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A Discussion of the Reliability of Results Obtained with Long-Run Identifying Restrictions

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Abstract

In a recent article, Faust and Leeper (1997) discuss reasons why inference from structural VARs identified with long-run restrictions may not be reliable. In this paper, the authors argue that there are reasons to believe that Faust and Leeper's arguments are not devastating in practice. First, simulation exercises suggest that this approach does well when used with data generated with standard macroeconomic models. Second, empirical applications suggest that it gives results that are much more robust than would be implied by Faust and Leeper's main proposition. A reasonable approach would appear to be, therefore, to follow Sims' (1971; 1972) and Dufour's (1997) recommendation and to present robustness checks, allowing readers to judge for themselves what the effects of possible approximation errors might be.

Résumé

Dans un article récent, Faust et Leeper (1997) analysent les raisons pour lesquelles on ne pourrait se fier aux déductions tirées de vecteurs autorégressifs structurels (VARS) assortis de restrictions d'identification à long terme. Pierre St-Amant et David Tessier soutiennent, dans leur étude, que la portée pratique des arguments invoqués par ces auteurs n'est pas dramatique. Premièrement, les simulations indiquent que la méthode fondée sur l'emploi de restrictions à long terme aboutit à des déductions valables lorsque les données utilisées sont générées au moyen de modèles macroéconomiques standards. Deuxièmement, l'application empirique de cette méthode débouche sur des résultats bien plus robustes que ce que laisse entrevoir l'argument central de Faust et Leeper. Il semble donc qu'une approche raisonnable consisterait à suivre la recommandation de Sims (1971 et 1972) et de Dufour (1997), qui proposent que les auteurs présentent des analyses de sensibilité afin de permettre aux lecteurs de juger par eux-mêmes de l'effet des erreurs possibles d'approximation.

1. Introduction

In a recent article, Faust and Leeper (1997) give three reasons why inference from structural VARs identified with long-run restrictions may not be reliable. The first reason is that the long-run effect of shocks would be imprecisely estimated in finite samples, leading to imprecise estimates of other parameters in the model. Two additional reasons discussed by Faust and Leeper concern the identification problems inherent in models that aggregate across variables and/or across time. The authors acknowledge that these latter problems are well known and very general in that they apply to most empirical studies using time series. Consequently, we make just a few comments on them, focusing most of our attention on the first reason.[1]

It is important to note that this line of argument can be applied to many econometric approaches. Sims (1971; 1972) initiated the analysis by studying the consequences of different approximations used in the context of estimated distributed-lag models. Faust (1996a) uses similar arguments that he applies to the calculation of confidence intervals for the estimated spectra of time series. Some authors have applied these arguments to highlight the limitations of many popular unit root tests (Cochrane 1991; Blough 1992; Faust 1996b). Finally, Dufour (1997), working with a slightly different set of assumptions,[2] shows that problems of this type can also affect several econometric techniques such as instrumental variables regressions, simultaneous equations models, and the estimation of cointegrated relationships. In this paper, we discuss the specific case of the identification of structural models with long-run restrictions but, again, we believe that one should keep in mind that a very large class of econometric approaches might be affected.

In Section 2, we provide a brief overview of the approach based on long-run restrictions. In Section 3, we examine more explicitly the problem associated with the estimation of long-run effects and discuss different solutions. In Section 4, we discuss briefly the other two points made by Faust and Leeper. An empirical application is presented in Section 5 and we conclude in Section 6.

1. Although we concentrate our analysis mainly on this first point, the consequences inherent to aggregation are as important.
2. To be more precise, Dufour's paper is about problems involving parameters that are locally almost unidentified in the context of models with finite parameterization.

2. The identification of VAR models with long-run restrictions[3]

Let $X_t = (X_{1t}, \ldots, X_{nt})'$ be a covariance-stationary process for which, ignoring deterministic components, there is a Wold representation:

$$X_t = F(L)u_t . \tag{1}$$

The innovation process u_t has zero mean and is serially uncorrelated with covariance matrix $E[u_t u_t'] = \Sigma$ for all t. $F(L)$ is an $(n \times n)$ matrix whose typical element, $f_{ij}(L)$, is a polynomial in the lag operator: $f_{ij}(L) = \sum_{k=0}^{\infty} f_{ijk}L^k$, and $L^k X_t = X_{t-k}$.

