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On the sources of business cycles in the G-7

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Abstract

This paper examines sources of cyclical movements in output, inflation and the term structure of interest rates in the G-7. It employs a novel identification approach which uses the sign of the theoretical cross correlation function in response to shocks to catalog orthogonal disturbances. We find that demand shocks are the dominant source of output and inflation fluctuations in several of the G-7 countries. The proportion of term structure variability explained by different structural sources does not depend on the horizon. Apart from the US and Canada, structural shocks are nearly uncorrelated across countries.

Keywords: Structural shocks; Business cycles; Dynamic correlations; Impulse responses

JEL classification: C68; E32; F11

1. Introduction

The term ‘‘business cycle’’ refers to the presence of common elements in the cyclical behavior of macroeconomic aggregates. Several authors, including Baxter and Stockman (1989), Backus and Kehoe (1992), Fiorito and Kollintzas (1994) and Gregory et al. (1997) among others, have documented the properties of cycles in economic activity in different countries using a variety of methods.

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Whether cyclical movements in economic activity are primarily attributable to demand or supply disturbances is a question with a long standing tradition, tackled from many points of view but with often contradictory answers, see e.g. Blanchard (1989), King et al. (1991), Cooley and Ohanian (1991), Christiano and Eichenbaum (1992), and Gali (1992, 1999). Open economy extensions, e.g. Amhed et al. (1993) or Canova and Marrinan (1998), have similarly reached opposite conclusions. Within this literature, the question concerning the real effects of monetary policy has received substantial attention in recent years (see e.g. Leeper et al., 1996; Christiano et al., 1996; or Kim, 1999).

The interest in the sources of cyclical fluctuations stems from two different angles. First, researchers engaged in constructing models of the business cycle are interested in knowing whether a small number of disturbances is sufficient to capture the dynamics of the actual data, and in characterizing their typology. Second, policymakers care about what drives the cycle when making day to day decisions about the conduct of monetary and fiscal policy. If, as widely perceived, fluctuations are undesirable and demand shocks are largely responsible, there may be a role for aggregate Keynesian-type policies cushioning the economy. On the other hand, as often emphasized in the real business cycle literature, if cyclical fluctuations in economic activity are the optimal response to unforeseen disturbances, rather than mitigating fluctuations per se, a more appropriate role for the government is to reduce economically relevant uncertainties.

In this paper we examine what generates cyclical movements in economic activity using a novel two-step procedure. First, we extract orthogonal innovations from reduced form residuals using a statistical-based approach. These innovations have, in principle, no economic interpretation, but they have the property of being contemporaneously and serially uncorrelated. In the second step, we examine their informational content using restrictions derived from aggregate dynamic macroeconomic theory. The restrictions we employ are widely agreed upon and shared by a number of models with different microfoundations. If, for example, a positive *temporary* orthogonal innovation in one variable represents a supply disturbance (e.g. a shock to labor supply), then it should generate positive transitory output responses, negative transitory responses in inflation and an upward movement in real balances. On the other hand, if it is a real demand disturbance (e.g. increases in government purchases), it should generate positive transitory responses in output and inflation and negative transitory responses in real balances. Finally, if it is a nominal disturbance (e.g. an unexpected increase in the money supply), it should generate positive responses of output, inflation and real balances.

Our identification approach has a number of advantages over competing ones. First, relative to Cooley and Ohanian (1991) or Chada and Prasad (1994), who have used unconditional contemporaneous cross correlations of output and prices (or inflation), we use *conditional* cross-correlations in response to orthogonal shocks to establish sources of business fluctuations. Unconditional correlations may be a fallacious instrument to recover structural shocks, unless additional restrictions are imposed on the DGP of the data (see Judd and Trehan, 1995). Second, relative to structural VAR analyses, e.g. Blanchard and Quah (1989), our procedure clearly separates the statistical problem of orthogonalizing the covariance matrix of reduced form shocks from issues concerning the identification of structural disturbances. More importantly, instead of imposing ‘‘sluggish’’ restrictions on impact responses, which maybe inconsistent with a large class of general equilibrium models (see Canova and Pina, 1999), or on the long run response of certain variables to shocks, for which distortions due to measurement errors and small sample biases may be substantial (see e.g. Faust and Leeper, 1997), we employ theoretically based sign restrictions on the dynamic responses of a vector of variables to examine whether orthogonal disturbances have any interesting economic interpretation.

The scope of our study is limited: we are interested in the identification of a set of shocks, which we generically call supply and demand (real and nominal), whose dynamic effects can be robustly characterized in the context of a large class of macroeconomic models. Once we have recovered the information content of orthogonal innovations, we quantify their importance in generating output and inflation cycles and study their effects on the variability of the slope of the term structure across countries. It is known that the slope of the term structure has predictive power for future movements in real activity at short horizons and inflation at long horizons in many G-7 countries (see e.g. Plosser and Rowenhorst, 1994). Our analysis attempts to give a structural interpretation to this phenomenon.

One important aspect of our exercise, which distinguishes it from the existing literature (Kim, 1999 is one exception), is the cross country focus of the analysis. We would like to know, in particular, whether sources of structural disturbance and their transition mechanism are similar across the G-7 countries. Such an assessment could help policymakers to design coherent national policies, as well as international policy coordination capable of accounting for the path of international integration among world economies.

Several conclusions can be drawn from our analysis. First, demand shocks are the most important source of output and inflation fluctuations in several of the G-7 countries: elimination of these shocks would considerably reduce fluctuations in both variables. Second, within the class of demand shocks, nominal disturbances dominate. Third, the transmission of structural shocks looks similar across countries: we recognize three general patterns characterizing nominal disturbances and a common pattern underlying the transmission of real demand and supply shocks. Fourth, apart from US and Canadian shocks, identified disturbances tend to be uncorrelated across countries, regardless of their type. Fifth, fluctuations in the slope of term structure are almost equally explained by demand and supply shocks and we do not find significant differences in the proportion of variability explained by different structural sources at different horizons.

