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# Exchange Rate Shocks and U.S. Services and Agricultural Exports: Which Export Sector is More Affected?

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*In this article, a vector autoregressive model is constructed with monthly data from 1992:1 to 2009:12 to investigate the exchange rate propagation mechanisms to real exports of U.S. services and agricultural sectors. Using plausible identification assumptions consistent with many open economy macro models, the results indicate that exchange rate shocks impact services exports more than they do on agricultural exports. Moreover, the shocks are more persistent on services relative to agricultural exports.*

*KEYWORDS* *exchange rates, sectoral decomposition, USA, VAR*

## I. INTRODUCTION

Empirical analyses of the impact of exchange rate fluctuations on exports have been widely documented. The conventional argument is that uncertainty about exchange rate fluctuations increases risks in both import and export competing industries and negatively impacts trade.[1] Data on foreign trade indicate a big change in the shares of U.S. services and agricultural exports in total exports. Whereas the share of services in total U.S. exports has been increasing over the past four decades, agricultural export share has

[1] Baldwin and Krugman (1989) provide quite extensive evidence and analysis on the entry and exit decisions of firms following large depreciation of the dollar. Their case studies provide interesting lessons from the large devaluation of the U.S. dollar in the 1980s.

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been diminishing. Data on foreign trade also suggest that U.S. manufactured exports account for a larger and fairly constant proportion of U.S. total exports to the rest of the world.

Many economists have modeled the dynamics of structural change in the U.S. economy that have occurred in the three sectors of agriculture, services, and manufacturing. For instance, Kongsamut et al. (2001) find that the structural change in terms of labor shares in the production process has shifted from agriculture to manufacturing and more recently to the services sector. This result is consistent with the fact that services now account for more than 60% of U.S. GDP. Uy et al. (2013, 672) argue that trade contributes indirectly to structural transformation in the three sectors of agriculture, manufacturing, and services through expenditure switching mechanisms. Evidently, the changes in the composition of U.S. GDP as a result of the structural change happening in the sectors of the economy seem to mimic the trends in the export sectors of agriculture and services.

Figure 1 plots the trends in the shares of U.S. services and agricultural exports to total exports to the rest of the world. The two stylized facts that can be drawn from Figure 1 are: (1) the share of services exports in total U.S. exports has been increasing for the past three decades while the share of agricultural exports in total exports has declined continuously over the same period; and (2) the changes in the export shares of the two sectors seem highly volatile in all quarters of the sample period. The theoretical literature on structural change is consistent with stylized fact (1). What is missing is the explanation for the possible drivers of the short-run movements in the shares of U.S. services and agricultural exports around their long-run trends. The question that this article seeks to address is two-fold. First, do fluctuations in the U.S. dollar trade weighted exchange rate explain the short-run cyclical

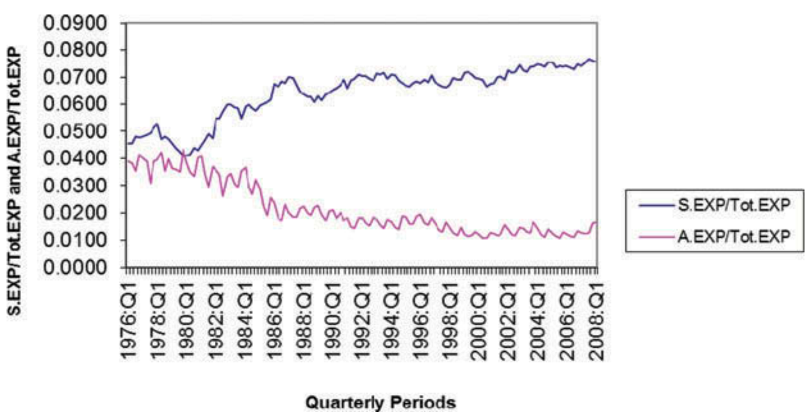


**FIGURE 1** U.S. share of agricultural and services exports to total exports from 1976:Q1 to 2008:Q1.

*Source:* U.S. Department of Commerce, Census Bureau and the Federal Reserve Economic Databank.

movements in the export shares of services and agricultural sectors? Second, how do the two sectors simultaneously respond to a shock in the U.S. dollar trade weighted exchange rate and how persistent are these shocks?

