Toward a Better Understanding of Macroeconomic Interdependence

By Alexander Chudik

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The Globalization and Monetary Policy Institute's mission is promoting research that helps the public better understand how globalization affects the conduct of U.S. monetary policy. Determining the consequences of trade and financial globalization is challenging. Understanding macroeconomic interdependence is necessary to fully comprehend globalization's consequences. This touches on a number of fields, including theoretical open economy macroeconomic research, empirical data-driven applied research and development of new econometric tools to handle large international datasets.

This article examines how my work has contributed to the institute's mission, particularly to our understanding of macroeconomic interdependence. This essay is in three parts. The first reviews how theoretical open economy macroeconomic modeling helps assess interdependence. Specifically, it identifies shortcuts used in the literature that may be misleading. The second part summarizes contributions regarding development of new econometric tools for modeling interdependent economies, including use of the global vector autoregressive (GVAR) approach. In the final part, I review applications developed with the GVAR approach, a modeling technique widely used to measure how economic shocks affect interdependent economies.

These efforts would not be possible without my coauthors at the European Central Bank (ECB), Banque de France, International Monetary Fund (IMF) and various academic institutions.

Part 1: Theoretical Open Economy Macroeconomic Modeling

Economists strongly prefer simplicity and seek to develop models requiring minimal structure to analyze a given question. This is understandable, since comprehending the innerworkings of a relatively uncomplicated economic model is easier than working with something overly complex. Because of this desire for simplicity, mainstream open economy macroeconomic models typically feature just two economies—a domestic economy and a representative foreign economy—rather than a multilateral setting of many economies.

However, the concept of a representative foreign economy has no proper justification in the literature, and the consequences of aggregating the rest of the world into one representative economy are not fully understood. In an institute working paper (Chudik and Straub 2011), we sought to fill this gap. We developed a multicountry general equilibrium model that helps investigate conditions under which aggregating foreign economies into a single representative foreign economy would be reasonable.[1] The findings are quite surprising, but intuitive.

We found that the concept of a representative single economy could produce misleading conclusions. For instance, an increase in trade openness in two-country models is commonly associated with an increase in dependence of the domestic economy on foreign idiosyncratic shocks. In contrast, we found that in a multicountry model, the degree of macroeconomic interdependence is not necessarily connected to the notion of trade openness, as usually contemplated. Instead, we found that the degree of foreign trade diversification is key.

Specifically, diversification of foreign trade can help reduce the impact on the domestic economy from idiosyncratic shocks in foreign economies. The main intuition for this result is quite simple: We can draw analogies with finance

literature on portfolio diversification. It is understood that idiosyncratic risk is irrelevant for a well-diversified portfolio; only systemic risk matters. The same applies in a multicountry macro model, where the dependence of a domestic economy on foreign idiosyncratic shocks is mitigated by diversifying trade flows. However, it is clear that diversification of trade and financial flows would not insulate a country from global systemic events.

Second, we found that the concept of a representative foreign economy can result in a sizable bias due to aggregation of rest-of-the-world economies. This is perhaps less surprising, since there are large heterogeneities across individual economies in the world. The two-country approximation in the literature is especially poor when trade and financial flows are not well diversified across economies. This suggests that the two-country framework is consequently not a good approximation for many small open economies with a sizable exposure to the U.S. or to another large economy. In another institute working paper, Ca' Zorzi and Chudik (2013) documented the size of this type of aggregation bias in the question of international price convergence (an issue that has puzzled economists for many decades). We found that, depending on how the foreign economies are aggregated in a single representative rest-of-the-world economy, the estimates of the speed of price convergence may be biased by a very large degree. This bias could overshadow all the others identified in the literature.

Last, two-country models are insufficient for studying how real or financial shocks transmit across economies in a globalized world.

Taken together, these arguments suggest abandoning the restrictive two-country framework to more fully comprehend the consequences of globalization. In particular, estimating the impact of U.S. monetary policy on the rest of the world and the repercussions in the U.S. should be based on a multicountry model.