We assume that $F(L)$ is invertible, which implies that it has an autoregressive representation, $R(L)X_t = u_t$, where $R(L) = F(L)^{-1}$ and $R_0 = I$. This representation is known as the "reduced form," while the Wold representation is called the "final form."

An observationally equivalent representation of (1) can be formed by taking any non-singular matrix A_0 and writing

$$X_t = F(L)A_0A_0^{-1}u_t = A(L)\varepsilon_t \tag{2}$$

where $A(L) = F(L)A_0$ and $\varepsilon_t = A_0^{-1}u_t$.

Identification requires choosing the n^2 elements of A_0. Typically, the standard deviations of the shocks are normalized to 1, which provides n restrictions. Additional $n(n-1)/2$ restrictions come from the assumption that the structural shocks ε_t are mutually uncorrelated.

Authors such as Blanchard and Quah (1989), Shapiro and Watson (1988), and King, Plosser, Stock, and Watson (1991) suggest that the remaining restrictions required to complete the identification could come from long-run neutrality assumptions. For example, Blanchard and Quah assume that aggregate demand shocks have no long-run effect on real output. If real output is the i^{th} variable in an estimated two-variable VAR and the j^{th} shock is the aggregate demand shock,

3. This section follows Faust and Leeper's own presentation.

their restriction can be written as: $a_{ij}(1) = \sum_{k=0}^{\infty} a_{ijk} = 0$, or

$$[\hat{F}(1)\hat{A}_0]_{i,j} = 0 . \tag{3}$$

The reliability of the conclusions concerning the relationship between the structural variables thus depends on the quality of the estimate of $F(1)$.

3. Problem with inference regarding *F*(1)

3.1 The problem

As mentioned in the introduction, Faust and Leeper's argument is similar to that of Sims (1972) who considers distributed-lag models estimated by least-squares criterion. The main point is the following: when the underlying data-generating process (DGP) is characterized by an infinite parameterization, convergence of the estimates of the model's parameters is not sufficient to guarantee the convergence of some functions of those parameters. More precisely, Sims' (1972) Theorem 1 says that, relative to the Fourier transformation of parameters, the LS criterion provides an adequate approximation over the whole range of the spectrum but not necessarily for all particular points of this spectrum such as the frequency zero (associated with long-run effects). In other words, some problems are specific to infinitely dimensional spaces in that several distance measures are compatible with a good approximation while some of these measures present discontinuous features when applied to some particular functions. For instance, LS estimates of a distributed-lag model are convergent in the l^2 space, but an estimate of the sum of those coefficients needs convergence in the l^1 .[4]

The point underlined by Sims is contingent upon estimation techniques and then is not intrinsically associated to an identification problem. Therefore, some techniques that are convergent in the space l^1 , such as the least absolute deviation technique (see Gouriéroux and Monfort 1989), may not suffer from that limitation.[5] However, we argue below that reasonable assumptions can be made to ensure that usual estimation techniques provide reasonable results when applied to some procedures such as the approach based on long-run restrictions. Therefore,

4. l^2 is a space where the convergence criterion is in terms of square summable sequence; l^1 space concerns convergence criteria in terms of absolute summable sequences (see Royden 1968).
5. We thank Alain Guay for mentioning that point.

given the relative complexity of these alternate estimation techniques, we do not find it necessary to explore this avenue further.

Faust and Leeper apply Sims' arguments to the estimation of $F(1)$. In their view, these arguments imply that one cannot construct valid confidence intervals for $F(1)$ unless strong assumptions are made concerning the underlying DGP. To illustrate their point, they consider the case of the structural impulse responses obtained on the basis of an estimated VAR identified with long-run restrictions. Remember that $\hat{F}(L)$ is derived from an estimated VAR and $\hat{A}_0$ is then chosen in such a way that $[\hat{F}(1)\hat{A}_0]_{i,j} = 0$. This gives the polynomial $\hat{A}(L) = \hat{F}(L)\hat{A}_0$, where $\hat{A}(L)$ is the matrix of estimated structural impulse responses.