Previous studies on open economies suggest weak exchange rate pass-through effects on import prices and trade.[2] In this article, it is conjectured that the heterogeneity in the sectors of agriculture and services could generate unique responses to any given shock in the exchange rate. Whereas the response of real exports of manufactured goods can move countercyclical to an exchange rate shock, services and agricultural exports may experience pro-cyclical movements to the same shock, resulting in an offsetting impact of exchange rate fluctuations on aggregate exports. Gopinath and Rigobon (2008) show important differences in the price rigidity of highly disaggregate goods. The immediate implication from their study is that any shock in the exchange rate or monetary policy is likely to affect the different categories of goods differently and may result in offsetting impacts.

While the propagation mechanisms of exchange rate movements to a country's aggregate exports and current account have been extensively studied, little attempt has been made to investigate the simultaneous dynamic behavior of exports of different key sectors that constitute a country's aggregate exports following a shock in the exchange rate. In other words, what is true as a whole regarding aggregate exports following a shock in the exchange rate is almost conventional, but what is true in parts is still less clear. In a related article, Burda and Gerlach (1992) develop a simple non-stochastic dynamic general equilibrium model that disaggregates the current account into durable and non-durable trade balances. They show that the durable trade balance is more sensitive to changes in the inter-temporal prices relative to the non-durable components following a shock in the exchange rate.

The vast majority of empirical studies that look at the relationship between trade and exchange rates have arrived at mix evidence. Most of these studies have been focused on specific countries and/or regional experiences. Bahmani-Oskooee and Hegerty (2010a) provide an excellent review of this literature. There are a number of methodologies that have been employed in the studies looking at the exchange rate-trade relationship using time series data. The three important methodologies that have been widely applied in this topic are: (1) the GARCH volatility models; (2) the VAR and

[2] Some recent macro studies suggest weak relationships between inflation and exchange rate volatility (see, for instance, Burnstein, Eichenbaum & Rebelo 2007). The notion that incomplete exchange rates pass due to nominal rigidities has been dismissed in many open economy quantitative studies. Many open economy New Keynesian models attribute the low exchange rate pass through effects to imperfect competition where the producers either price their exports in the currency of the importer, a scenario dubbed as local currency pricing (see, for instance, Devereux & Engel 2003), or in other instances, where the producer sets the price of their exports in their own currency. This latter case is known as producer currency pricing. (For a more complete discussion of this latter case and its implication on exchange rate pass through, refer to Obstfeld & Rogoff 2000).

cointegration techniques; and (3) the autoregressive distributed lag (ARDL) model developed in Pesaran et al. (2001). The GARCH volatility models and their variants, for instance, have been used extensively to study the effect of exchange rate volatility on trade (see Fang et al. 2006).

Recently, the ARDL methodology has been used extensively in many empirical studies that investigate the *J*-curve hypothesis and other trade-exchange rate-related issues. This methodology has been widely applied in studies that employ deeper disaggregate industry-level data (see, for instance, Bahmani-Oskooee et al. 2014; Bahmani-Oskooee & Zhang 2013; Bahmani-Oskooee 2010b). However, the ARDL is only designed for single-equation modeling and cannot be applied to a simultaneous multi-equation system.

The previously mentioned studies, which typically use highly disaggregate trade data at several industry digit levels, are based on a long established proposition that aggregation can conceal the underlying effects of exchange rate on trade. In addition, a majority of these empirical studies often employ bilateral trade data. There are a couple of limitations with this approach. First, even if disaggregation is important, overly disaggregating the components of exports and/or the trade balance makes identification of the effect of an exchange rate shock on different industry exports extremely difficult, if not completely impossible to achieve. This limits our understanding of how aggregate exports from the different sectors—for instance, those in services and agricultural industries—may respond simultaneously to any given exchange rate shock. Yet knowledge of the heterogeneity between the different sectors can be a useful basis for identifying the propagation mechanisms of an exchange rate shock to the exports of each sector. Second, using bilateral as opposed to multilateral trade data further limits our understanding of how exports respond to a shock in the exchange rate. It could be the case that the changes in bilateral trade are driven by institutional factors, such as free trade agreements that occur with a trading partner or some other countries. In this context, the bilateral trade data are unable to empirically isolate the impact on exports due to the trade diversion and trade creation effects from regional trading agreements from changes in exports that are driven by exogenous exchange rate shocks.

