

# Response to Discussion of “Global Forces and Monetary Policy Effectiveness” by Lucrezia Reichlin

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## 1 Main Issues

Our discussant criticizes the paper on the grounds that “all exercises performed are difficult to interpret” (p. 2). According to her, this problem arises because domestic factors  $C_t$  are affected jointly by domestic and foreign shocks. She takes issue with our interpretation of “VAR based results with international variables” and concludes, on the basis of two simple polar examples, that “[i]n order to estimate the effect of global forces, we need to identify global shocks and their propagation” (p. 7).

Given that the discussant argues that her main critique of the paper “applies whether we are focusing on a VAR on observed domestic and foreign variables or a VAR on unobserved factors” (p. 7), we focus here on issues raised in the context of our conventional VAR. These issues are both about econometric identification and economic interpretation. A more detailed discussion of these points as well as a discussion of issues referring to the estimation of factors from large data sets are left in the next section.

### 1.1 Discussion’s examples, stochastic singularity and VARs

The discussion is essentially about the fact that when the correlation among macroeconomic variables is too high, it might not be possible to identify quantities of interest. To illustrate this point, the discussant provides *two examples* in which this correlation is so high in fact that the systems suffer from stochastic singularity. As the discussion mentions, the two proposed examples have the property that the foreign factors  $C_t^*$  *do not Granger cause* the domestic factors  $C_t$ , after controlling for past domestic variables. The discussant argues that the effects of foreign factors on domestic factors cannot be interpreted in these examples, and concludes from this that our results cannot be interpreted.

We fully agree with our discussant that *if* foreign factors *did not* Granger cause domestic factors, as is assumed in both examples, it would be difficult to identify and interpret our results (see sections 2.3, 3.3 and 4.1 of paper). It is well known that VARs may be inadequate in such situations. Fortunately, this problem can be detected empirically, and it turns out that the data that we consider reject the hypothesis of stochastic singularity. Our paper reports and discusses test results showing that foreign factors  $C_t^*$  *do Granger cause* the domestic factors  $C_t$ , after controlling for past domestic variables. As argued in the paper, Granger causality from foreign factors to domestic factors in our empirical setup implies that the effect of foreign factors on domestic factors

can be properly identified by the empirical strategy that we adopted. So, as interesting as the examples presented in the discussion might be, and despite their elegance, our findings suggest that they are not relevant in practice.

## 1.2 Can we estimate the VAR coefficients?

Aside from the issue just addressed, the discussion suggests that our empirical procedure might not identify the true effect of foreign variables on domestic variables. It is alleged that our VAR parameters are inconsistently estimated depending on whether the VAR residuals involve global (i.e., worldwide common shocks) or merely region specific shocks. While this issue arises in multiple parts of the discussion, it appears most clearly in section 5 (“A simple statistical point”). That section refers to our general formulation of the VAR for the factors  $C_t^*$  and  $C_t$ . To simplify the notation, and without loss of generality, let us reduce this system to a VAR(1) in the scalar variables  $C_t^*, C_t$ :

$$\begin{bmatrix} C_t^* \\ C_t \end{bmatrix} = \begin{bmatrix} \psi_{11} & \psi_{12} \\ \psi_{21} & \psi_{22} \end{bmatrix} \begin{bmatrix} C_{t-1}^* \\ C_{t-1} \end{bmatrix} + \begin{bmatrix} u_t^* \\ u_t \end{bmatrix}. \quad (1)$$

The reduced-form shocks  $u_t^*$  and  $u_t$  (assumed to be iid over time) may be driven both by a global (or “worldwide” common) shock  $g_t$  and by region-specific shocks  $\varepsilon_t^*, \varepsilon_t$  (assumed to be uncorrelated across regions), say in the following way:

$$\begin{bmatrix} u_t^* \\ u_t \end{bmatrix} = Fg_t + \begin{bmatrix} \varepsilon_t^* \\ \varepsilon_t \end{bmatrix}. \quad (2)$$

The coefficient  $\psi_{21}$  reveals the dynamic effect of the past foreign factor  $C_{t-1}^*$  on the domestic factor  $C_t$ , controlling for the past value of  $C_t$ .