Faust and Leeper are specifically interested in the case where one would want to test the hypothesis that the response of the i^{th} variable to the j^{th} structural shock at the k^{th} horizon is null: H_0: $a_{ijk} = 0$. Their main contribution, Proposition 1, states that the level of any test of H_0: $a_{ijk} = 0$ is greater or equal to its maximum power. In practice, this means that a test rejecting H_0 when it is in fact true 5 per cent of the time will reject that same hypothesis at most in no more than 5 per cent of cases when it is false. This result remains asymptotically valid in that increasing the sample size does not increase the power of the test. As a consequence, there is no convergent test of H_0.[6] Now we simply try to give the intuition of that proof.

Faust and Leeper's proof is in two steps. First, an unconstrained polynomial $A(L)$ is modified so that it is made compatible with H_0. Then the fact that $A(L)$ goes to infinity allows for the modification of a very large number of coefficients in a way that leaves the corresponding process observationally equivalent to the original one. While the latter process is compatible with H_0, the original was not. We thus have two processes that are observationally equivalent but compatible with two contradictory hypotheses. In this context, a test of H_0 would be uninformative. Consequently, the estimation of $F(1)$ turns out to be very uncertain. That uncertainty could be reflected in the estimation of the structural parameters (impulse responses, variance decompositions, etc.). We can restate this proposition by saying that, because the test statistic depends on an infinite number of parameters through $F(1)$, a specific sum of coefficients does not constrain in practice the distribution of any finite sample. We thus need more constraints on the model to make the identification possible.

6. A convergent test is a test in which power converges to one as the sample tends towards infinity.

3.2 Solutions proposed by Faust and Leeper

A simple solution would be to assume that the DGP is a finite order autoregressive process. As Faust and Leeper put it: "There is surely some K [lag order] large enough to accommodate most models of interest." However, a small sample limitation to this simple solution is that a relatively small K would have to be assumed in order to avoid losing too many degrees of freedom. An alternative solution would be to assume that the effect of a given shock is null past a certain horizon.

3.3 Discussion

Faust and Leeper's solutions thus consist of imposing restrictions on the parameter space to make it finite. While their first solution is to fix the number of parameters in the DGP, the second is to fix the parameterization in the Wold representation. Limiting the DGP to be a finite process appears sufficient in that the problem identified by Sims (1972) applies to cases where the infinite character of the parameter space renders an adequate approximation impossible.[7] However, one should be careful not to impose *a priori* restrictions that are too constraining empirically. In fact, imposing a DGP with a finite autoregressive representation may not be realistic (Berk 1974; Granger 1986; Lewis and Reinsel 1985; Lütkepohl and Poskitt 1996). From an economic point of view, finite autoregressive representations do not exist for some classes of models (Lippi and Reichlin 1993; Söderlind and Vredin 1996).

Restricting the order of the Wold representation appears more attractive in practice. Sims (1972) mentions that the maximum order required does not have to be known *a priori,* which facilitates the analysis. Also, empirical exercises reveal that the estimated parameters of the moving-average representation collapse very rapidly towards zero (see Section 4), leading to a matrix $\hat{F}(1)$ that converges rapidly. Consequently, it does not appear to be particularly constraining to impose the nullity of the parameters of the moving-average representation past a

7. A finite autoregressive representation does not preclude the Wold representation being an infinite order polynomial. Although there are an infinite number of parameters associated with the moving-average representation, these are linked to the finite number of autoregressive parameters through non-linear relationships. The constraints linking the parameters of the moving-average representation could thus be sufficient to ensure that specific functions of those parameters are not arbitrary.

certain boundary.[8] Since this boundary is not known *a priori,* Sims' argument appears particularly appropriate. Moreover, Blanchard and Quah (1989) show that in practice it is not necessary that the zero-constraints in $A(1)$ be strict. It is sufficient that the constraints belong to some neighbourhood of zero (see their footnote number 2). The error associated with the truncation of the polynomial would then have a marginal impact on identification.