In this article, I argue that moving a level in disaggregation to decompose a country's exports into broad categories such as services and agricultural exports in a multilateral setting and using the trade weighted exchange rate series instead of bilateral exchange rates potentially minimizes the previously mentioned limitations. In this regard, by using the multilateral export data, the trade diversion and trade creation effects due to the creation of regional trading agreements are likely to cancel each other out. In addition, disaggregating aggregate exports into services and agricultural export goods in general provides a valid identification strategy based on the heterogeneity in those sectors. This provides an avenue to distinctively isolate the propagation mechanisms of an exchange rate shock to the exports of each sector. In addition, one can use the forecast error variance decomposition to study the persistence of such a shock in each sector.

Even though many empirical studies have been carried out to investigate the effect of exchange rate movements on commodity trade, there are few studies which have particularly examined the behavior of trade in services (see, for instance, Pattichis 2012; Kimura & Lee 2006; Sichei et al. 2007). In particular, Sichei et al. (2007) examine the South African-U.S. bilateral trade in services. They find that a depreciation in the South African rand relative to the U.S. dollar leads to a significant increase in the South African service exports to the U.S. Despite recent attempts to use disaggregate trade data in several empirical studies, no studies (to the best of my knowledge) have investigated the impact of services and agricultural exports collectively in a single framework in order to examine empirically their simultaneous dynamic responses to any given exchange rate shock.

This article therefore employs an open economy vector autoregressive framework to investigate the impact of exchange rate shocks on U.S. services and agricultural exports. The identification restrictions employed in this article are novel in that; I am able to show how services and agricultural exports simultaneously respond to any given shock in the exchange rate. These simultaneous responses of services and agricultural exports cannot be captured within the single equation autoregressive distributed lag (ARDL) framework that has been extensively applied in recent studies. Moreover, using only lagged values of the variables within the ARDL framework does not completely account for endogeneity issues. The vector autoregressive model does control for endogeneity and/or simultaneity by modeling every variable endogenously in a multi-equation setting. Given the heterogeneity between services and agricultural exports, the restrictions employed within the identified VAR framework provide plausible identification assumptions of the exchange rate propagation mechanisms in those sectors. One critical identifying restriction that I make in this article is that the long gestation period experienced within the agricultural industry generates additional rigidity. This may result in sluggish or lagged responses of agricultural exports to the exchange rate and/or monetary policy shocks.

Under alternative identification schemes—that is, the recursive and non-recursive structures—the analysis indicates that there is small but negative correlation between exchange rate shocks and the real sectoral exports of agriculture and services with important distinctions. First, exchange rate shocks impact services more than agricultural exports. Second, as the shock dissipates into the future, service exports show relatively slower reversion to their pre-shock average relative to agricultural exports.

The VAR framework also incorporates the real price of oil to isolate the effects that monetary policy shocks alone may have on the economy. This modeling assumption has been explored by many researchers, including Kim and Roubini (2000) and Rahman and Serletis (2009). By including oil and/or other commodity prices, one is able to distinguish the sources of inflation that result from domestic monetary policy shocks alone from those emanating from negative or positive supply shocks brought about by the fundamentals external to the economy being modeled. A typical scenario of such external forces is that the oil shock might be due to an overall surge in the global demand for energy, particularly from the emerging market economies. This article's methodological approach and identification restrictions are more in context with Rahman and Serletis (2009). The main difference is that they use aggregate U.S. exports within the VAR framework in combination with the GARCH volatility model, while this current work looks at disaggregate exports one level below aggregate exports using an identified vector autoregressive framework.

The remainder of the article proceeds as follows. Section two discusses some additional literature on the exchange rate-trade relationship. In section three, the VAR econometric methodology, including its key identifying assumptions/restrictions, is presented and justified. In section four, the characteristics of the data vector and how data were collected are discussed. The results and discussions are presented in section five and section six concludes.

## II. ADDITIONAL LITERATURE

Modeling exchange rate fluctuations as a fundamental source of international business cycle fluctuations has accelerated, particularly after the collapse of the Bretton Woods agreement. Conventional wisdom suggests that a large depreciation of the U.S. dollar would lead to a substantial gain in the world market position of U.S.-based firms because exports would be less expensive.[3]

Many empirical studies and textbook analyses have shown that a substantial decline in the U.S. dollar positively impacts the trade balance with a lag, in that the trade balance falls first and then rises afterwards. This lagged pattern is often referred to as the *J*-curve (Caves & Jones 1985) and arises because of the low exchange rate-pass-through effects of import prices to consumer price inflation. However, there is also a strand in the literature that suggests that the correlation between exchange rates and trade is insignificant (see, for instance, Koray & Lastrapes 1989). A survey by McKenzie (1999) concludes that the impact of exchange rate fluctuations on different markets varies and calls for tests using market- or sector-specific data. Studies that model the relationship between exchange rates and trade based on Marshall Learner condition also do find mixed evidence on the

[3] See for instance explanations by Catherine L. Mann (2002) on the perspective of U.S. dollar stance and current account deficit.

impact of exchange rates on trade[4] (see, for instance, Hoathakker & Magee 1969; Goldstein & Khan 1976; 1978; Marquez 1990; Bahmani-Oskooee & Niroomand 1998).