Theoretical multicountry DSGE models (for example, the EAGLE model at the ECB, or the SIGMA model at the Federal Reserve Board) are quite useful in solving important policy questions, including welfare analysis. But moving to more than two economies comes at a great cost in terms of model transparency. This weighs heavily on the usefulness of large theoretical models for policy analysis, since the role of individual assumptions becomes more difficult to ascertain, and the answers these models provide are effectively hardwired in the underlying assumptions. Furthermore, theoretical macroeconomic multicountry models impose many restrictions that the data may not support. Therefore, theoretical models should be accompanied by coherent and pragmatic empirical global models capable of handling interdependent economies. Empirical models could also help us better understand different features of large international datasets and could provide stylized facts and new empirical puzzles, which theory could then seek to explain.

Part 2: Empirical Global Macroeconomic Modeling

The main challenge faced when building empirical models of interdependent economies is the large number of variables involved. For example, one can focus on the 30 largest economies, accounting for more than 90 percent of world output. However, even with a few key macroeconomic variables per economy—short- and

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long-term interest rates, consumer price inflation, real gross domestic product (GDP), equity price index and exchange rate—the overall number of variables in the global model would require an overwhelmingly large dataset. The number of unknown parameters to be estimated in unrestricted empirical models—those models not based on theoretical relationships, that accurately describe the data—generally grows at a quadratic rate with the number of variables. Therefore, given that typical macro datasets do not cover more than three to five decades of quarterly data, empirical multicountry models cannot be estimated without imposing restrictions on a model's parameters. This problem is also known as the "curse of dimensionality."[2]

The literature recognizes that the standard econometric tools are insufficient for large international datasets due to the curse of dimensionality. With increasing interest in the modeling of the global economy in addition to greater availability of large international datasets, research over the last decade has looked at developing new econometric tools that can handle interdependent economies. The key challenge is avoiding imposing restrictions that would be considered inappropriate in a globalized world, while, at the same time, being parsimonious so that individual parameters can be reliably estimated.

We have contributed a number of methodological breakthroughs involving large datasets. We provided new results on estimation and inference in panels featuring interdependent economies (Chudik et al. 2014; Chudik and Pesaran forthcoming). We studied the consequences of aggregation in a global context (Chudik and Pesaran 2014a; Chudik, Ca' Zorzi and Dieppe 2012) and provided a statistical characterization of the pattern of dependence across individual cross-sectional units (be they individual economies in the global economy or other types of units, such as households, firms, sectors or regions), which, unlike the time dimension, does not have any natural ordering (Chudik, Pesaran and Tosetti 2011). Additionally, we contributed to the methodological foundations of the GVAR approach in the literature (Chudik and Pesaran 2011, 2013; Chudik and Smith 2013).

Part 3: The GVAR Approach and Its Applications

The global VAR approach was originally proposed by Hashem Pesaran and his coauthors in the aftermath of the 1997 Asian financial crisis. It became clear that major financial institutions were exposed to risks from adverse global or regional macro shocks. Simulating these effects required a coherent and transparent global model. The original aim was to develop such a model to quantify the effects of macroeconomic developments on the losses of systemically important financial institutions.

The solution to the curse of dimensionality in this approach is quite simple and can be described in two steps. In the first, a small scale model for each country is estimated separately. These individual country models include domestic variables, globally dominant variables (such as the price of oil) and country-specific weighted cross–section averages of foreign variables. In the second step, all estimated models are stacked and solved in one large system (or GVAR) featuring all variables. The GVAR model is coherent and easy to use for scenario analysis and forecasting.

Although developed originally for credit risk analysis, the GVAR approach has numerous other applications. In an institute working paper, Chudik and Pesaran (2014b) survey the methodological foundations and empirical applications of the GVAR approach. We reviewed about 60 academic empirical papers that use GVAR. Institutions, including the IMF and the ECB, have used the approach as well.[3] At the institute, we developed four applications of the GVAR approach.