At this point, we must mention that the Wold representation that we have to deal with is always derived from an estimated model that by definition is finite and for which we know that the problem underlined by Sims is irrelevant. Consequently, some can argue that the apparent robustness of $\hat{F}(1)$ has nothing to do with the real characteristics of the unknown DGP. However, we believe that the estimated model, even though it is characterized by a finite parametrization, reveals pertinent information on the underlying DGP. Furthermore, if the specification resulting from the data had nothing to do with the DGP, all statistical inferences would be incredible.[9] The only way to guarantee to some extent the validity of the approximation is to put some confidence in the reliability of finite parametrized models for characterizing a stationary process.[10]

To that effect, several results have stated that some useful finite models remain compatible under quite general DGP. For instance Lewis and Reinsel (1985), considering the class of invertible and stationary processes, showed that the estimates of the parameters of a finite VAR model are asymptotically convergent.[11,12] The conditions required for this result to hold are general enough to encompass most parametric models that are used (VAR or VARMA). One of these conditions relates to the speed of convergence that, at $\sum_{k=0}^{\infty} \sqrt{k}\,\|F_k\| < \infty$, is much higher than the one required in Faust and Leeper ($\sum_{k=0}^{\infty} \|F_k\| < \infty$).[13]

Although these are favourable conjectures, we should be aware that some doubt remains about the adequacy of the approximation. How can we deal with such uncertainty? Sims (1972)

8. Faust and Leeper mention that such constraints imply that the model is over-identified. However, if in practice constraining the moving-average representation to be zero after 100, 250, or 500 steps does not change the estimation of $F(1)$, it will also not affect the estimation of the structural form.
9. This remark can be applied to the majority of statistical problems.
10. Note that the fact that it is impossible to allow for design experiments including an infinite parameterization makes Monte Carlo experiments useless for dealing with the point made by Faust and Leeper. However, such experiments are still of interest to see how well the approach based on long-run restrictions performs with data generated with finite statistical models. DeSerres and Guay (1995) find that, in most cases, the method performs well when "generous" lag selection criteria are used.
11. Most of the series we have to model belong to this wide class.
12. For such models, we can show that there exists an autoregressive representation of infinite order.
13. It would be interesting to see whether this different convergence speed might affect Faust and Leeper's Proposition 1.

proposes the following solution: “Estimation should be accompanied by information which allows the reader to judge for himself what the effects of approximation error may have been.” Similarly, Dufour (1995) proposes: “The only way [the approximation] can be meaningfully done is by studying much more carefully the finite-sample distribution.” In practice, this is a call for robustness checks of the results. Section 5 presents such an exercise for the specific case of the estimation of the U.S. real GDP transitory component.

From an economic point of view, it could be interesting to see how these robustness problems might affect some empirical analysis based on data generated from a credible economic model. For example, Söderlind and Vredin (1996), working with data generated with the monetary real business cycle of Cooley and Hansen (1995), arrive at the following conclusion:

“Faust and Leeper ... argue that long-run restrictions are highly unreliable in any finite sample, unless we can (correctly) restrict the way short-run dynamics are linked to long-run effects .... In the model we use, we really cannot do that since it has an infinite VAR order due to the MA terms. The evidence [we obtain] suggests that this critique, while correct in principle, does not seem to be devastating for the type of data-generating process implied by monetary equilibrium business cycle models.”

4. Problems with the aggregation of shocks and time aggregation

The approach based on long-run restrictions is often applied to small-dimension VARs (e.g., Blanchard and Quah (1989) estimate a two-variable model) that permit the identification of only a limited number of shocks. Therefore, these shocks have to be seen as the aggregation of many underlying types of shocks and Faust and Leeper show that these aggregated shocks may be poorly identified. Braun and Mittnik (1993) reached the same conclusion using a different approach. The solution proposed by these authors is to estimate VAR models with many variables. Faust and Leeper also propose that the robustness of the results be assessed relative to changes in the specification of the estimated VARs.

As regards time aggregation, this problem has been discussed by many authors including Telser (1967) and Sims (1971). For our purposes, it might affect the identification restrictions if, for example, some causality relations are encompassed by the time separating two observations. As in the case of shock aggregation, the possible presence of such a problem suggests that the practitioner must perform robustness checks. The practitioner should also query whether, in theory, the data frequency used is adequate for the identification of the model.

5. An empirical exercise

Faust and Leeper's analysis, and in particular their Proposition 1, suggests that the results obtained with the approach based on long-run restrictions could be unreliable. In this section, we present a simple empirical application performed with U.S. economic data. This exercise consists of estimating the transitory component of U.S. real GDP. This corresponds to what Blanchard and Quah (1989) call the U.S. aggregate demand component. We want to see whether the results we obtain have as little robustness as suggested by Faust and Leeper's analysis.