Developments in panel data and time series have ignited studies that investigate the relationship between exchange rate and trade. Many studies based on panel data usually model the exchange rate-trade relationship using the gravity model (Rose 2000; Tenreyro 2007; Chit et al. 2010). However, the use of vector autoregressive (VAR) models and cointegration techniques in time series settings gained popularity in the 1990s and the 2000s. For instance, Hsing (2005) uses a generalized impulse response function from the vector autoregressive model to examine whether the *J*-curve effect exist for Japan, Korea, and Taiwan. The analysis is conducted using both bilateral trade data with the U.S. as well as multilateral trade data with the rest of the world. They only find evidence of the *J*-curve hypothesis in the Japanese data. Das (2003), using quarterly data from 1980-2001, applies the error correction and cointegration techniques to study the response of exports following a shock in the exchange rate, finding a negative and significant effect on exports due to a depreciation in the exchange rate. Hook and Boon (2000), using a vector autoregressive approach with quarterly data, find a negative effect on exports following a depreciation in the domestic currency, while Arize (1995), using a cointegration and an error correction model, finds significant negative impact of the exchange rate on trade. As mentioned earlier, the more recent studies have extensively applied the Autoregressive Distributed Lag (ARDL) methodology to investigate the relationship between exchange rate and trade.

While contemporary empirical and theoretical works on new open economies have focused on intertemporal aspects of the current account, decomposing foreign trade into key real sectors of agriculture, manufacturing, and services has not been collectively examined in a single-vector autoregressive framework. It is important to note that modeling the key real sectors that constitute total trade collectively in a multi-equation system is different from incorporating just one sector in the model. The single-equation autoregressive distributed lag (ARDL) model is incapable of dynamically modeling a multi-equation system to investigate how the real exports of services and agricultural sectors respond to a given exchange rate shock.

In this article, I model the U.S. export sectors of agriculture and services collectively in a VAR framework and offers a new look at their behavior

[4] More recent studies on the correlation between exchange rates and trade indicate the problem of country aggregation bias of earlier studies and they remedy the problem by the use of bilateral trade data instead of a country's trade with the rest of the world. See, for instance, Rahman and Serletis (2009). However, many still continue to use data on aggregate exports and imports. I move down a level of disaggregation to analyze this problem. Bahmani-Oskooee and Ardalani (2006) move down two levels of disaggregation and employ a cointegration technique to examine the long-run relation between real exchange rates and trade flows of 66 commodities in the U.S. They find a negative relationship between the exports of those commodities and exchange rates but no significant impact on imports.

following a shock in the dollar trade-weighted exchange rate. This is important because many studies have theoretically examined the economic growth process related to structural change in services, manufacturing, and agricultural sectors which constitute a macro economy (Uy et al. 2013; Kongsamut et al. 2001), but limited work has been done to establish the dynamic movements in trading in those sectors following a shock in the exchange rate.

## III. THE OPEN ECONOMY VECTOR AUTOREGRESSIVE MODEL

In this section, a VAR model for the open economy comprising real and nominal variables is constructed. The VAR model is built using the following data vector: the U.S. industrial production (*Y*); the consumer price index (*P*); the money supply aggregate (*M2*); the U.S. federal funds rate (*FFR*); the real price of oil (*OP*); the trade weighted exchange rate (*E*); the real value of services exports (*SX*); and the real value of agricultural exports (*AX*). All of the variables except the federal funds rate are expressed in logarithms. The structural shocks related to the listed eight economic variables are generated. These include $\mu^{Y}$ (a shock to output), $\mu^{CPI}$ (a shock to the *CPI*), $\mu^{FFR}$ (a shock to *FFR*), $\mu^{M2}$ (a shock to *M2*), $\mu^{OP}$ (a shock to *OP*), $\mu^{E}$ (a shock to *E*), $\mu^{SX}$ (a shock to the U.S. real services exports), and $\mu^{AX}$ (a shock to the U.S. real agricultural exports).