The finding that demand shocks play an important role in generating real, nominal and financial fluctuations in G-7 countries casts some doubts on theoretical efforts attempting to explain business fluctuations via temporary technological disturbances, and suggests that a careful monitoring of demand conditions may still be an important objective of government policies. Furthermore, since demand shocks are largely uncorrelated across countries and this occurs in an environment where the real and financial sides of the G-7 economies are becoming more integrated, there appears to be room for improving the coordination of policy activities. The fact that nominal disturbances have an important role as sources of real and financial fluctuations confirms recent results by Roberts (1993) and Faust (1998), and stresses the importance of predictable policy behavior for orderly and well functioning goods and financial markets. Finally, the pattern of responses to nominal shocks calls into question the mechanics of transmission employed in standard version sticky-price monopolistic competitive models (e.g. Gali, 1999) and appears to be more supportive of specifications where inflation tax effects and/or liquidity effects are the crucial ingredient in the propagation of these shocks (see Greenwood and Huffman, 1987; or Christiano et al., 1996).

The reminder of the paper is organized as follows. The next section presents the reduced form and the issues connected with its specification. Section 3 discusses the basic intuition behind our identification procedure. Section 4 presents the results. Section 5 analyzes how the slope of the term structure reacts to identified shocks. Section 6 concludes.

2. The specification of the model

Our reduced form model for each country is an unrestricted VAR which includes a measure of real activity (IP), of inflation (INF), of the slope of the term structure of the nominal interest rates (TERM) and of real balances (M/P). The sample we use refers to end of the month seasonally adjusted data from 1973:1 to 1998:12; industrial production, CPI and nominal interest rates are from the OECD database while monetary (M1) data are from IFS statistics. Inflation is measured as the annualized one month change in CPI. The slope of the term structure is the difference between 3 months and 5 years long interest rates.

Reduced form VAR models, which include a measure of real activity, inflation, interest rates and money have been examined by many authors in the literature (e.g. Sims, 1980). Here we maintain the same structure except that we employ a measure of the slope of the term structure in place of a short term interest rate. We do this because recent results by Stock and Watson (1989), Estrella and Hardouvelis (1991), Plosser and Rowenhorst (1994) demonstrated the superior predictive power of the slope of term structure for real activity and inflation relative to a single measure of short term interest rates in many countries. Also, the slope has information about nominal impulses that other variables, such as unemployment or real wages, may not have. We also differ from part of the literature in the fact that we use real balances, as opposed to nominal ones. One justification for this choice is that the model we present in the next section has important implication for real balances. Another is that the responses of real balances allow us to distinguish nominal from real demand disturbances. We have experimented with specifications including other variables (e.g. stock returns) or with using both a short and a long term nominal rate separately. The results we present are insensitive to these changes.

The lag length of each VAR, selected using the Schwarz criteria, varies across countries and we include a constant and a linear trend in each specification to maintain a structure similar to the one employed in the literature.

Because the VAR is a reduced form, the contribution of structural disturbances to output and inflation cycles cannot be directly computed. To obtain structural shocks we proceed in two steps. First, we construct innovations from reduced form residuals having the property of being serially and contemporaneously uncorrelated. Second, we use theory to tell us whether any of the components of the orthogonal innovation vector has a meaningful economic interpretation.

Formally, let the Wold MA representation of the system be:

$$Y_t = \phi + B(\ell)u_t \qquad u_t \sim (0, \Sigma) \tag{1}$$

where Y_t is a 4×1 vector and $B(\ell)$ a matrix polynomial in the lag operator. All orthogonal decompositions of a Wold MA representation with contemporaneously uncorrelated shocks featuring unit variance–covariance matrix are of the form

$$Y_t = \phi + C(\ell)e_t \qquad e_t \sim (0,I) \tag{2}$$

where $C(\ell) = B(\ell)V$, $e_t = V^{-1}u_t$ and $\Sigma = VV'$. The multiplicity of these orthogonal decompositions comes from the fact that for any orthonormal matrix Q, $QQ' = I$, $\Sigma = \hat{V}\hat{V}' = VQQ'V'$ is an admissible decomposition of Σ. One example of an orthogonal decomposition (which will not be used in this paper) is the Choleski factor of Σ, where V is lower triangular. In that case, it is well known that alternative ordering of the variables of the system (i.e. different orthogonal representations of Σ) may produce different structural systems. Another example of an orthogonal representation is the eigenvalue–eigenvector decomposition $\Sigma = PDP' = VV'$ where P is a matrix of eigenvectors, D is a diagonal matrix with eigenvalues on the main diagonal and $V = PD^{1/2}$. Under the assumption of orthogonal shocks, the impulse response of variable i to any shock is given by the vector of lag polynomials $C_i(\ell)\alpha$, where α satisfies $\alpha'\alpha = 1$.

As shown in the next section, dynamic economic theory provides important information on the signs of the pairwise dynamic cross correlations of certain variables in response to structural shocks. The dynamic cross correlations function of Y_{it} and Y_{jt+r}, $r = 0, \pm 1, \pm 2, \ldots$ is

$$\rho_{ij}(r) \equiv \mathrm{Corr}(Y_{it}, Y_{j,t+r}) = \frac{E[C^i(\ell)e_t C^j(\ell)e_{t+r}]}{\sqrt{E[C^i(\ell)e_t]^2 E[C^j(\ell)e_{t+r}]^2}} \quad (3)$$

where E indicates unconditional expectations and $C^h(\ell)$ the h-row of $C(\ell)$. Hence, the pairwise dynamic cross correlation conditional on the particular shock defined by α, is

$$\rho_{ij|\alpha}(r) \equiv \mathrm{Corr}(Y_{it}, Y_{j,t+r}|\alpha) = \frac{(C^i(\ell)\alpha)(C^j(\ell+r)\alpha)}{\sqrt{[(C^i(\ell)\alpha)]^2[(C^j(\ell+r)\alpha)]^2}} \quad (4)$$

whose sign depends on the sign of $(C(\ell)^i\alpha)(C^j(\ell+r)\alpha)$, the cross product of the responses of variables i, j at lag r to the shock. Hence, given one orthogonal representation, it is easy to check whether a shock produces the sign of the cross correlation function required by theory.