Admittedly, our application is specific in nature and cannot be used to draw general conclusions. Nevertheless, we still think that it is interesting to see whether Faust and Leeper's point applies to this very important specific case. Using real data has an important advantage also in that no specific DGP has to be assumed *a priori*. Indeed, the underlying DGP could be characterized by an infinite parameterization and be affected by the type of problem identified by Faust and Leeper in the context of their Proposition 1. Of course, the exercise could also be affected by the other problems that they identify.

The assumptions that we use are those described in Section 2. We thus assume that one type of shock has a permanent effect on real GDP while the other (or the others) can have only transitory effects. In other words, we assume that $A(1)$ is lower triangular (we perform a Choleski decomposition of $F(1)$) with the U.S. real GDP being ranked first in the estimated VAR. Since we are not trying to identify more than two types of shocks, when more than two variables are used, we simply sum the impulse responses of the shocks having a transitory effect on real GDP.

Different VAR models are considered. Our first VAR, VAR1, includes the following two variables: real GDP and the difference between real GDP and real consumption. Cochrane (1994) and Cogley (1995) suggest that the latter is useful for identifying the transitory component of U.S. real output. Our second VAR, VAR2, adds a nominal variable: the fed funds rate. Results obtained by King et al. (1991) and Dupasquier, Guay, and St-Amant (1997) suggest that nominal variables, and in particular interest rates, can help identify the transitory component. VAR3 is the same as VAR2 except that it substitutes the unemployment rate for the difference between real output and real consumption. VAR4 includes all four variables mentioned to this point. VAR5 adds to VAR4 a measure of the nominal effective exchange rate.

The data are quarterly and cover the period 1963Q4 to 1997Q2. We use the first difference of the logarithm of real GDP, the difference between the level of that series and that of real consumption of non-durables and services (the variable used by Cochrane), and the following series in first differences: the unemployment rate; the fed funds rate; and a measure of the nominal effective exchange rate. The latter is calculated at the Bank of Canada using bilateral exchange rates, GDP deflators, and weights based on trade for the United States' six most important trading partners. We take our series from the data base of Data Resources Incorporated (DRI). Unit root tests results (available on request) are consistent with the specification of the VARs.

A likelihood ratio test, applied in the context of a "general-to-specific" strategy (as suggested by DeSerres and Guay 1995) with a maximum number of lags of 8, was used to choose the number of lags to be included in the VARs. The number of lags selected for VAR1 to VAR5 were 4, 5, 8, 5, and 6 respectively.

Note that our results are extremely robust to the choice of a truncation point for the calculation of $F(1)$. The results are based on a truncation point corresponding to 500 quarters, but results based on truncation points at 250 or 1,000 quarters would be indistinguishable from the ones presented. This suggests that the first point made by Faust and Leeper, that related to Proposition 1, does not affect this specific application.

Chart 1 (responses to permanent shocks) and Chart 2 (responses to transitory shocks) show the impulse responses resulting from the empirical exercise. We use one-standard-deviation shocks so that differences between impulse responses can reflect differences in the estimation of shocks. It is clear that, although these impulse responses are produced on the basis of different empirical models, they are still qualitatively, if not quantitatively, very similar. Normal parameter uncertainty is sufficient to account for most of the differences we observe. Indeed, confidence intervals generated with Monte Carlo simulations in RATS show that these impulse responses are not distinguishable statistically at conventional levels. It is not very often that results we obtain in