Assume that $x_t$ is a vector containing the above eight economic variables, where $x_t = [Y_t, CPI_t, FFR_t, M2_t, OP_t, E_t, SX_t, AX_t]'$. After a transformation is carried out on all variables in the system, $x_t$ is covariance stationary. A test for unit roots is conducted using the augmented Dickey and Fuller (1979) and Perron (1989) tests and, with the exception of the federal funds rate, the variables entering the system are stationary in their first differences. In addition, a cointegration test indicates no evidence of a long-run relationship among the variables in the system and an error correction representation of the model is ruled out in this context. Instead, an identified VAR model is specified. The reduced form representation of these economic variables is written as:

$$A(L)x_t = e_t \qquad \text{var}(e_t) = E(e_t e_t') = \Omega\,, \tag{1}$$

where $A(L) = A_0 + A_1 L + \ldots\ldots + A_p L^p$.

In estimating Equation 1, two lags have been used and selected based on the Akaike information criteria. A test is also conducted to ensure that there is stability and invertibility in the system and all the roots of the matrix polynomial $A(L)$are greater than one in modulus. This guarantees a moving average Wold-chain representation to be written as:

$$x_t = B(L)e_t \tag{2}$$

The structural representation of Equation 1 is written as:

$$D(L)x_t = \mu_t \qquad \mathrm{var}(\mu_t) = E(\mu_t \mu_t{}') = \eta \tag{3}$$

Note that Equations 1 and 3 are related according to:

$$e_t = B_0 u_t \tag{4}$$

Squaring both sides of Equation 4 and taking expectation of both sides result in the following expression:

$$\Omega = B_0{}^{-1} \eta \, B_0{}^{-1} \tag{5}$$

By estimating the reduced form of Equation 2 and imposing realistic identification assumptions, one can recover the structural parameters of the model with meaningful interpretable economic implications using Equations 4 and 5.

## Estimation and Identification

In a VAR system containing $n$-variables, $\frac{n(n+1)}{2}$ restrictions are needed to identify the system. From Equation 5, $\Omega$ estimates can be inferred from estimates of $\beta_0$ and $\eta$ obtainable through maximum likelihood procedure. Normalizing the diagonal element to one places $n$ restrictions on the VAR system. The difference between $n(n+1)/2$ and $n$ means that there are still $n(n-1)/2$ other identification restrictions needed. In Sims (1980), the matrix of contemporaneous effects of structural shocks on the variables is assumed to be lower triangular, which yields exactly the needed $n(n-1)/2$ other identification restrictions. This recursive identification strategy proposed in Sims (1980) was criticized because different ordering of variables in the system results in different parameter estimates. Cooley and Leroy (1985) and Bernanke (1986), for instance, have proposed the non-recursive structural relations among contemporaneous variables in the system. These structural identifications, combined with the use of Bayesian priors, have become the cornerstone in many recent macroeconomic studies. In this article, the non-recursive assumptions are employed to identify the exchange rate and monetary policy shocks. The matrix representing the identifying restrictions is presented in Equation 6 below:

$$\begin{bmatrix} e_Y \\ e_P \\ e_R \\ e_{M2} \\ e_{OP} \\ e_E \\ e_S \\ e_A \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & b_{17} & b_{18} \\ b_{21} & 1 & 0 & 0 & 0 & 0 & b_{27} & b_{28} \\ 0 & 0 & 1 & b_{34} & b_{35} & 0 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & 1 & 0 & 0 & 0 & 0 \\ b_{51} & b_{52} & b_{53} & b_{54} & 1 & 0 & 0 & 0 \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_Y \\ u_P \\ u_R \\ u_{M2} \\ u_{OP} \\ u_E \\ u_S \\ u_A \end{bmatrix} \quad (6)$$

