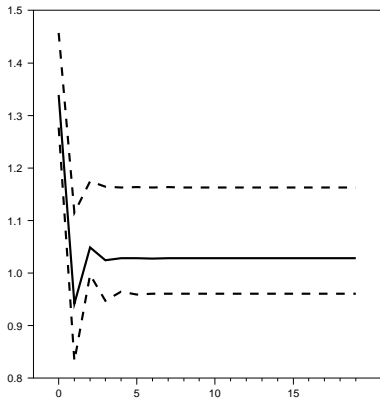
	Original Model		Augmented Model		
	Tech	Nontech	Tech	Nontech	Oil
Baseline: Hours $\sim I(1)$					
• Whole sample	-0.9923*** (0.0167)	0.6724 (0.5119)	-0.9930*** (0.0169)	0.6611 (0.4526)	-0.9207*** (0.2797)
• Pre- <i>Oljefond</i>	-0.9717*** (0.0520)	-0.8133 (0.6873)	-0.9671*** (0.0651)	0.7731 (0.7102)	-0.8955*** (0.2595)
• Post- <i>Oljefond</i>	-0.9985*** (0.0227)	0.4304*** (0.1666)	-0.9991*** (0.0233)	0.4344*** (0.1665)	-0.8528* (0.4718)
Alternative: Hours $\sim TS$					
• Whole sample	-0.9685*** (0.2344)	0.7084 (0.7336)	-0.9656*** (0.2351)	0.6902 (0.7290)	-0.9362*** (0.2844)
• Pre- <i>Oljefond</i>	-0.9478*** (0.1419)	0.8929 (0.7856)	-0.9474*** (0.1313)	0.7707 (0.6907)	-0.8508*** (0.2728)
• Post- <i>Oljefond</i>	-0.9782 (0.6008)	0.9221 (0.8912)	-0.9787 (0.6151)	0.9276 (0.8982)	-0.8444* (0.4938)

tab13

Notes:

(a) See Notes to Table 1.

(b) Unconditional correlation based on hours = -0.5834 (p-value = 0.0017).



productivity

employment

output

E Estimation procedures

E.1 Galí's point estimation strategy

The strategy start by formulatong a finite order Vector Autoregression (VAR) representation for the stochastic process Δx_t and Δn_t , namely,

$$\begin{bmatrix} \Delta x_t \\ \Delta n_t \end{bmatrix} = \sum_{i=1}^{+T} \begin{bmatrix} b_{11i} & b_{12i} \\ b_{22i} & b_{23i} \end{bmatrix} \begin{bmatrix} \Delta x_{t-i} \\ \Delta n_{t-i} \end{bmatrix} + \begin{bmatrix} \nu_t^1 \\ \nu_t^2 \end{bmatrix} \quad (3)$$

$$\text{With, } \begin{bmatrix} \nu_t^1 \\ \nu_t^2 \end{bmatrix} \sim N[0, \Sigma].$$

Or in a more compact way,

$$B(L) \begin{bmatrix} \Delta x_t \\ \Delta n_t \end{bmatrix} = \nu_t \quad (4)$$

Such that $\nu_t = \begin{bmatrix} \nu_t^1 \\ \nu_t^2 \end{bmatrix}$ and $B(L)$ is a matrix polynomial in the lag operator, L , with $B(0) = I$.

A point estimate of $B(L)$ —let label it $\hat{B}(L)$ —is obtained applying Least Square estimation equation by equation, and the resulting estimated residuals—say $\hat{\nu}_t$ for $t = 1, 2, \dots, T$ —are used in their turn to get a point estimate of Σ —let label it $\hat{\Sigma}$. This estimated model is inverted into its moving average representation, namely,

$$\begin{bmatrix} \Delta x_t \\ \Delta n_t \end{bmatrix} = \hat{\Psi}(L)\nu_t \quad (5)$$

$$\text{Where } \hat{\Psi}(L) \equiv \hat{B}(L)^{-1}.$$

In this point a crucial assumption is introduced, on the grounds of the fundamental nature of the random innovations in ε_t , namely that, for some nonsingular matrix S , it holds that,

$$\nu_t = S\varepsilon_t \quad (6)$$

And from thios assumption follows that,

$$SS' = \Sigma \quad (7)$$

Using 8, the representation in 5 can expressed in terms of ε_t , i.e,

$$\begin{bmatrix} \Delta x_t \\ \Delta n_t \end{bmatrix} = \hat{\Psi}(L)S\varepsilon_t \quad (8)$$