Chart 1 Responses to permanent output shocks

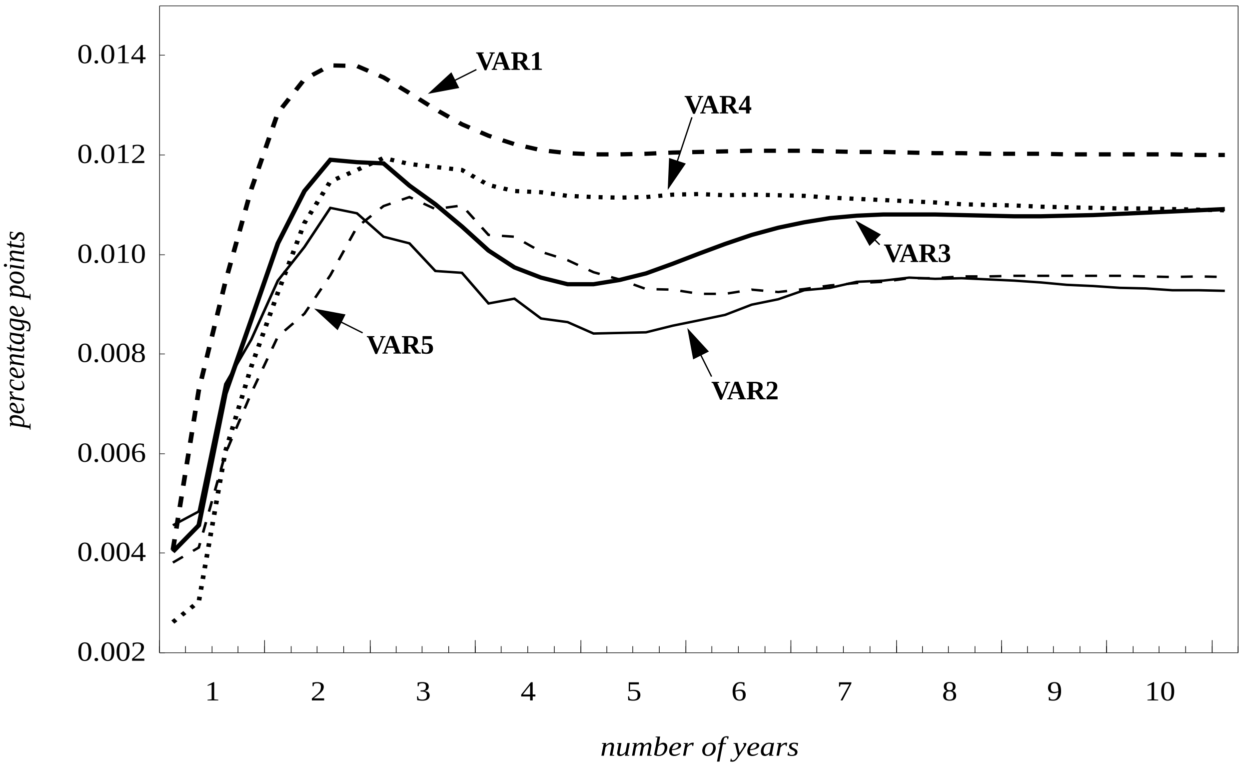
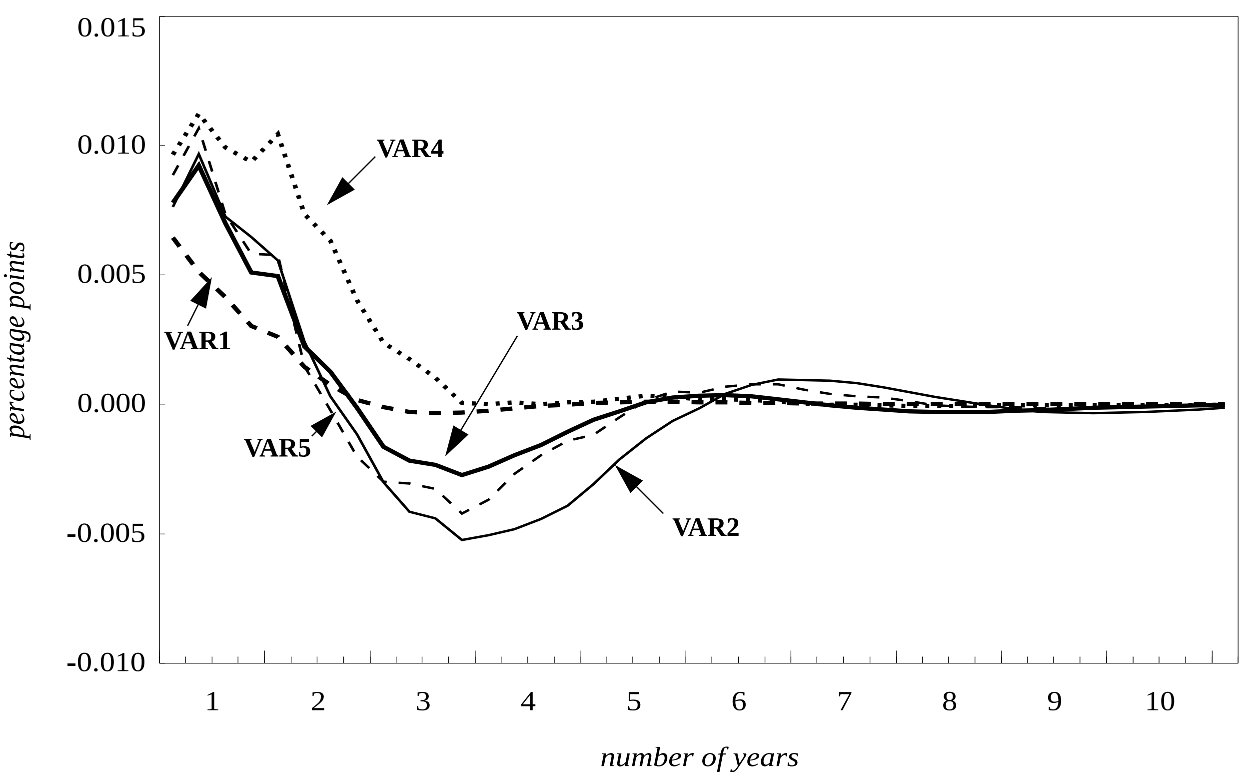