Our objective is to explore the space of orthogonal decompositions to see whether for some α and certain variables i, j, $\rho_{ij|\alpha}(r)$ conforms with the predictions of economic theory. Because with non-recursive models, the space of V is uncountably large and the restrictions are nonlinear two questions arise. First, how to systematically search over the space of orthogonal decompositions for shocks which conform to theory. In the appendix we detail an algorithm, based on Press (1997), which we found useful for that purpose. Second, how to choose among various decompositions which recover *some* interpretable disturbance. Here we follow three general principles. First, we restrict attention to those decompositions that maximize the number of shocks exhibiting conditional correlations consistent with theory. If there is no decomposition for which all four shocks are identifiable, we concentrate on those for which only three shocks are identifiable, and so on. Second, if for some r there is more than one decomposition that produces the same maximum number of identifiable shocks, we eliminate candidates making the sign requirements more stringent. Thus, for example, suppose that when one considers sign restrictions at $r=0$ one obtains some candidate decompositions which identify all four shocks. Then, we repeat the exercise imposing sign restrictions at $r=0$ and $r=\pm 1$ and if this is not sufficient yet to select one decomposition, we repeat the exercise using $r=0, \pm 1, \pm 2$, etc.[1]. Third, if this is still not enough to uniquely select a decomposition, we enlarge the vector of conditional correlations whose sign need to be matched, adding the pairwise correlation between the variables of the system and an additional one for which theory has information. For example, one may use the cross-correlation

[1] As a referee pointed out, since restrictions are nonlinear, candidates selected sequentially using restrictions at $r=0$, at $r=\pm 1$, etc. need not to be the same, in general, as those obtained imposing the restrictions jointly. In our specific case, the order in which the restrictions were imposed did not matter and the same candidates were obtained with both approaches.

between money and prices to identify monetary shocks. If, after having used, say, r up to ± 12, there is still more than one decomposition available, one may also want to look at the cross-correlation of money and interest rates to eliminate decompositions which, e.g., do not generate liquidity effects.

Although we rely on the *sign* of the theoretical cross correlation function, one may be, at times, interested in using the *magnitude* of these correlations to identify shocks. In this case one could select the orthogonal decomposition that minimizes the distance between a vector of cross correlation functions of the model and of the data. While sign restrictions are shared by a large class of models with different microeconomic foundations, magnitude restrictions are typically model and parametrization dependent. Therefore, matching magnitudes requires a firm stand on the reference model producing the correlations. As we will argue in the next section, this requirement is not needed when sign restrictions are employed.

In small scale VAR models sign restrictions may be only weakly identifying in the sense that more than one shock belongs to one type (more than one orthogonal disturbance simultaneously satisfies the restrictions we impose). To further disentangle the informational content of these shocks one may use additional restrictions, add variables to the VAR or examine the reasonableness of the responses of variables not used in the identification process. There is also a distinct possibility that no shock of a certain type is found (there is no shock that simultaneously satisfies the restrictions). There are two reasons for why this may occur. First, the restrictions imposed by the model are false and therefore that part of the model should be respecified. Second, the type of shocks we try to identify have different characteristics from the ones present in the data. For example, if supply shocks are permanent, a procedure which uses temporary movements in the variables will fail to find these shocks.

It is worth commenting on the differences between our identification approach and the one commonly used in structural VARs (SVAR). In SVAR one imposes ‘‘economic’’ or ‘‘sluggish’’ restrictions on the matrix of impact coefficients or on long run multipliers and interprets the resulting long run (short run) dynamics. The imposition of economically or informationally motivated restrictions achieves two goals at once: disentangle the reduced form shocks and make them structurally interpretable. The two step approach we propose separates the statistical problem of producing uncorrelated shocks from the economic one of interpreting them. Also, instead of imposing zero restrictions on the contemporaneous impact of shocks, which may be inconsistent with a large class of general equilibrium models (see Canova and Pina, 1999), or on their long run impact, for which small sample biases may be substantial (see Faust and Leeper, 1997), we use the sign of the comovements of a vector of variables in response to shocks to identify their informational content.

Our approach has similarities with the ones recently proposed by Faust (1998) and Uhlig (1999). We share with both authors the desire of systematically examining a variety of identification schemes and of making all restrictions formal. We differ in the function used to identify shocks (cross correlations vs. impulse responses or variance decompositions) and in the criteria used to select among orthogonal decompositions satisfying the restrictions.

Finally, while Cooley and Ohanian (1991), Chada and Prasad (1994) have considered *unconditional* cross correlation function, and concluded that supply disturbances dominate output fluctuations across countries in most time periods, we consider the cross correlation function *conditional* on the shocks to identify sources of cyclical variation. Judd and Trehan (1995) have forcefully argued that simple cross correlations may be unable to discern sources of cyclical fluctuations unless further assumptions on the dynamics of the variables are made. Conditional cross correlations do not face these problems.

3. The theoretical restrictions

The idea behind our approach to identify the informational content of orthogonal innovations is very simple and can be illustrated using a standard undergraduate textbook picture (see e.g. Abel and Bernanke, 1995, p. 382) depicting a downward sloping aggregate demand curve (AD), an upward sloping short-run aggregate supply curve (SRAS) and a vertical long-run aggregate supply curve (LRAS) in the inflation-output plane.

Suppose we observe a temporary negative inflation innovation. If it is driven by a temporary (positive) supply disturbance it should generate a positive response of output in the short run, increase money demand and produce a positive response in real balances. These changes in the equilibrium values of the variables are caused by an outward movement of the SRAS curve, keeping AD and LRAS fixed. Suppose, on the other hand, that a positive inflation innovation is driven by a temporary (positive) real demand disturbance, for example, an increase in government expenditure financed by bond creation. In that case we should observe a positive short-run response in output and a decline in real balances. These changes are the result of an outward movement in AD curve, keeping SRAS and LRAS fixed. Finally, suppose a positive inflation innovation is driven by a temporary shock in money growth. Then, we should also observe a positive response of output, if money has real effects and a positive response of real balances, if prices do not fully adjust instantaneously. This combined set of circumstances is obtained by moving the AD curve along the SRAS curve, keeping the LRAS curve fixed. A similar pattern holds when we observe a temporary innovation in output. Hence, these three types of structural disturbances produce joint comovements of output, inflation and real balances of different signs.

The undergraduate textbook approach has not much to say about the exact timing of these comovements. If prices are flexible, the majority of the adjustments should occur almost contemporaneously and the pairwise contemporaneous cross-correlation of these three variables in response to innovations can be used to identify the informational content of shocks. If prices are sticky, or there is sluggishness in output adjustments peak responses may occur with a delay. In these cases the leads and lags of the pairwise cross correlation function contain the information needed to identify structural disturbances.

Since the former discussion is based on static theory, it is legitimate to wonder whether dynamic models with different micro-foundations generate similar signs in the cross correlation function in response to shocks. The class of models where shocks move aggregate demand and supply curves in the way we have described is relatively broad and includes, for example, Lucas (1972) model, new-keynesian models with menu costs and/or sticky-price monopolistic competition of the type examined by Mankiw (1985) or Gali (1999), models of indeterminacy of the type described in Farmer (1999) and also market clearing flexible price models.