In this way we arrive to a candidate estimator of $C(L)$ —let call it $\hat{C}(L)$ —given by,

$$\hat{C}(L) = \hat{\Psi}(L)S \text{ for all } L \quad (9)$$

Expression 9 give us a consistent estimator for $C(L)$ if we knew the right or true value of S , which is not the case, or at least we count with a consistent estimator for it. As matter of fact, the later can be obtained by noticing that. The gist of the methodology consist in obtaining a consistent estimate of S , such that plugging it in ?? allows $\hat{C}(L)$ become a consistent estimator of $C(L)$. This target is attain firstly by noticing that 8 and 9 together imply that,

$$\hat{\Psi}(1)SS'\hat{\Psi}(1) = \hat{\Psi}(1)\hat{\Sigma}\hat{\Psi}(1) \quad (10)$$

From 10 follows that $\Psi(1)S$ is just a factor on the decomposition of the matrix $\Psi(1)\Sigma\Psi(1)$, and if such a factor were unique the resulting estimator of S —label it \hat{S} — get as the factor of $\hat{\Psi}(1)\hat{\Sigma}\hat{\Psi}(1)$ would be consistent. However, this uniqueness could only be attain if we impose some a priori restrictions on the elements of $\Psi(1)S$.

But as a matter of fact, the require assumptions derive from the definitional assumptions made to distinguish technology and nontechnology shocks, namely that only technology shocks produce long-run or permanent effects on labor average productivity, x_t , which implies that $C(1)$ and henceforth $\Psi(1)S$ must be lower triangular, i.e, its upper-right element must be zero, i.e,

$$C(1) = \Psi(1)S = \begin{bmatrix} \Psi_{11}(L) & 0 \\ \Psi_{21}(L) & \Psi_{22}(L) \end{bmatrix} \quad (11)$$

Therefore, $\Psi(1)S$ must be the choleski factor of the matrix $\Psi(1)\Sigma\Psi(1)$ and as such unique. This granted, thet a consistent estimator, \hat{S} for S can be obtained by extracting the choleski factor of $\hat{\Psi}(1)\hat{\Sigma}\hat{\Psi}(1)$, and a consistent estimator of $C(L)$ simply as $\hat{C}(L) = \hat{\Psi}(L)\hat{S}$. Summarizing,

$$\hat{C}(L) = \hat{\Psi}(L)choleski[\hat{\Psi}(1)\hat{\Sigma}\hat{\Psi}(1)] \quad (12)$$

E.2 Galí's interval estimation strategy

To assess the uncertainty around $\hat{C}(L)$ and, in particular, be able to test hypothesis about it, Galí switches from the frequentist or classics perspective and narrative used through the computation and reporting of his point estimate of $C(L)$ to a bayesian perspective, namely the standard Monte Carlo Integration algorithm long popularized by Tom Doan specially thanks to its codification in his econometric package, RATS.

The starting point of the procedure it's again tha VAR model in ??, just that now it is estimated in a bayesian fashion from the following prior distribution,

$$P(\beta, \Sigma) \propto |\hat{\Sigma}|^{-(n+1)/2} \quad (13)$$

Where β is the vectorized version of the parameters in $B(L)$.

By applying Bayes Theorem to combine this prior with the likelihood of a sample series of size N (the size of the actual sample at hand) randomly generated by model ??, the following posterior probability distribution results,

$$\beta|\Sigma \sim N[\hat{\beta}, \Sigma] \text{ and } \Sigma \sim IW[N - 2, \hat{\Sigma}] \quad (14)$$

Where $\hat{\beta}$ is the vectorized version of the parameters in \hat{L} and $\hat{\Sigma}$ is the previous estimate for Σ .

Given the structure of the posterior it is straightforward to get samples from it applying the following Monte Carlo Integration algorithm,

1. Get a sample for Σ , say $\Sigma^{(i)}$, from the Inverse-Wishart with parameters $N - 2$ and $\hat{\Sigma}$.
2. Conditional on $\Sigma^{(i)}$, sample a value for β , say $\beta^{(i)}$, from the multivariate Normal distribution with parameters $\hat{\beta}$ and $\Sigma^{(i)}$.

