Global Spillovers of a Chinese Growth Slowdown

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November 2022

Online Appendix

A – Structural VAR

Let Y_t denote a K-dimensional time series, t=1,…,T, which we assume to be well approximated by an SVAR model of order p:

$$B_0 Y_t = C_0 X_t + B_1 Y_{t-1} + \cdots + B_p Y_{t-p} + \omega_t. \qquad (1)$$

In equation (1), B_i, i=1,..,p, and C_0 are KxK matrices of coefficients, ω_t is a vector of structural white noise shocks, and X_t is an Lx1 vector of exogenous variables (such as a linear trend or the constant of the model). Multiplying each side of equation (1) by B_0^{-1} yields the reduced-form representation of the model,

$$Y_t = A_0 X_t + A_1 Y_{t-1} + \cdots + A_p Y_{t-p} + u_t, \qquad (2)$$

where $u_t = B_0^{-1}\omega_t$ represents the vector of reduced-form shocks, $A_0 = B_0^{-1}C_0$, and $A_i = B_0^{-1}B_i$, i=1,..,p. While we estimate (2), we are ultimately interested in using (1) to analyze the effects of changes in ω_t on Y_t. The problem is that there is not a unique mapping between (1) and (2), and, in order to go from (2) to (1), it is necessary to make some identifying assumptions. In our application, we assume that B_0 is lower triangular and that its main diagonal elements are all equal to 1. This, in practice, means that we assume that each variable y_{jt}, j=1,…,K, included in

Y_t is only contemporaneously affected by the variables y_{bt} for which b<j. That is, we assume a recursive relationship between the elements of Y_t. Another implication from our assumption for B_0 is that we can identify the variance of the structural shocks, and therefore the structural shocks are in the same unit as the corresponding variable.[1]

B – SIGMA Model

This appendix outlines the SIGMA model that is used for the simulations. See Erceg, Guerrieri, and Gust (2006) for a more detailed discussion of the core of the underlying model. Many of the extensions used in the current version of the model are contained in Erceg, Guerrieri, and Gust (2008); Gust, Leduc, and Sheets (2009); Erceg and Linde (2010); and Bodenstein, Erceg, and Guerrieri (2011).

The SIGMA model is a general-equilibrium open-economy model with three country blocs. The three blocs represent the United States, the advanced economies excluding the United States (AFEs), and the emerging market and developing economies (EMEs). They are structurally identical but are allowed to differ in terms of parameter values. The model is calibrated at a quarterly frequency. At the end of the appendix, we briefly describe how the shocks we use for the simulations enter the model.

Households

Each country is populated by two types of households. First, there is a continuum of infinitely lived, fully rational households. They make decisions over consumption, savings, and labor supply in a forward-looking manner. A continuum of unions sets the wage for the households, taking the households' desired level of hours and labor demand into account. However, the unions are subject to Calvo-style wage rigidities and, therefore, cannot reset the wage fully each period. Households are then forced to supply the hours of work demanded by the firms at the current wage. Household consumption preferences are of the constant relative risk aversion type but subject to a consumption habit.

[1] Assuming that the main diagonal elements B_0 are all equal to 1 and that the structural shocks do not have a unit variance has no implications for our results. We make this assumption so that we do not need to adjust the shocks in the second-stage VAR to mimic the shocks in the first-stage VAR.

Second, there is a continuum of hand-to-mouth consumers that spend their entire income, consisting of labor income and transfers, on consumption each period and do not own any type of assets. As these households do not smooth their consumption, the consumption response to shocks is amplified relative to a model with only the first type of households.

Production and Trade

Production in the model has two stages. Using labor and capital, each country produces intermediate goods, which are traded internationally. Each country then combines imported and domestic intermediate goods to produce consumption and investment goods. The latter two goods are produced using different mixtures of imported and domestic goods, allowing for international trade to be more dominated by trade in intermediate goods used in investment. Trade is subject to import adjustment costs, generating a lower short-run trade elasticity.

Intermediate goods are traded as varieties by intermediate good producers, who are monopolists for their variety and are subject to Calvo price-adjustment costs. As in Gust, Leduc, and Sheets (2009), we use Kimball (1995)-type demand curves that give rise to variations in optimal markups in response to shocks. These variations induce incomplete pass-through. Specifically, we assume that the demand elasticity can be expressed as an increasing function of a firm's relative price. The resulting variable demand elasticity gives rise to complementarities in price setting. Local currency pricing stemming from Calvo price stickiness as in Erceg, Guerrieri, and Gust (2006) implies that pass-through is incomplete in the short term, but not in the long term. However, the assumption of optimal variable markups embedded in our model implies that pass-through from nominal exchange rates is incomplete even in the long run.[2]

Investment and Interest Rates

We incorporate a financial accelerator mechanism into each country of our model following the basic approach of Bernanke, Gertler, and Gilchrist (1999). Thus, the intermediate goods producers rent capital services from entrepreneurs rather than directly from households. Entrepreneurs obtain new capital from capital good producers, who face adjustment costs in setting up new capital. To

[2] The model also contains an oil sector. Oil is modeled as a country endowment that is traded and enters both production and the consumption of households. As the oil sector plays only a minor role for the simulations at hand, we do not discuss it in detail here.

finance the acquisition of physical capital, each entrepreneur combines net worth with a loan from a bank, for which the entrepreneur must pay an external finance premium due to an agency problem. Banks obtain funds to lend to the entrepreneurs by issuing deposits to households at the interest rate set by the central bank. We follow the assumption in Bernanke, Gertler, and Gilchrist (1999) so that banks make zero profits in each state of the economy and there is no credit risk to households associated with bank deposits. The presence of the financial accelerator makes both firm spreads and investment responsive to nonbank leverage in the economy.

The model also features a set of other interest rates that are introduced into the model as the product of the real rate and a set of wedges, which are subject to stochastic variations. Finally, international interest rates are subject to a small adjustment cost in order to allow net foreign asset positions to be stationary.

Monetary and Fiscal Policy

Monetary policy follows an interest rate targeting rule with smoothing and is constrained by the zero lower bound, which we impose through anticipated monetary policy shocks. The rule responds to inflation and a modified output gap. The government in the economy raises labor and capital taxes and borrows in order to finance debt repayment, government expenditures, general transfers, and transfers targeted to the hand-to-mouth consumers. In the version of the model we used in this project, we assumed that the government stabilizes debt in the long run by slowly adjusting the general transfer.

Shocks in the Simulation

We use three types of shocks during our simulation. First, we have financial shocks, which we use to match our desired paths of spreads in the model. These shocks enter the model as changes in the wedge between a household's interest rate on liquid savings and a corporation's borrowing interest rate. Second, there is a consumption preference shock in each country, which we use as our confidence shock in addition to the financial shock. Third, we allow for shocks to the uncovered interest parity condition to target movements in the exchange rate.

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