To outline one model in such a class consider the following open economy version of the model used by Den Haan (1990) and Gavin and Kydland (1999). There are two countries and we let ζ be the proportion of agents in country 1. In each country agents need either time or money to purchase consumption goods and sells labor to a domestic firm. Following the existing literature we abstract from capital. At the beginning of each t shocks to technology, government purchases and money growth are realized in each country, new money is distributed to domestic agents who exchange money for internationally traded bonds in financial markets according to their needs. When financial markets close agents sell labor on competitive labor markets, production takes place, the government takes a fraction of output away for its own purposes and what is left is sold to consumers, which pay cash for their purchases. The proceedings of the sale are distributed to the household in the form of wages and profits, the firm shutdowns at the end of period t to reopen at $t+1$ under the same arrangement. The problem for the representative consumer/firm in country i is:

$$\max_{\{c_{it}, l_{it}, M_{it}, B_{it}\}} E_0 \sum_{t=0}^{\infty} U(c_{it}, l_{it}) \tag{5}$$

subject to:

$$l_{it} = 1 - h_{it} - v_{it} \tag{6}$$

$$c_{it} + \frac{B_{it+1}}{p_{it}} + \frac{M_{it+1}}{p_{it}} = y_{it} + \frac{M_{it}}{p_{it}} + \frac{B_{it}}{p_{it}}(1 + I_t) - T_{it} \tag{7}$$

where $y_{it} = f(h_{it}, A_{it})$. The government budget constraint and the supply of money are

$$\frac{M_{it+1} - M_{it}}{p_{it}} = g_{it} - T_{it} \tag{8}$$

$$M^s_{it+1} = (1 + \mu_{it+1})M^s_{it} \tag{9}$$

and the world market clearing condition for bonds is

$$\zeta B_{1t} + (1-\zeta)B_{2t} = 0 \tag{10}$$

where μ_{it} is the growth rate of the money supply, A_{it} is a technology disturbance, g_{it} are government purchases of goods, T_{it} are lump sum transfers of money, B_{it} is the stock of outstanding internationally bonds held in country i and I_t the one period interest rate, v_{it} is shopping time, l_{it} is leisure, h_{it} hours worked and p_{it} is the price level at t in country i.

Define $m_{it} = M_{it}/p_{it}$, $b_{it} = B_{it}/p_{it}$ and $\pi_t = p_{t+1}/p_t$. We assume that the utility function is of the form $U(c_t, l_t) = (c_t^{\delta} l_t^{1-\delta})^{\tau} - 1/\tau$, that the shopping time technology is $v_t = v(c_t, m_t) = c_t(M_t/p_t c_t)^{\gamma} + \eta_2(M_t/p_t)$ where $\gamma = -\eta_1/1-\eta_1$, and the production function is $f(h_t, A_t) = h_t^{\alpha} A_t$ for both countries. The first order conditions of the problem, the shopping time constraint (6), the resource constraint, the production function, the money supply rule (9), the budget constraint of the monetary authority (8) and the market clearing condition (10) constitute a system of nonlinear equations driven by the six exogenous shocks (A_{it}, g_{it}, μ_{it}, $i=1, 2$). We assume that the shocks are AR(1) processes, independent across countries and type, with persistent matrix ρ_i.

In Fig. 1 we report the theoretical pairwise cross correlation function of output, inflation real balances in country 1, conditional on each of the three domestic disturbances when $\rho_i = \text{diag}[0.99, 0.90, 0.50]*I$, $\delta = 0.5$, $\tau = -2$, $\alpha = 0.64$, $\eta_1 = 2.5$, $\eta_2 = 1.0$, $\beta = 0.99$, $\zeta = 0.5$ and the system is log-linearized around the steady states. With these choices the steady state values of leisure, consumption to real balances, consumption to output, and money growth, are respectively, $\bar{l} = 0.6$, $c/m = 1/6$, $c/y = 0.7$, $\bar{\mu} = 0.001$, which are all very similar to those of Gavin and Kydland (1999).

A technology disturbance generates negative contemporaneous cross correlations between output and inflation and inflation and real balances and the shapes of the two correlations are very similar. The correlation between real balances and output is tent-shaped but positive everywhere. Government expenditure shocks produce a positive contemporaneous cross correlation between output and inflation. The cross correlation between inflation and real balances and between real balances and output has an inverted tent shape. In both cases, the contemporaneous cross correlation is negative. Finally, monetary disturbances produce positive cross correlations for all pairs of variables.

The interpretation of the dynamics generated by the three shocks is simple: the adjustments induced are in fact driven by the effects of shocks on labor supply. A surprise increase in A_{it} increases domestic output on impact since g_{it} is constant at its steady state level. Given the partial risk sharing agreement, consumption of both countries will increase. This increase in consumption requires an increase in the money or time to finance expenditure. With a fixed money supply, the first channel is shut down. Shopping time therefore increases and this requires that either leisure or hours decline to keep the time constraint satisfied. Because the