In Bussière, Chudik and Mehl (2013), we used a GVAR model to uncover how shifts in risk appetite and other shocks influence real effective exchange rates. The Japanese yen, Swiss franc and U.S. dollar are familiar safe-haven currencies facing significant appreciation pressure when risk appetite declines. Such was the case following the Lehman Brothers failure in 2008, the 9/11 attacks, and the Russian and Long-Term Capital Management crises in 1998. We found that before the start of Economic and Monetary Union (EMU) in 1999, the Deutsche mark also played an important safe-haven role, which is not surprising. In contrast, we

learned that following the start of the EMU, the euro tended to depreciate in response to a decline in risk appetite. Another key finding from this empirical exercise is that the divergence in external competitiveness among euro-area countries over the last decade was more likely due to country-specific shocks, as opposed to global shocks with asymmetric effects on individual euro-area member states.

In Chudik and Fratzscher (2011, 2012), we employed weekly financial data on bonds, stocks and currencies to investigate how key shocks—to liquidity and risk—are transmitted across global financial markets. Additionally, we attempted to identify the determinants that explain differences in transmission of shocks across countries. In particular, we investigated to what extent external exposure (either through trade or financial linkages) or idiosyncratic, country-specific characteristics (such as countries' macroeconomic fundamentals and perceived riskiness) made countries vulnerable to different types of shocks. We found that transmission of liquidity and risk shocks is highly heterogeneous—across countries, across asset classes and over time. Moreover, we found that countries' sovereign credit ratings, quality of institutions and financial exposure are important determinants of cross-country transmission pattern differences.

In Bussière, Chudik and Sestieri (2012), we applied the GVAR approach to investigate the underlying factors of global trade flows using data on 21 advanced and emerging economies. The results suggest that relative demand terms, as opposed to relative prices (exchange rates), tend to have a much stronger effect on trade flows. This finding is in line with observations following the 2008 financial crisis—that the adjustment in global imbalances was not associated with a sharp depreciation of the dollar (contrary to what many observers expected). In the model, a positive shock to U.S. domestic output—for example, an unexpected rise in GDP—profoundly affected foreign countries' exports as well as their output expansion, which in turn positively affected U.S. exports (*Chart 1*).

By comparison, a positive shock to the U.S. real effective exchange rate, which immediately strengthens the dollar by about 2.5 percent, has an unambiguous negative effect on U.S. exports

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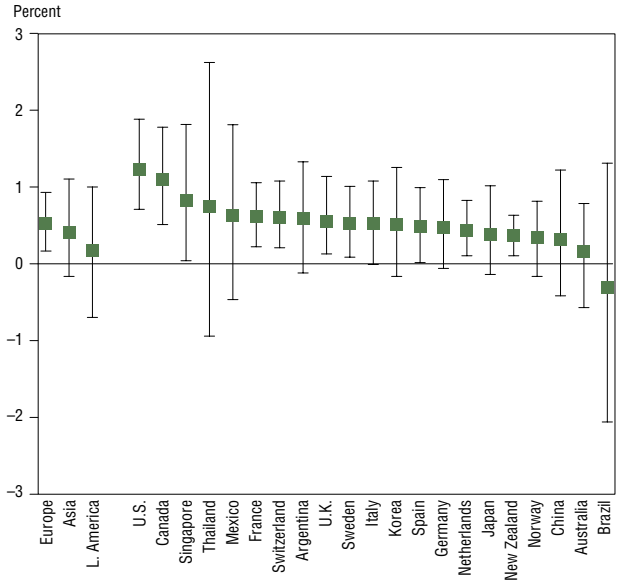
Chart 1

Global Exports Increase as U.S. Output Rises



NOTE: This chart shows the impact of a positive U.S. output shock on exports after one year with 90 percent confidence bounds. The size of the shock is one standard error (a size considered statistically typical), which is equal to 0.6 percent of U.S. GDP at the time of impact.
SOURCE: "Modeling Global Trade Flows: Results from a GVAR Model," by M. Bussière, A. Chudik and G. Sestieri, Globalization and Monetary Policy Institute Working Paper no. 119 (Federal Reserve Bank of Dallas, June 2012).

Macroeconomic interdependence is a challenging and active field of economics research with much more to discover.