The discussant claims that “in the limit case in which  $C_t$  and  $C_t^*$  are entirely driven by a global component [ $g_t$ , the coefficient  $\psi_{21}$ ] will be zero and we would wrongly conclude that international factors have no effect on domestic factors” (p. 6). This raises issues of economic interpretation which we discuss in section 4 below, as well as econometric issues. The discussant furthermore argues that “[i]f the correlation [between  $C_t^*$  and  $C_t$ ] is not perfect, the estimates of the coefficients will reveal the effect of foreign-specific forces on domestic factors, but not the effect of foreign factors (global plus foreign specific) on domestic factors.” This is a claim that OLS estimation of VAR parameters is not consistent. However standard econometric results show that VAR coefficients,  $\psi_{ij}$ , can in general be consistently estimated and do not depend on the mixture of common,  $g_t$ , versus variable-specific shocks,  $\varepsilon_t^*, \varepsilon_t$ . In the detailed discussion provided in the section 2 if this note, we show, using a simple simulated example, that our empirical procedure generally recovers the true coefficients.

### 1.3 Do we need to identify all shocks?

The discussant criticizes our so-called exercise 4, in which we attempt to determine whether global forces mitigate the effects of US monetary policy more than they used to. The discussant interprets this exercise as an attempt to identify how *worldwide common shocks* might have mitigated the effect of US monetary policy. The discussant's main point is to argue that our strategy does not identify worldwide exogenous shocks, and hence that it cannot shed light on the question.

This interpretation of our exercise and of our results is however inappropriate. As we emphasized in the paper, the goal of our exercise 4 is *not* to determine the role of such worldwide shocks, but instead to determine to what extent the transmission of US monetary policy shocks on the US economy depends on the subsequent adjustment of foreign variables, which we summarize by *endogenous* foreign factors ( $C_t^*$ ).

To determine the effect of foreign variables on the transmission of US monetary policy, we merely need to identify one shock: a monetary policy shock. This is done in our paper by adopting a common recursive identification assumption. Clearly the validity of such assumption is debatable, but once one accepts it, the exercise performed is well defined and entirely conventional in the VAR literature. As is common in the literature, *we don't need to identify all of the other exogenous shocks* to determine the effect of monetary policy shocks, under this identifying assumption. We then perform a simple counterfactual experiment which involves shutting down the feedback effect of foreign endogenous variables on domestic variables. Clearly, as we recognize at the end of section 4.4, such an exercise is potentially subject to the Lucas critique, but this is not the object of the discussant's complaints.

In our setup, as is the case in the examples proposed by the discussant, worldwide common *shocks* are by construction orthogonal to the US monetary policy shocks, and hence do not contribute to the object of our interest, i.e., the transmission of US monetary policy. While identifying worldwide shocks might be interesting for other exercises, it is not necessary to do so for the question that we are interested in.

It is important to note that there is nothing special about the international aspect of our VAR. Our exercise 4 is completely analogous to the exercises performed by many researchers using closed-economy VARs to investigate the effect of systematic monetary policy. In such a context, the variables of the VAR are typically believed to be driven by common shocks such as productivity shocks. Yet, again, in order to characterize the effects of monetary policy, it is not necessary to identify all shocks.

### 1.4 Economic interpretation

Finally, the discussion claims that the coefficients  $\psi_{21}$  measuring the effect of foreign factors ( $C^*$ ) on domestic factors ( $C$ ), even if they could be perfectly estimated, do not provide any relevant information. For instance, in example 2 of the discussion, the true value of  $\psi_{21}$  is 0. The discussant

thus concludes on this basis that (on p. 6) “[t]he procedure proposed by the authors would assess that the rest of the world consumption has no impact on domestic consumption. However [...] this conclusion is clearly wrong [...] The coefficients  $[\psi_{21}]$  do not tell us anything about the effects of international factors on national variables.”