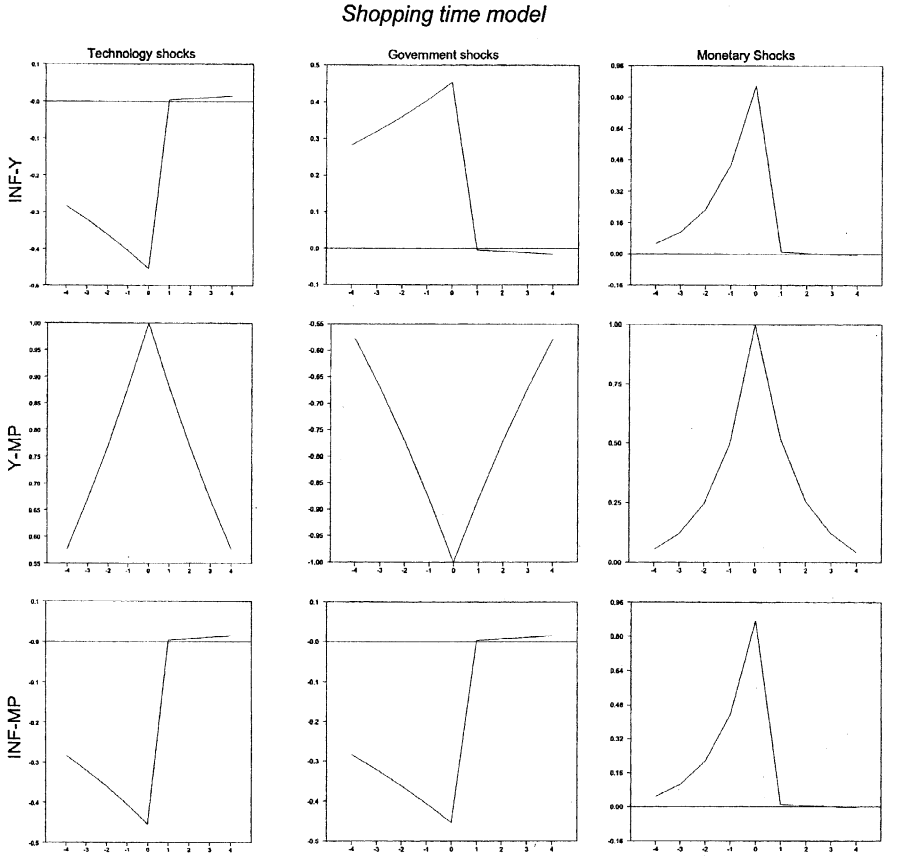

Fig. 1. Cross correlations.

wealth effect of the shock is strong, hours decline and leisure increases temporarily. Also, because the price level declines, real balances increases after the shock.

A unitary surprise increase in g_{it} makes domestic (and foreign) consumption decline and, because of a wealth effect, domestic labor supply and domestic output increase. Given the money supply, domestic aggregate demand increases and this raises domestic prices on impact. Since consumption declines, money demand declines, shopping time and leisure decline to maintain the time constraint satisfied, and real balances also decline.

Finally, a unitary surprise increase in μ_{it} increases prices and alters current leisure (via an inflation tax effect). When leisure instantaneously declines, resources for shopping and production are freed so output and consumption both increase. After one period shopping time needed to finance consumption declines, both leisure and hours increase leading to an increase in output and consumption in the medium run. Furthermore, since the increase in inflation is smaller than the increase in μ_t, real balances increase.

In conclusion, the model generates the same sign restrictions on the cross correlation function of output, inflation and real balances in response to structural disturbances as the undergraduate textbook model. Since the joint behavior of these variables in response to shocks is shared by a large class of models with different micro-foundations, we feel confident in using sign restrictions to recover structural disturbances without reference to any specific model in this class.

4. The results

4.1. Identifying structural disturbances

There are three important features of our identification results which we would like to emphasize. First, we identify the informational content of all four shocks for all countries. That is, the restrictions imposed by the class of models we have described have some counterpart in the data. Second, we identify at least two nominal disturbances in all countries, and in Japan and Italy three shocks are of this type. Third, one of the orthogonal shocks can be classified as a real demand disturbance in all countries except Italy, and one supply shock is identifiable in all countries except Japan.

The transmission properties of structural shocks fall into few distinctive patterns. Nominal disturbances belong to three broad groups. One type of nominal shocks produce responses that are consistent with a standard policy interpretation of this disturbance, i.e. a shock which contracts nominal balances decreases output, reduces inflation and real balances, while the short term nominal rate increases relative to long term one. There is at least one shock with these characteristics in Japan, France, Germany and Italy. In this case (see e.g. Japan 3 in Fig. 2) the response of output and inflation is humped shaped and it takes about 10–12 months for the shock to have its maximum effects.

A second type of nominal shocks produces qualitative similar responses for output, inflation and real balances, but short term interest rates decrease instantaneously in response to a contractionary nominal shock, suggesting the presence of important short term expected inflation effects. Shocks with these characteristics are present in the US, Japan, Germany and Italy. In this case (see e.g. Germany 2 in Fig. 2), the peak response of output occurs within 6 months of the shock but the response of inflation is instantaneous and very strong. Inspection of the time path of these disturbances indicates that they have high variability at times when the level of inflation is higher than its historical average.

A final type of nominal shocks, present in UK, Italy and Canada, has a perverse effect on output: a disturbance that increases the level of nominal balances

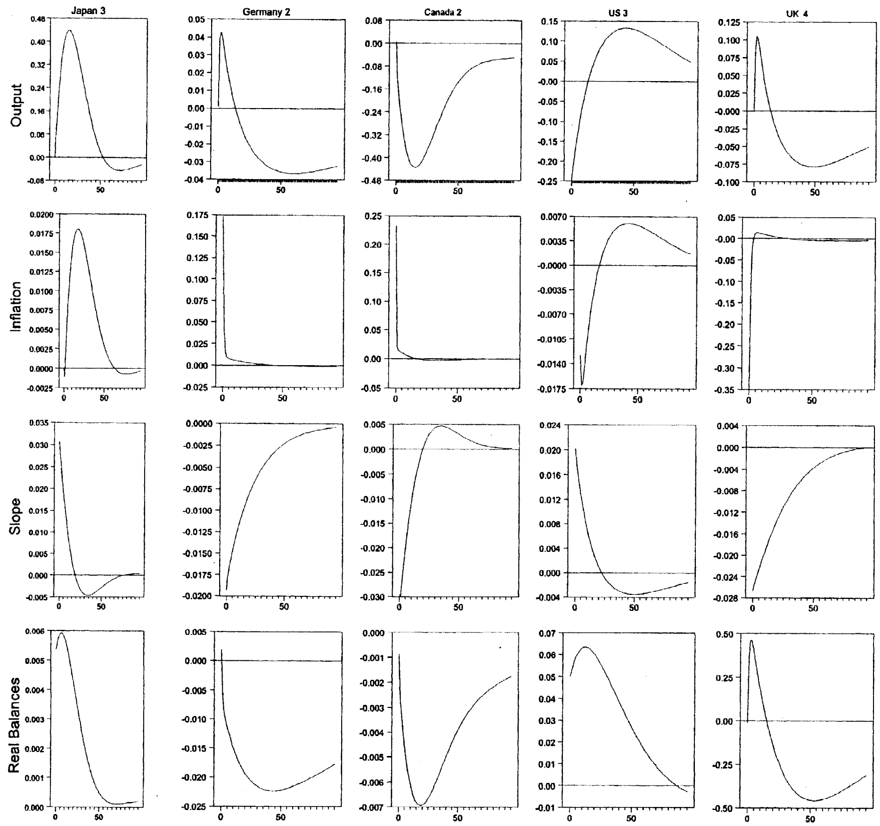

Fig. 2. Responses to shocks, 73.1–98.12.

produces a strong positive response of inflation and this makes real balances decline (see e.g. Canada 2 in Fig. 2). Output then declines, possibly because of an inflation tax effect (see Greenwood and Huffman, 1987), and changes in inflation expectations increase short term interest rates relative to long term ones. Shocks that produce this pattern appear to be linked to international factors. That is, their variability tends to increase at the time of turbulence in international money and financial markets and, in Italy and the UK, at the time of realignment of their exchange rates.