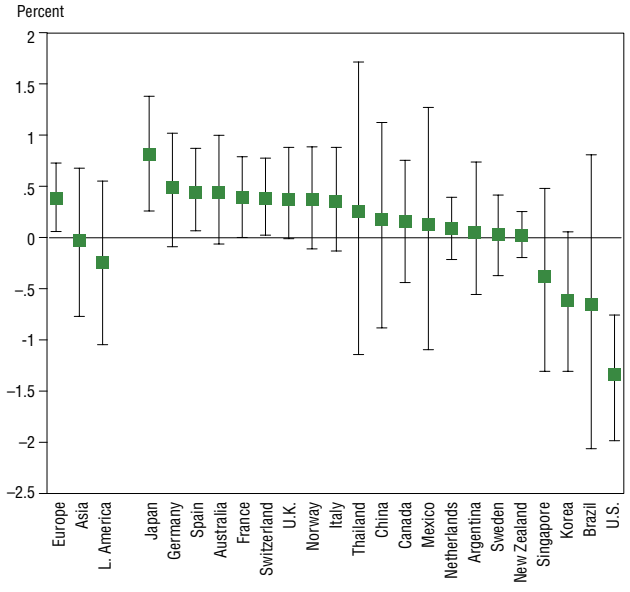
(which fall 1.3 percent in the first year) and a strong positive effect on Japan and European countries' exports (*Chart 2*), Bussière, Chudik and Sestieri (2012) also argued.

We argued that the GVAR model is helpful for monitoring trade flows and can be used to understand the so-called Great Trade Collapse (GTC). World exports contracted more than 6 percent in fourth quarter 2008 and 10 percent in first quarter 2009, a drop that was sharp, sudden and synchronized. In the past few years, the GTC has stimulated a wealth of theoretical and empirical research. We compared the observed decline during the GTC with the model's prediction, conditioned on the observed values for real output and real exchange rates. We found that the observed fall in demand and the change in global foreign exchange rates alone could not explain the GTC, which suggests that other factors, such as trade credit and finance, may have played a role.

In an institute working paper by Chudik, Grossman and Pesaran (2014), we also used the GVAR approach to investigate the value of the PMI (formally called the Purchasing Managers' Index) for forecasting global (48 countries) output growth. GDP data are available with a substantial release lag (one to three quarters, depending on an individual economy); PMIs are more timely. Moreover, there is great similarity between PMIs and quarterly output growth. However, PMI usefulness as a forecasting tool of output growth—over and above what past output growth data say about future performance—can only be ascertained using conditional models, with and without PMIs. We found that PMIs contribute a 15–20 percent improvement in forecasting performance for output growth projections in the current quarter.[4] By comparison, when forecasting output growth in the next quarter or across longer horizons, PMIs aren't very helpful.

Chart 2

U.S. Dollar Appreciation Felt Most in Japan and Europe



NOTE: This chart shows the impact of a U.S. exchange rate shock on exports after one year with 90 percent confidence bounds. The size of the shock is one standard error (a size considered statistically typical), which is equal to 2.5 percent appreciation of the U.S. dollar at the time of impact.
SOURCE: "Modeling Global Trade Flows: Results from a GVAR Model," by M. Bussière, A. Chudik and G. Sestieri, Globalization and Monetary Policy Institute Working Paper no. 119 (Federal Reserve Bank of Dallas, June 2012).

Researching Interdependence

Understanding macroeconomic interdependence is a difficult research problem and essential for assessing the consequences of globalization for the conduct of U.S. monetary policy. Since joining the institute in 2011, I have worked with a network of coauthors developing theoretical multicountry macroeconomic models, pioneering new econometric tools for large international datasets and applying these methods with the aim of better understanding the interdependence of individual economies in the global economy. Macroeconomic interdependence is a challenging and active field of economic research with much more to discover.

Notes

[1] In particular, we have developed a multicountry dynamic stochastic general equilibrium (DSGE) model. DSGE modeling is a branch of general equilibrium theory that is influential in contemporary macroeconomics.

[2] This expression was coined by Richard E. Bellman when considering problems in dynamic optimization.