The critique is unfortunately misguided. Nowhere in our paper have we suggested that the rest of the world would, in such an example, have no effect on the domestic economy. In fact we don’t assess the importance of foreign factors for domestic factors on the basis of  $\psi_{21}$ . Instead we do so by looking at  $R^2$  statistics. Contrary to the discussant’s claim, if the model of example 2 in the discussion were true, we would find that much of the variance of domestic consumption is strongly correlated with foreign consumption; in the case that the domestic and foreign elasticities of intertemporal substitution are equal ( $\gamma = \gamma^*$ ), the  $R^2$  statistics reported in table 1 of our paper would be precisely 1 in this example, suggesting considerable comovement of foreign and domestic variables.

Does the coefficient  $\psi_{21}$  then provide any relevant information in that case? Certainly. Again if the model of example 2 were true, the true value of  $\psi_{21}$  would be 0. This coefficient is used in the context of our exercise 4, for the characterization of the effect of foreign variables on the transmission of monetary policy. Having the coefficient  $\psi_{21}$  equal to 0 in this example simply reflects the fact that in response to a monetary policy shock, unexpectedly raising the domestic (and world) real interest rate by a given amount results in the *same* response of domestic consumption in the open economy as in the case of complete autarky, i.e., if there were no interaction with the rest of the world. This is precisely what the theoretical model proposed in the example 2 of the discussion predicts, and it is also what our empirical procedure would conclude.

Our empirical strategy would thus have delivered the right answers in this example. As we argue in the next section, our approach would also generally provide the right answer in example 1 of the discussion. The discussion’s conclusion that “[t]he coefficients  $[\psi_{21}]$  do not tell us anything about the effects of international factors on national variables” is therefore inaccurate.

## 2 Some Additional Detailed Comments

### 2.1 Are our VAR estimates unidentified and/or inconsistent? A review of “A simple statistical point”

The discussion suggests that the coefficients of our VAR are inconsistently estimated depending on whether the VAR residuals involve global (i.e., worldwide common shocks) or merely region specific shocks. Consider the VAR of the form

$$\begin{bmatrix} C_t^* \\ C_t \end{bmatrix} = \begin{bmatrix} \psi_{11} & \psi_{12} \\ \psi_{21} & \psi_{22} \end{bmatrix} \begin{bmatrix} C_{t-1}^* \\ C_{t-1} \end{bmatrix} + \begin{bmatrix} u_t^* \\ u_t \end{bmatrix}. \quad (3)$$

mentioned in section 5 of the discussion. The reduced-form shocks  $u_t^*$  and  $u_t$  (assumed to be iid over time) may be driven both by a global (or “worldwide” common) shock  $g_t$  and by region-specific shocks  $\varepsilon_t^*$ ,  $\varepsilon_t$  (assumed to be uncorrelated across regions), say in the following way:

$$\begin{bmatrix} u_t^* \\ u_t \end{bmatrix} = Fg_t + \begin{bmatrix} \varepsilon_t^* \\ \varepsilon_t \end{bmatrix}. \quad (4)$$

The discussant argues in the context of such a VAR that “[i]f the correlation [between  $C_t^*$  and  $C_t$ ] is not perfect, the estimates of the coefficients will reveal the effect of foreign-specific forces on domestic factors, but not the effect of foreign factors (global plus foreign specific) on domestic factors.”

To illustrate that this claim is incorrect, we report below the results of a simple Monte-Carlo exercise in which we take the model (3)-(4) seriously, simulate time series for the variables  $C_t^*$ ,  $C_t$ , and reestimate by OLS the VAR coefficients. Specifically, we consider 1000 simulated paths of these series, running for 100 periods. The shocks  $g_t$ ,  $\varepsilon_t^*$ , and  $\varepsilon_t$  are all assumed to be drawn from iid standard normal distributions,  $F = [1, 1]'$ , and the assumed VAR parameters are the ones listed in the first column of Table 1. This table reports the results of this estimation.