The majority of the nominal shocks we identified produce responses of inflation which are instantaneous, have the correct sign and varying degrees of persistence. Since these dynamics may look at odds with existing empirical work and with popular sticky price models, it is worth discussing how our results compare with the literature. First, the conventional wisdom that prices are sluggish in response to nominal shocks is based on VAR exercises where this restriction is imposed at the identification stage. Since we refrain from requiring that the price level (inflation) does not respond instantaneously to nominal shocks, we are in the position to ''test'' the validity of this restriction. Overall, the data does not appear to support it. Second, while the behavior of inflation in response to nominal shocks is in contrast with extreme versions of sticky price models (e.g. one-period in advance price setting) it is not inconsistent, for example, with the predictions of sticky price models with labor hoarding and capacity utilization (see e.g. Neiss and Pappa, 2001). In these models monetary shocks instantaneously alter both the aggregate demand and the aggregate supply of the economy. Therefore, there are self-enforcing factors which immediately act on inflation when nominal shocks hit the economy. Third, the recent literature has noted the presence of perverse price dynamics in response to nominal disturbances (see e.g. Sims, 1992). In the majority of the cases the nominal shocks we have identified do not generate inflation puzzles, even in VAR which do no include variables proxying for expectations of future inflation (like commodity price inflation). Hence, the price (inflation) puzzle may be the result of inappropriate identification assumptions. Interestingly, there are cases when nominal shocks generate humped shaped responses on inflation which starts from one side of zero and go to the other over the adjustment path. Had we zeroed by assumption the instantaneous response, the pattern could be mistakenly taken to generate an inflation puzzle.

The adjustments induced by real demand shocks are similar across countries and, by and large, standard: if contractionary, a disturbance of this type causes both industrial production and inflation to decline on impact, real balances to increase and the short term rate to fall relative to the long term one (see e.g. US 3 in Fig. 2). Note that the adjustment in response to these shocks takes considerable time and that there is some overshooting in the convergence to the steady state.

Responses to supply shocks are also homogeneous across countries and adjustments are consistent with theoretical expectations: if expansionary, these shocks produce a hump-shaped increase in industrial production and a sharp but short lived decline in inflation. Real balances responses mimic those of industrial production while short term nominal interest rates decrease relative to long ones in all countries but the UK (see, UK 4 in Fig. 1). Also in this case, real adjustments to shocks take time while inflation is back at the steady state within a year. Consistent with expectations, the volatility of these shocks tends to be higher before 1980.

In sum, the disturbances that our procedure identifies produce similar dynamics across countries. In the case of nominal disturbances the adjustments can be broadly associated with domestic expansionary effects, domestic expected inflation effects and international expected inflation effects. For the other two disturbances, the pattern of responses is consistent with standard theoretical characterizations of these shocks.

Table 1
Forecast error variance of industrial production and inflation explained by structural innovations

Structural innovations	Sample 1973:1–1998:12					
	Industrial production			Inflation		
	Nominal	Real demand	Supply	Nominal	Real demand	Supply
USA	42–71 0–5	9–17	11–32	2–26 50–81	1–6	12–20
Japan	2–18 20–36 1–10	48–62	66–88 0–4 5–15	0–3		
Germany	49–66 2–8	18–36	1–13	8–29 36–58	0–11	15–29
UK	21–33 3–24	20–39	13–33	5–11 31–37	0–6	49–55
France	10–20 0–8	37–70	10–28	15–42 0–3	15–18	10–42
Italy	35–75 0–3 20–34		2–11	0–12 10–13 3–10		45–74
Canada	52–72 11–28	0–9	1–7	1–5 60–62	0–2	29–36

Notes: The forecast error variance is computed using a 4 variable VAR model. The table shows the 68% error band for the 24 month forecast error variance in the variable explained by sources of structural innovations. Bands are computed using a bootstrap algorithm.

4.2. The explanatory power of structural disturbances

Having identified the informational content of orthogonal VAR innovations, we next calculate the contribution of structural shocks to output and inflation cycles for every G-7 country. Table 1 presents 68% bootstrap bands for the forecast error variance decomposition of output and inflation at 24 step horizon due to structural disturbances. Varying the forecasting horizon between 24 and 48 steps has no effects on the qualitative features of the results.

Three important regularities are present in the table. First, in all seven countries demand shocks are the major source of fluctuations in industrial production and only in US, UK and France supply shocks account for a significant amount of its variability. Second, the combined contribution of nominal disturbances to variability in industrial production in the US, UK, Germany, Italy and Canada is large. Third, demand disturbances are the most important source of inflation fluctuations in five of the seven countries and nominal disturbances play a crucial role in all the cases. Fourth, supply disturbances constitute a significant source of inflation fluctuations in all countries but Japan.

At first sight, one may be surprised about the importance of the nominal shocks for real fluctuations. As we have seen in the previous section, not all identified nominal shocks can be related to domestic policy disturbances that the literature has studied. Furthermore, in some countries there is more than one shock which satisfies the restrictions needed to be considered nominal. Hence, although no direct comparison with existing estimates is possible, our results are suggestive of the existence in the data of nominal shocks with high predictive power for real and nominal fluctuations in several countries.

One may also be puzzled about the relative minor importance of supply shocks for real fluctuations. Recall that the supply shocks we identify are temporary and, as the model suggest, they alter the relative preference of agents for consumption and leisure. Therefore, our results are not in contrast with those of authors finding that permanent supply shocks dominate the short run variability of output nor with standard RBC models driven by technology disturbances, unless these shocks are temporary.

4.3. A counterfactual experiment

Output and inflation fluctuations are typically perceived as undesirable. The presumption is that they disrupt the current and future course of economic activity by altering expectations or surprising market participants. Here we ask the following counterfactual question: how large would output and inflation fluctuations be if demand shocks were absent?