[3] See the following IMF policy publications for examples of use of the GVAR approach by IMF staff: 2011 and 2014 Spillover Reports; 2006 World Economic Outlook; October 2010 and April 2014 Regional Economic Outlook: Asia and Pacific Department; April 2014 Regional Economic Outlook: Western Hemisphere Department; November 2012 Regional Economic Outlook: Middle East and Central Asia Department; October 2008 Regional Economic Outlook: Europe; April and October 2012 Regional Economic Outlook: Sub-Saharan Africa; and IMF country reports for Algeria, India,

Italy, Russia, Saudi Arabia, South Africa and Spain.
[4] As measured by the GDP-weighted average mean square forecast error.

References

Bussière, M., A. Chudik and A. Mehl (2013), "How Have Global Shocks Impacted the Real Effective Exchange Rates of Individual Euro Area Countries Since the Euro's Creation?" *The B.E. Journal of Macroeconomics* 13: 1–48.

Bussière, M., A. Chudik and G. Sestieri (2012), "Modeling Global Trade Flows: Results from a GVAR Model," Globalization and Monetary Policy Institute Working Paper no. 119 (Federal Reserve Bank of Dallas, June).

Ca' Zorzi, M., and A. Chudik (2013), "Spatial Considerations on the PPP Debate," Globalization and Monetary Policy Institute Working Paper no. 138 (Federal Reserve Bank of Dallas, January).

Chudik, A., M. Ca' Zorzi and A. Dieppe (2012), "The Perils of Aggregating Foreign Variables in Panel Data Models," Globalization and Monetary Policy Institute Working Paper no. 111 (Federal Reserve Bank of Dallas, March).

Chudik, A., and M. Fratzscher (2011), "Identifying the Global Transmission of the 2007–09 Financial Crisis in a GVAR Model," *European Economic Review* 55 (3): 325–39.

———— (2012), "Liquidity, Risk and the Global Transmission of the 2007–08 Financial Crisis and the 2010–11 Sovereign Debt Crisis," Globalization and Monetary Policy Institute Working Paper no. 107 (Federal Reserve Bank of Dallas, January).

Chudik, A., V. Grossman and M.H. Pesaran (2014), "A Multi-Country Approach to Forecasting Output Growth Using PMIs," Globalization and Monetary Policy Institute Working Paper no. 213 (Federal Reserve Bank of Dallas, December).

Chudik, A., K. Mohaddes, M.H. Pesaran and M. Raissi (2013), "Debt, Inflation and Growth: Robust Estimation of Long-Run Effects in Dynamic Panel Data Models," Globalization and Monetary Policy Institute Working Paper no. 162 (Federal Reserve Bank of Dallas, November).

Chudik, A., and M.H. Pesaran (2011), "Infinite Dimensional VARs and Factor Models," *Journal of Econometrics* 163 (1): 4–22.

———— (2013), "Econometric Analysis of High Dimensional VARs Featuring a Dominant Unit," *Econometric Reviews* 32 (5–6): 592–649.

———— (2014a), "Aggregation in Large Dynamic Panels," *Journal of Econometrics* 178 (Part 2): 273–85.

———— (2014b), "Theory and Practice of GVAR Modeling," Globalization and Monetary Policy Institute Working Paper no. 180 (Federal Reserve Bank of Dallas, May).

———— (forthcoming), "Common Correlated Effects Estimation of Heterogeneous Dynamic Panel Data Models with Weakly Exogenous Regressors," *Journal of Econometrics*.

Chudik, A., M.H. Pesaran and E. Tosetti (2011), "Weak and Strong Cross Section Dependence and Estimation of Large Panels," *Econometrics Journal* 14 (1): C45–C90.

Chudik, A., and V. Smith (2013), "The GVAR Approach and the Dominance of the US Economy," Globalization and Monetary Policy Institute Working Paper no. 136 (Federal Reserve Bank of Dallas, January).

Chudik, A., and R. Straub (2011), "Size, Openness, and Macroeconomic Interdependence," Globalization and Monetary Policy Institute Working Paper no. 103 (Federal Reserve Bank of Dallas, December).