	True	Estimated	Percentiles		
		mean	5%	50%	95%
$\psi_{11}$	0.5	0.4882	0.3506	0.4896	0.6188
$\psi_{12}$	0.4	0.4032	0.2125	0.4060	0.5753
$\psi_{21}$	-0.1	-0.1041	-0.2391	-0.1028	0.0194
$\psi_{22}$	0.5	0.4911	0.3062	0.4935	0.6612

Table 1: Monte-Carlo experiment (3 shocks:  $g_t$ ,  $\varepsilon_t^*$ ,  $\varepsilon_t$ )

Clearly, the estimated coefficients are very close to the true VAR parameters. This simply reflects the well-established result that OLS regressions of the VAR above provide consistent estimates of the

coefficients  $\psi_{ij}$ , regardless of whether the reduced-form shocks  $u_t^*$ , and  $u_t$  are driven by worldwide shocks or by region-specific shocks. There is thus no reason that we are aware of according to which  $\psi_{21}$  should capture only the effect of foreign-specific forces.

The discussant then argues that “in the limit case in which  $C_t$  and  $C_t^*$  are entirely driven by a global component [ $g_t$ , the coefficient  $\psi_{21}$ ] will be zero and we would wrongly conclude that international factors have no effect on domestic factors” (p. 6) Again, we don’t see any reason why this should be true. To illustrate this, we re-simulate our model, shutting down region-specific shocks and leaving only the global shock  $g_t$ . The results of this estimation are:

	True	Estimated	Percentiles		
		mean	5%	50%	95%
$\psi_{11}$	0.5	0.4796	0.2745	0.4771	0.6845
$\psi_{12}$	0.4	0.4111	0.1008	0.4244	0.6851
$\psi_{21}$	-0.1	-0.1204	-0.3255	-0.1229	0.0845
$\psi_{22}$	0.5	0.5111	0.2008	0.5244	0.7851

Table 2: Monte-Carlo experiment (1 shocks:  $g_t$ )

Here, even though there is only one common shock, we are still able to estimate consistently the VAR coefficients (although less precisely). The reason is that the series  $C_t$  and  $C_t^*$  are not perfectly correlated. This correlation amounts on average to 0.85. As the table makes clear, there is no reason to believe that the estimated value  $\psi_{21}$  should be 0. The estimate is in fact very close to the true value of -0.1.

As mentioned in our paper, it may however be difficult to recover the true VAR coefficients in the case that the variance-covariance matrix of the VAR innovations ( $u_t^*, u_t$ ) is reduced rank. Consider for instance the case in which there is only one common global shock, as before, but that in addition, the true VAR coefficients are such that the sums  $\psi_{11} + \psi_{12}$  and  $\psi_{21} + \psi_{22}$  are equal. In that case, both series  $C_t$  and  $C_t^*$  are perfectly correlated. Any attempt to estimate the VAR coefficients automatically fails in this case, as this involves inverting a singular matrix. As a reflection of this,  $C_t^*$  does *not* Granger cause  $C_t$ , after controlling for  $C_{t-1}$ . Of course, there is again no reason to believe that the estimated value  $\psi_{21}$  should be 0; the estimated value of  $\psi_{21}$  can simply not be recovered as it is not identified.

While this latter example may sound non-generic, it is worth mentioning, as it corresponds to the example 2 in the discussion. The next section thus reviews these examples in some details, and provides a further discussion of the identification issue.

We note that the discussant states: “Notice that the fact that we cannot identify the effect of global forces on the transmission mechanism of monetary policy has nothing to do with whether the coefficients of the VAR are identified (rank condition discussed by the authors in the text).” As this statement is unsubstantiated, it is difficult to determine why it would be correct. We simply

note that it contradicts the numerical examples just provided, our discussion of identification in this note as well as in our paper (p. 27-28).