But, given that there exists a one-to-one relationship between β and Σ and $C(L)$ given by 12, then a sample of $C(L)$, say $C^{(i)}(L)$, is obtained by applying 12 to each sample of β and Σ from their unrestricted posterior. Summarizing, the algorithm to get draws of $C(L)$ is the following,

1. Get a sample for Σ , say $\Sigma^{(i)}$, from the Inverse-Wishart with parameters $N - 2$ and $\hat{\Sigma}$.
2. Conditional on $\Sigma^{(i)}$, sample a value for β , say $\beta^{(i)}$, from the multivariate Normal distribution with parameters $\hat{\beta}$ and $\Sigma^{(i)}$.
3. Compute $\Psi^{(i)}(L) = B^{(i)}(L)$, where the parameters in $B^{(i)}(L)$ come from $\beta^{(i)}$
4. Compute $C^{(i)}(L) = \Psi^{(i)}(L) \text{choleski}[\Psi^{(i)}(L)\Sigma^{(i)}\Psi^{(i)}(L)']$

E.3 Empirical strategy for the extended version of Galí's Model

As should be obvious, in the context of the extended model ?? the single zero restriction on the elements of $C(L)$ imposed in Galí (1999) is not sufficient to identify $C(L)$. But, as it is argued in the last part of this section, judgement as well as statistical tests justify the assumption of exogeneity of oil price in the model, which implies restrict to zero the effect on the oil price of non-oil shocks at all horizons, or in terms of the matrices R_i in ??,

$$r_{i12} = r_{i13} = 0 \text{ for } i = 1, 2, \dots, +\infty \quad (15)$$

These are more restrictions than required to exact identification, so if incorporate all of them the system becomes overidentified and the estimation strategy in Galí (1999) wouldn't work anymore. One simple alternative, that would avoid overidentification, would be to care only on the long-run exogeneity of the oil-price leaving unrestricted the short-run effects of non-oil shocks on it, because it would just imply the triangularization of $R(1)$, i.e,

$$R(1) = \begin{bmatrix} R_{11}(1) & 0 & 0 \\ R_{21}(1) & R_{22}(1) & 0 \\ R_{31}(1) & R_{32}(1) & R_{33}(1) \end{bmatrix} \quad (16)$$

about technology shocks insufficient to attain identification ideThe empirical strategy of citegalí99 could be readily applied to the extended model in refrudolf0 if one were cotented

just with adding the set of restrictions required to exactly identify the parameters of $R(L)$, being the most immediate alternative just to add to citegali99 original restriction the additional restrictions required to triangularize $R(1)$ —the matrix of the cummulated effect of the structural innovations—, such that it would became,

These additional zero restrictions imply to add to citegali99’s identification assumption—only technology shocks have long-run or permanent effects on average labor productivity—given by the zero in the second row of $R(1)$ in refrudolf3, also the assumption that only oil shocks have long-run or permanent effects on the oil price. This is a sensible but mild assumption becuase, as it is argued in the last part of this section, judgment as well as statistical tests justify the more stringent assumption that oil price is in fact exogeneous respect to the rest of variables in the model, which implying that, as well in the short-run, only oil price shocks affect oil price.

As Zha(1998) and Zha(1999) have demonstrated with striking examples, fail to take into account in a *SVAR*-based analysis exogeneity restrictions known true may significantly distort the results conducting to measleading conclusions. It’s for this reason that in what follows the analysis of model ?? incorporate

On these grounds, the estimation strategy of the extended model refrudolf0 opts for the incorporation of the whole set of additional restrictions implied by the exogeneity of the oil price, namely,

These restrictions together with Galí’s restriction imply as a byproduct a triangular $R(1)$ as in refrudolf3.

Summarizing, the extended benchmark model to analysis is given by,

$$\begin{bmatrix} \Delta p_t \\ \Delta x_t \\ \Delta n_t \end{bmatrix} = \sum_{i=0}^{+\infty} \begin{bmatrix} r_{i11} & 0 & 0 \\ r_{i21} & r_{i22} & r_{i23} \\ r_{i31} & r_{i32} & r_{i33} \end{bmatrix} \begin{bmatrix} \epsilon_{t-i}^o \\ \epsilon_{t-i}^z \\ \epsilon_{t-i}^m \end{bmatrix} \equiv \sum_{i=0}^{+\infty} R_i \epsilon_{t-i} \quad (17)$$

$$\text{Where, } \sum_{i=0}^{+\infty} r_{i23} = 0 \text{ and } \epsilon_\tau \equiv \begin{bmatrix} \epsilon_\tau^o \\ \epsilon_\tau^z \\ \epsilon_\tau^m \end{bmatrix} \sim N[0, I].$$

If the number of restrictions implied by the mere triangularization of $R(1)$ represented a exact identification of refrudolf0, then should be obvious that the addition of the restrictions in refrudolf4 produce the overidentification of refrudolf0, and this fact as shown in citezha98 invalidates the application of the estimation strategy use in citegali99 to the case of the extended model refrudolf5. However, as it’ll be explained in what follows, thanks to the recursive form of the system refrudolf5, the alternative bayesian estimation strategy summarized in the algorithm 1 of citezha98 does suit nicely the estimation of refrudolf5.