We have seen that in all seven countries demand shocks are identifiable. Since in Japan all identifiable shocks are of this type, eliminating the influence of demand shocks would simply set output and inflation to their long run trend. In

Table 2
Cross country correlations of structural shocks sample 1973:1–1998:12

	US Shocks			
	Nominal 1	Nominal 2	Real demand	Supply
Japan Nominal 1	−0.00	−0.03		
Japan Nominal 2	0.04	0.19(*)		
Japan Nominal 3	0.00	0.03		
Germany Nominal 1	−0.02	0.08		
Germany Nominal 2	−0.09	0.02		
UK Nominal 1	−0.03	−0.09		
UK Nominal 2	−0.04	−0.01		
France Nominal 1	−0.08	−0.06		
France Nominal 2	0.07	−0.01		
Italy Nominal 1	−0.01	−0.15		
Italy Nominal 2	0.13	0.12		
Italy Nominal 3	0.02	−0.00		
Canada Nominal 1	−0.01	0.39(*)		
Canada Nominal 2	−0.25(*)	0.06		
Japan Real Demand			−0.00	
Germany Real Demand			−0.27(*)	
UK Real Demand			−0.20(*)	
France Real Demand			0.01	
Canada Real Demand			0.18(*)	
Germany Supply				−0.07
UK Supply				0.00
France Supply				0.06
Italy Supply				0.01
Canada Supply				−0.24(*)

Notes: All correlations are contemporaneous. Those significantly different from zero at a 5% confidence level are marked with a ‘‘*’’.

three countries the elimination of demand shocks would lead to a substantial reduction in output and inflation fluctuations (the standard deviation of (detrended) industrial production index would be 92% lower in the US, 80% lower in Germany and 90% lower in the UK) while in the other three countries the reductions are smaller. For inflation the reductions are more homogeneous and substantial: the standard deviation of inflation would drop by 88% in UK and by 56% in France, and by values in this range in the other countries. Most of the gains, as expected, come from neutralizing nominal disturbances. For example, in the US 66% of the decline in industrial production and inflation variability are obtained by neutralizing the two nominal disturbances. That is, a more stable environment in national money markets would have systematically reduced cyclical fluctuations in output and inflation. Hence, this exercise reinforces the view that nominal shocks are important and that variance reduction could have been achieved by employing more deterministic policy conducts.

4.4. Are source of cycles common?

One question of interest for policymakers and students of international business cycles is whether and to what extent sources of cyclical fluctuations are correlated across countries. For example, if G-7 industrial production cycles were driven by a common world productivity disturbance, one should naturally expect the syncronicity of output fluctuations which is found in the literature (see Backus and Kehoe, 1992; or Fiorito and Kollintzas, 1994). Similarly, if demand shocks are correlated across countries, it may be reasonable to expect that policy coordination may be beneficial in stabilizing world output fluctuations. Table 2 provides evidence on whether sources of shocks are also correlated across countries by presenting the contemporaneous cross country correlations (relative to the US) for the various shocks.

Four major regularities are worth emphasizing. First, the maximum correlation always occur at lag zero. Second, there are significant commonalities in the sources of shocks in the US and Canada: the correlation between the two nominal shocks is −0.25 and 0.39, the correlation of supply shocks is −0.24 and the one of demand shocks is −0.18. Third, the US demand shock is also correlated with the German and the UK demand shocks (0.27 and −0.20) but all the other demand shocks are not. Fourth, there is little relationship between supply shocks across countries. In fact, the supply shocks in UK, Germany, Italy and France are not only uncorrelated with US and Canadian ones, but also with each other.

To summarize, there is some evidence of contemporaneous commonalities in the sources of cyclical fluctuations, but the phenomenon is geographically localized. Hence, the similarities in output and inflation cycles we observe are probably due more to the similarities in the transmission of structural shocks then to commonalities in the sources of shocks[2].

[2] We have examined the sensitivity of the results obtained in this section with respect to the specification, the sample and the estimation technique: we have studied a specification where output and inflation enter in first difference; we have identified shocks over two subsamples (1973–1982; 1983–1998) and we have estimated the VAR model before identification pooling the seven data sets. No major changes to the entries of Table 1 are found when the growth rate of IP and of inflation are used in the VAR. Splitting the sample in two produces some heterogeneity in the sense that the type of structural disturbances we disentangle is different across the two subsamples and that their relative importance for output and inflation fluctuations is altered. Nevertheless it is still true that demand shocks are more important than supply shocks, that the contribution of nominal disturbances to the variability of industrial production is large and that demand disturbances are more important than supply disturbances in accounting for inflation fluctuations. Pooling the data produces estimates of the cross correlation function which are interpretable in the full and the first subsample and generally consistent with the ‘‘average’’ result we had obtained across countries. In the second subsample, the heterogeneity present is such that estimates of the cross correlation function are not structurally interpretable and, in general, non comparable with those obtained by considering the 7 countries separately. More information of these issues is contained in Canova and DeNicoló (2000).

Table 3
Forecast error variance of the term structure explained by structural innovations

Structural innovations	Sample 1973:1–1998:12					
	3 months horizon			24 months horizon		
	Nominal	Real demand	Supply	Nominal	Real demand	Supply
USA	0–1 7–14	16–26	58–74	0–5 5–13	13–28	41–72
Japan	1–3 63–91 3–28	0–1	1–5 38–62 13–49	1–13		
Germany	7–21 18–31	0–12	41–60	35–57 8–20	5–16	17–30
UK	0–5 53–65	0–4	24–40	5–29 28–42	1–8	30–46
France	21–36 0–1	4–40	17–53	20–34 0–5	8–29	12–40
Italy	0–2 75–95 1–7		1–8	2–10 40–75 3–40		1–8
Canada	0–26 47–60	0–1	16–42	7–47 26–48	2–20	7–27

The forecast error variance is computed using a 4 variable VAR model. The table shows the 68% error band for the 24 month forecast error variance in the variable explained by sources of structural innovations. Bands are computed using a bootstrap algorithm.

5. The variability of the slope of the term structure

The literature has documented that the slope of the term structure can be used to forecast future movements in output and inflation. In particular, the slope carries information about the real side of the economy in the short run and about inflation in the long run (see e.g. Plosser and Rowenhorst, 1994). One explanation for this fact is that supply and demand disturbances move the slope of the term structure and that the relative importance of the two types of shocks changes with the horizon. Here, we would like to examine (i) which type of structural disturbance accounts for the variability of the slope of the term structure and (ii) whether different structural shocks have different explanatory power for the slope at different horizons.