## 2.2 A review of the discussant's examples

We now review the two examples considered in the written discussion, and used as the basis for the main critiques.

### 2.2.1 A review of example 2

The equilibrium law of motion for domestic consumption,  $y_t$ , and foreign consumption,  $y_t^*$ , in this example can be expressed in its VAR representation as follows:

$$\begin{bmatrix} y_t^* \\ y_t \end{bmatrix} = \begin{bmatrix} \rho & 0 \\ 0 & \rho \end{bmatrix} \begin{bmatrix} y_{t-1}^* \\ y_{t-1} \end{bmatrix} + \begin{bmatrix} -\frac{\gamma}{1-\rho} \\ -\frac{\gamma^*}{1-\rho} \end{bmatrix} g_t$$

where the exogenous shock here labeled  $g_t$  represents innovations to the world real interest rate. Again, this VAR is a special case of the empirical framework considered in the paper, and corresponds to the above system (3)-(4), in the case that  $\psi_{11} = \rho$ ,  $\psi_{21} = 0$ ,  $\psi_{22} = \rho$ ,  $F = [-\frac{\gamma}{1-\rho}, -\frac{\gamma^*}{1-\rho}]$ , and the variances of the shocks specific each region (US and rest of the world)  $\varepsilon_t^*$ ,  $\varepsilon_t$  are assumed to be zero.

An important feature of this example is that the *only* shock is a *worldwide common shock*, so that  $y_t^*$  does not Granger cause  $y_t$  (conditional on past values of  $y_t$ ).

There are two aspects of the discussant's critique based on this example. The first is the claim that our empirical strategy would not be able to properly estimate the coefficients of the VAR, especially  $\psi_{21}$ . This is only because of non-generic features of this example which might make the VAR coefficients not identified, an issue revealed by the lack of Granger causality in this example. However, as mentioned above, the data considered in the paper clearly rejects the absence of Granger causality, so that this critique does not apply to our paper.

A second critique is the claim that the coefficient  $\psi_{21}$ , even if it could be perfectly estimated, does not provide any relevant information. However, as discussed in section 1 above, our empirical strategy would have delivered the right answers in this example.

### 2.2.2 A review of example 1

In example 1, the US output in each sector  $k$  is assumed to be characterized by

$$y_{k,t} = A_k(L) y_{k,t-1} + \gamma_k B_k(L) Y_t^* + u_{k,t}$$

where  $Y_t^* \equiv \sum_{j=1}^J \theta^j Y_{j,t}^*$  is an aggregate of national incomes of all non-US countries. (This is the fourth equation in section 3 of the discussion; here, we denote the aggregate  $Y_t^*$  instead of  $X_t$  in

order not to confound readers with our notation for domestic data). Let us suppose without loss of generality (and solely to simplify notation) that the lag polynomials take the following form  $A_k(L) = A_k$  and  $B_k(L) = B_{k0} + B_{k1}L$ . Aggregating over all sectors  $k$  of the US economy, we obtain

$$Y_t = AY_{t-1} + B_0Y_t^* + B_1Y_{t-1}^* + u_t$$

where  $Y_t \equiv \sum_{k=1}^K \omega_k Y_{j,t}$  denotes US GDP and the weights  $\omega_k$  denote the relative sizes of the sectors. Our discussant assumes that the evolution of foreign variables is “driven purely by ‘foreign’ disturbances, unrelated to developments in the US.” Let us formalize this by assuming, without loss of generality for the issue at hand, that  $Y_t^*$  follows a simple AR(1) process

$$Y_t^* = A^*Y_{t-1}^* + u_t^*$$

where the foreign disturbance  $u_t^*$  is assumed to be uncorrelated with domestic disturbances  $u_t$ .