Chart 2 Responses to transitory output shocks



econometrics are much more robust.[14] This means that the shock aggregation problem is not of much qualitative importance here.[15] Maybe one could say that the impulses corresponding to VAR1 are a bit different (the transitory component is a bit less important in that case). This would suggest that more variables than the ones that are used in VAR1 need to be considered.

Faust and Leeper present a similar empirical exercise. They estimate two bivariate VARs including the first difference of the logarithm of the U.S. real GDP plus another variable. In one case, this variable is the level of the U.S. unemployment rate while in the other case it is the first difference of the U.S. GDP deflator. The results obtained suggest that the impulse responses cannot be estimated with reasonable precision. However, we think there are some problems with what they have done. First, and on this point they would probably agree with us, two variables might be too few to identify the shocks of interest (although our two-variable model does not seem to be very bad). Second, the levels of the unemployment rate and of inflation are either non-stationary or quasi–non-stationary. When such variables are used in a VAR, Phillips (1995) shows that the estimated impulse responses converge rapidly towards random variables. It is thus not very surprising that Faust and Leeper obtain results that are different for their two estimated models.

6. Conclusion

The analysis presented in this paper suggests the following conclusions:

- The type of arguments used by Faust and Leeper (1997) in the context of their Proposition 1 can be applied to a wide class of econometric applications such as unit root testing, cointegration analysis, and distributed-lag models. These arguments can even be applied to the estimation of objects such as an monetary conditions index.[16] If the approach based on long-run restrictions has to be abandoned because of these arguments, many other econometric and economic practices would also have to be abandoned.

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14. Lalonde, Page, and St-Amant (forthcoming) and St-Amant and Tessier (1997) perform similar robustness checks with Canadian, French, and German data and arrive at a similar conclusion.
15. We have already mentioned that robustness checks with higher frequency data would have to be performed to see whether time-aggregation is a problem. However, there are no monthly data on U.S. GDP. Also, we are less interested in time-aggregation problems here since they are not at all specific to the approach based on long-run restriction.
16. Indeed, Ericsson et al. (1997) show that the possibility of locally almost unidentified parameters can lead to invalidation of the usefulness of this concept in practice.

- Fortunately, there are reasons to believe that Faust and Leeper's arguments are not devastating for the approach based on long-run restrictions. First, simulation exercises suggest that this approach does well when used with data generated with standard macroeconomic models (see Söderlin and Vredin 1996). Second, empirical applications such as the one presented in this paper suggest that this approach gives results that are much more robust than what would be obtained if the data-generating process had a truly infinite parameterization.

- A reasonable approach would thus be to follow Sims' (1971; 1972) and Dufour's (1997) recommendation and present robustness checks allowing readers to judge for themselves what the effects of possible approximation errors might be. Results that are robust to small changes in the number of lags or the variables included in the estimated VAR would suggest that Faust and Leeper Proposition 1 does not apply to the specific empirical exercise of interest. Robustness of this type would also suggest that time and shock aggregation is not an important problem. Non-robustness would suggest that one of these problems, or another problem, might be at play.

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