Table 3 reports the percentage of variance in the slope of the term structure explained by identified shocks at 3 and at 24 months horizons. Three observations can be made. First, the variability of the slope of the term structure is almost equally explained by demand and supply shocks at the three step horizon. The exceptions here are the US, where supply shocks clearly dominate, and Japan and Italy, where demand shocks account for a large percentage of the variance of the slope. Second, within the class of demand disturbances, nominal shocks play an important role in every country except the US. Third, the relative importance of various sources of fluctuations does not significantly change with the horizon: supply shocks lose some of their predictive power at long horizons in favor of demand shocks in Germany and Canada but, qualitatively, no major changes occur.

The conclusion that nominal shocks are an important sources of term structure fluctuations agrees with the recent evidence of Evans and Marshall (1998), and is consistent with liquidity theories of monetary policy (see e.g. Christiano et al., 1996). The fact that demand shocks are partly responsible for term structure variability at both short and long horizons confirms that a careful monitoring of the conditions in monetary markets may provide not only orderly behavior in goods markets but also more stability in bonds markets. Finally, the fact that supply shocks matter for the variability of the slope suggest that fluctuations in financial markets may have different causes than those in real and monetary markets.

6. Conclusions

This paper examined sources of cyclical movements in economic activity, inflation and their transmission features using a novel two-step approach. The proposed procedure is advantageous for several reasons: it uses the joint dynamics of output, inflation and real balances to identify shocks; it clearly separates the statistical issue of obtaining contemporaneously uncorrelated innovations from the one of identifying their informational content; finally, it allows to systematically examine the space of identifications. For the cross section of G-7 countries, we find that demand shocks are the most important source of output and inflation fluctuations in several of the G-7 countries and that within this class of shocks, nominal shocks dominate. We also showed that the transmission of structural shocks looks similar across countries but that these structural disturbances tend to be uncorrelated across countries with the exclusion of US and Canada. Finally, we showed that fluctuations in the slope of term structure are almost equally explained by demand and supply shocks and that there are no significant differences in the proportion of its variability explained by structural sources at different horizons.

Some important conclusions can be drawn from our exercise. First, temporary supply disturbances seems to play a small role as source of fluctuations in all countries except the US. Hence, the emphasis that the RBC literature has put on these shocks seems ill-posed. Our results are not necessarily in contrast with the existing literature since in previous exercises (Blanchard and Quah, 1989; Gali, 1992) identified supply shocks have permanent characteristics. Second, contrary to the conventional wisdom, we find that nominal disturbances play an important role as a source of real fluctuations in all countries. Our results therefore reinforce the claims of Roberts (1993) and Faust (1998), who found that there are identification schemes which give nominal disturbances an important role for output variability in the U.S., and contrast those of Kim (1999), who found very little importance of monetary disturbances in the G-7. While our results provide empirical support to the recent resurgence of interest in theoretical models where nominal shocks are the engine of the business cycle, they are inconsistent with a class of simple sticky price models currently used in many policy circles and more supportive of flexible price specifications. Third, contrary to previous studies (see e.g. Sims, 1992), identified nominal shocks do not generate any price puzzle and this result obtains even without using proxies for expectations of future inflation in the VAR. Finally, since demand shocks are largely uncorrelated across countries—and this is true in particular for nominal shocks—there appears to be room for substantial improvement in the coordination of policy activities.

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Appendix A

In this appendix we describe how we explore the space of orthogonal decompositions to find a candidate identification. It is well known that, if we exclude the case of recursive models, the set of possible identifications is uncountable and it is difficult to search effectively. Furthermore, since the sign restrictions we employ are nonlinear, the order in which they are imposed may matter for the results. The algorithm we employ makes use of the following result which is contained in Press (1997).

Result: Let P be the matrix of eigenvectors and D the matrix of eigenvalues such that $\Sigma = PDP'$. Then $P = \prod_{m,n} Q_{m,n}(\theta)$ where $Q_{m,n}(\theta)$ are rotation matrices of the form:

$$Q_{m,n}(\theta) = \begin{bmatrix} 1 & 0 & 0 & \dots & 0 & 0 \\ 0 & 1 & 0 & \dots & 0 & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & \cos(\theta) & \dots & -\sin(\theta) & 0 \\ \vdots & \vdots & \vdots & 1 & \vdots & \vdots \\ 0 & 0 & \sin(\theta) & \dots & \cos(\theta) & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

where $0 < \theta \leq \pi$ and the subscript (m, n) indicates that rows m and n are rotated by the angle θ.

To translate this result in an algorithm that searches the space of orthogonal decompositions, note first that in a system of N variables there are $(N(N-1)/2)$ bivariate rotations of different elements of the VAR, for a fixed θ. Hence, for $N = 4$ there are six possible rotation matrices. Second, since $Q_{m,n}(\theta)$ are orthonormal $\Sigma = \hat{V}\hat{V}' = VQ_{m,n}(\theta)Q_{m,n}(\theta)'V' = PD^{0.5}Q_{m,n}(\theta)Q_{m,n}(\theta)'D^{0.5}P'$ is an admissible decomposition. Hence starting from an eigenvalue–eigenvector decomposition we can ''decouple'' it in one direction or another, for each θ. Third, we grid the interval $[0, \pi]$ into M points, and construct 6M orthogonal decompositions of Σ. This last step transforms an uncountable into a large but finite search.

In practice, one needs to choose both how many r to include and how many points the grid should have. To maintain computations feasible we start the process by choosing $r = 0$. Since theory typically has strong prediction for either contemporaneous or one period lagged correlations (e.g. in model with sticky prices) this starting point is not restrictive. Moreover, as mentioned, the number of sign correlation restrictions considered can be increased if multiple candidates satisfy the restrictions. In the specific application of this paper, matching the sign of cross correlations at $r = 0, \pm 1$ was sufficient to select a unique candidate. Also, to keep computation manageable we limit the number of grid points to be less then 500. Depending on the country, between 30 and 500 points for each $Q_{m,n}(\theta)$ were sufficient to cover the interval effectively.

In some cases a number of grid points may be consistent with the restrictions. If these points belong to one interval, they typically produce the same impulse responses and therefore we treat them as a single point. If they belong to several intervals we add restrictions until only one interval remains.

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