The two previous equations can then be rewritten as the system:

$$Y_t^* = \psi_{11}Y_{t-1}^* + u_t^* \tag{5}$$

$$Y_t = \psi_{21}Y_{t-1}^* + \psi_{22}Y_{t-1} + B_0u_t^* + u_t. \tag{6}$$

This system is of course a special case of the empirical framework that we consider in the paper, and relates to the illustrative example presented in our paper (section 4.1, p. 27), in the case that  $\psi_{11} = A^*$ ,  $\psi_{21} = (B_0A^* + B_1)$ ,  $\psi_{22} = A$ ,  $\psi_{12} = \psi_{13} = \psi_{23} = 0$ , and the shocks to both equations satisfy

$$\begin{bmatrix} u_t^* \\ B_0u_t^* + u_t \end{bmatrix} \equiv \begin{bmatrix} 1 \\ B_0 \end{bmatrix} g_t + \begin{bmatrix} \varepsilon_t^* \\ \varepsilon_t \end{bmatrix}.$$

It is now worth considering 2 cases: the case in which the estimated factors  $C_t^*$  and  $C_t$  capture the variables  $Y_t^*$  and  $Y_t$ , and the one in which it does not.

**Case 1:  $C_t = Y_t$  and  $C_t^* = Y_t^*$ .** In that case, it is important to note that the discussant’s example *assumes that the rest of the world is not affected by any region-specific shocks*. In fact  $\text{var}(\varepsilon_t^*) = 0$ , so that  $g_t = u_t^*$  is a “worldwide” shock which affects simultaneously both the domestic and foreign countries, while  $\varepsilon_t = u_t$  is a shock that is specific to the US economy. All of the exogenous shocks that affect  $Y_t^*$  are *assumed* to affect  $Y_t$  at the same time. Recall that the discussant claims that (C1) the variance of observable domestic variables explained by foreign factors is not interpretable even when controlling for the correlation between domestic and foreign factors, and that (C2) the Granger causality tests proposed in exercise 3 are not informative on the role of global forces in national dynamics.

To address these claims, it is probably best to restate here what we wrote on p. 27 and 28 of our paper:

In this simple context, whether or not our strategy identifies the effect of international factors — i.e. the effect of  $Y_t^*$  — in the transmission mechanism of monetary policy depends solely on whether the parameter  $\psi_{21}$  is identified. As mentioned in section 2,  $\psi_{21}$  is identified provided that the variances of  $\varepsilon_t$  and  $\varepsilon_t^*$  are nonzero [...or if ]  $Y_t^*$  Granger causes  $Y_t$  (conditional on past values of  $Y_t$ ).

In other words, we entirely agree with the discussant that *if we had found* that  $Y_t^*$  does not Granger cause  $Y_t$  (conditional on past values of  $Y_t$ ), we would not have been able to identify the effect of foreign factors on domestic factors. However, as mentioned above, section 3.3.1 and Table 2 of the paper make clear that we strongly reject this absence of Granger causality. It thus follows that *we can identify* the effect of foreign endogenous factors on domestic factors, so that this example is not pertinent.

One may disagree with our classification of the shocks  $u_t^*$  as “worldwide” shocks. In fact the discussant argues that these are purely foreign disturbances. However they are by construction assumed to impact the domestic economy at the same time in this example. If we were trying to disentangle worldwide shocks from foreign shocks, we would need to impose additional identifying assumption which might be controversial. However, as explicitly stated in the paper, we do not attempt to disentangle foreign and worldwide shocks. We merely attempt to estimate the effect of foreign factors (driven by both foreign and worldwide shocks) on domestic factors.

Finally, we now illustrate why the determination of foreign shocks  $u_t^*$  as either worldwide common shocks,  $g_t$ , or as shocks that are specific to the rest of the world,  $\varepsilon_t^*$ , is not relevant for the identification of the effect of monetary disturbances on the economy, even if we could identify the VAR coefficients  $\psi_{ij}$ . Let us consider a very simple extension of the above model: we simply append to the system (5)-(6) above an interest rate rule, and let lagged values of the interest rate enter on the right-hand side of (6). In that model (see section 4.1, p. 27, of our paper), a shock to the domestic interest rate should affect domestic output but should have no impact on foreign output, since by assumption  $Y_t^*$  is only driven by contemporaneous and past foreign disturbances. The impulse response of domestic output to a monetary shock should in this example not be affected at all by the presence of foreign variables, regardless of whether foreign shocks  $u_t^*$  are global shocks or shocks that are specific to the non-US region. Again, provided that foreign factors do Granger cause domestic factors (which is the relevant case here), the coefficients of the VAR are identified, and we can appropriately characterize the effects of US monetary policy shocks.