The strategy of citezha98 goes directly to the estimation of the “structural vector autoregression” equivalent of refrudolf5, resulting of premultiply both sides of the expression by $R(L)^{-1}$, i.e,

$$A(L) \begin{bmatrix} \Delta p_t \\ \Delta x_t \\ \Delta n_t \end{bmatrix} = \epsilon_t \quad (18)$$

Where, $R(L)^{-1} \equiv A(L) = \sum_{i=0}^{+\infty} A_i L^i$

Or in a less compact way,

$$\begin{bmatrix} a_{011} & 0 & 0 \\ a_{021} & a_{022} & a_{023} \\ a_{031} & a_{032} & a_{033} \end{bmatrix} \begin{bmatrix} \Delta p_t \\ \Delta x_t \\ \Delta n_t \end{bmatrix} = \sum_{i=1}^{+\infty} \begin{bmatrix} a_{i11} & 0 & 0 \\ a_{i21} & a_{i22} & a_{i23} \\ a_{i31} & a_{i32} & a_{i33} \end{bmatrix} \begin{bmatrix} \Delta p_{t-i} \\ \Delta x_{t-i} \\ \Delta n_{t-i} \end{bmatrix} + \begin{bmatrix} \epsilon_t^o \\ \epsilon_t^z \\ \epsilon_t^m \end{bmatrix} \quad (19)$$

Then, premultiplying by $A_d(0)$ the previous model is transformed in the following reduced-form recursive system of equations model,

$$\begin{bmatrix} 1 & 0 & 0 \\ c_{021} & 0 & 0 \\ c_{031} & 0 & 0 \end{bmatrix} \begin{bmatrix} \Delta p_t \\ \Delta x_t \\ \Delta n_t \end{bmatrix} = \sum_{i=1}^{+\infty} \begin{bmatrix} c_{i11} & 0 & 0 \\ c_{i21} & c_{i22} & c_{i23} \\ c_{i31} & c_{i32} & c_{i33} \end{bmatrix} \begin{bmatrix} \Delta p_{t-i} \\ \Delta x_{t-i} \\ \Delta n_{t-i} \end{bmatrix} + \begin{bmatrix} \mu_t^1 \\ \mu_t^2 \\ \mu_t^3 \end{bmatrix} \quad (20)$$

$$\text{With, } \mu_t \equiv \begin{bmatrix} \mu_t^1 \\ \mu_t^2 \\ \mu_t^3 \end{bmatrix} \sim N[0, \Omega] \text{ and } \Omega = \begin{bmatrix} \omega_1^2 & 0 & 0 \\ 0 & \omega_2^2 & \omega_{23}^2 \\ 0 & \omega_{23}^2 & \omega_3^2 \end{bmatrix}$$

Notice the block-diagonality of Ω , that makes `refrudolf6` a **Recursive** Seemingly Unrelated Regression Model (SUR) in the terminology of ?, because it can be partitioned in two block models with uncorrelated error vectors.

$$\begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} \Delta p_t \\ \Delta x_t \\ \Delta n_t \end{bmatrix} = \sum_{i=1}^{+\infty} \begin{bmatrix} c_{i11} & 0 & 0 \end{bmatrix} \begin{bmatrix} \Delta p_{t-i} \\ \Delta x_{t-i} \\ \Delta n_{t-i} \end{bmatrix} + \begin{bmatrix} \mu_t^1 \end{bmatrix}$$

$$\begin{bmatrix} c_{021} & 0 & 0 \\ c_{031} & 0 & 0 \end{bmatrix} \begin{bmatrix} \Delta p_t \\ \Delta x_t \\ \Delta n_t \end{bmatrix} = \sum_{i=1}^{+\infty} \begin{bmatrix} c_{i21} & c_{i22} & c_{i23} \\ c_{i31} & c_{i32} & c_{i33} \end{bmatrix} \begin{bmatrix} \Delta p_{t-i} \\ \Delta x_{t-i} \\ \Delta n_{t-i} \end{bmatrix} + \begin{bmatrix} \mu_t^2 \\ \mu_t^3 \end{bmatrix}$$

Zellner (op.cit) demonstrated that the likelihood of the whole model is no more than the product of likelihood for each sub-model, what allows an independent estimation. Zha demonstrated that the same is true from a bayesian perspective.

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