**Case 2: Estimated factors do not capture variables  $Y_t, Y_t^*$  in respective regions.** The discussant finally suggests that set of estimated domestic factors  $C_t$  might include not only domestic variables  $Y_t$ , but also foreign variables  $Y_t^*$ , while the foreign estimated factors  $C_t^*$  would include  $Y_t^*$

and some other factors  $D_t^*$  so that:

$$C_t = \begin{bmatrix} Y_t^* \\ Y_t \end{bmatrix}, \quad C_t^* = \begin{bmatrix} D_t^* \\ Y_t^* \end{bmatrix}.$$

(The common components could also be any linear combination of these variables). In that case, the VAR imposed by the assumed model would be of the form

$$\begin{bmatrix} C_t^* \\ C_t \end{bmatrix} \equiv \begin{bmatrix} D_t^* \\ Y_t^* \\ Y_t^* \\ Y_t \end{bmatrix} = \begin{bmatrix} \psi_{00} & (1 - \alpha_0) \psi_{01} & \alpha_0 \psi_{01} & \psi_{03} \\ 0 & (1 - \alpha_1) \psi_{11} & \alpha_1 \psi_{11} & 0 \\ 0 & (1 - \alpha_2) \psi_{11} & \alpha_2 \psi_{11} & 0 \\ 0 & (1 - \alpha_3) \psi_{21} & \alpha_3 \psi_{21} & \psi_{22} \end{bmatrix} \begin{bmatrix} D_{t-1}^* \\ Y_{t-1}^* \\ Y_{t-1}^* \\ Y_{t-1} \end{bmatrix} + \begin{bmatrix} u_{0t}^* \\ u_t^* \\ u_t^* \\ B_0 u_t^* + u_t \end{bmatrix}$$

for arbitrary parameters  $\alpha_0, \alpha_1, \alpha_2, \alpha_3$ . Clearly, if  $Y_t^*$  were both in  $C_t$  and  $C_t^*$  then we couldn't identify the parameters of our VAR as there would be perfect multicollinearity in each of the regression and the foreign variables  $Y_t^*$  would not Granger-cause the domestic factors  $C_t$ . While this case is possible, we don't think it is a relevant issue in our framework as we found no apparent sign suggesting that our VAR parameters are not identified, and given that we can reject the absence of Granger causality of the foreign factors on all of the 11 domestic factors at the 10% level, and on 10 out of 11 domestic factors at the 5% level.

Finally, the discussant suggests that it might still be possible to find Granger causality and, at the same time, to have mis-classified  $Y_t^*$  in the domestic factors. This could occur if we omit  $Y_t^*$  from the vector of foreign factors altogether, so that  $C_t^* = D_t^*$ , and  $Y_t^*$  enters only in the vector domestic factors  $C_t$ . We recognize that this is possible, but this statement is not about a "conceptual problem" with our setup. It is instead about not allowing  $C_t^*$  to include a sufficient number of factors in the practical application, and hence about the worry that we might be performing an analysis with a mis-specified model. As always, the results are conditional on having well specified the model used. Even though model misspecification is always a potential problem, this issue may not undermine too much the results in our application, as we verified the robustness of our results by accounting for a larger set of domestic and foreign factors than those reported in the paper, and didn't observe any noticeable differences. In addition, while it is more likely for a small open economy to be affected by international variables which are themselves not important in driving the rest of the world's economy, this is less likely to be true for large economies like the US, which is the object of our investigation in the paper.