Before discussing the non-recursive identification assumptions used in the above matrix, it must be noted that certain exclusion restrictions on the structural parameters become standard for studies of both closed and open economy macroeconomics. For recursive identification, one needs to have an exact lower triangular matrix with all zero restrictions above the leading diagonal. The eight-variable VAR that is analyzed here would require 28 zero restrictions above the leading diagonal for an exact identification. However, a non-recursive overidentified structure with 37 zero restrictions is employed, leaving up to 19 free parameters to estimate. The first four elements listed in the above identification matrix are quite common in both closed and open economy macroeconomic literature (see, for instance, Sims 1980; 1992; Sims & Zha 1996; Grilli & Roubini 1996; Cushman & Zha 1997; Kim & Roubini 2000; Rahman & Serletis 2009). I follow the example of Kim and Roubini (2000) in using the same types of information lags necessary to identify the monetary policy shocks but with important distinctions.[5] What is known by the Federal Reserve at the time monetary policy is set includes the level of monetary aggregates, *M2*; the U.S. trade weighted exchange rates *E*; and commodity prices, including the price of oil, *OP*. Following Kim and Roubini (2000) and Rahman and Serletis (2009), the monetary aggregate, *M2*, and the price of oil, *OP*, are allowed to contemporaneously enter the equation for the federal funds rate. It must be noted that the oil price is included in the federal funds rate equation because fluctuations in oil prices are usually driven by the overall changes in the global supply and demand for energy and are unlikely to signal a general change in consumer prices brought about by the domestic monetary policy in the U.S. Including the price of oil in the model therefore allows the researcher to isolate the impact that the monetary policy shocks alone can have on prices and other variables in the system.

Although data on the trade weighted exchange rates are available within a month, the assumption made here is that the monetary authority does not respond contemporaneously to shocks in foreign variables, including the variability in the exchange rates. This assumption has been widely used in

[5] Kim and Roubini (2000) use bilateral trade exchange rates between the U.S. and the other G-7 countries. In this article, the U.S. trade weighed exchange rates with U.S. total trade in agriculture and services.

many open economy studies, even when many studies based on risk aversion suggest that exchange rate volatility disrupts trade and investments in both export and import sectors (see, for instance, Ethier 1973). Since data on GDP and the Consumer Price Index (CPI) may not be readily available within the policy formulation period, values of these variables, including trade in agricultural goods (A) and services (S), are assumed not to contemporaneously impact the federal funds rate. This assumption also recognizes the lag impact of monetary policy on the real economy.

The third and fourth rows of the identification matrix in Equation 6 represent the *LM*-framework or money market equilibrium. Row 3 of this matrix is the supply of real money balances. After observing the current values of money supply and oil prices, the monetary authority sets an interest rate that will eventually determine the level of money supply. Row 4 of the identification matrix in Equation 6 is the demand for real money balances. The fifth and sixth rows of the identification matrix in Equation 6 form a block representing financial sector variables in the system. These variables include exchange rates, *E*, and the price of oil, *OP*.

Rows 1, 2, 7, and 8 of the identification matrix in Equation 6 form a block of variables in the goods and services market (production sectors). These four equations together represent an open economy *IS*-type expression. Since the CPI is usually constructed to reflect the prices of both domestically produced goods and imports, trade in services and agricultural goods is assumed to contemporaneously impact real GDP and the general price level.

The real exports of agricultural goods enter last in the VAR ordering to account for the long gestation period within the agricultural industry. Negative or positive shocks in monetary policy and exchange rates or any other variables in the system are unlikely to affect trade in agricultural products within a period. This is a fairly realistic assumption as farmers are unable to respond contemporaneously to any given shock in the system. In addition, I continue to assume that financial sector variables and policy do not affect real GDP, prices, and foreign trade within a period.

## IV. DATA

Monthly data on U.S. foreign trade from 1992:1 to 2009:12 are used. The data on U.S. foreign trade in agricultural products were obtained from the United States Department of Agriculture (USDA). Data on exchange rates, U.S. foreign trade in services, the consumer price index, the federal funds rate, and monetary aggregates were obtained from the Federal Reserve Economic Databank (FRED) maintained by the Federal Reserve Bank of Saint Louis. Data on oil prices were obtained from the U.S. Department of Energy. The federal funds rate is used here as an index for interest rates and an instrument of U.S. monetary policy. The choice of the federal funds rate as an instrument of monetary policy was made following Bernanke and Blinder (1992), who argue that the federal funds rate is more informative for forecasting compared with other alternative policy instruments.

## V. EMPIRICAL RESULTS

Before presenting the results, it is important to mention what the theoretical stance is regarding movements in the macro variables following a shock in the exchange rate. Almost all exchange rate models predict that an appreciation shock in the exchange rate leads to a decline in exports and output while increasing imports. Although data on exchange rates are available within a period, the Federal Reserve does not respond contemporaneously to an exchange rate shock. However, after the effects of such a shock on exports become apparent, one would expect a monetary policy response leading to a change in the trade weighted value of the dollar.

### Effects of Exchange Rate Shocks under Recursive Identification Restrictions

Before presenting the results based on a non-recursive identification structure, we first report the results in Figure 2 for the baseline VAR that relies on

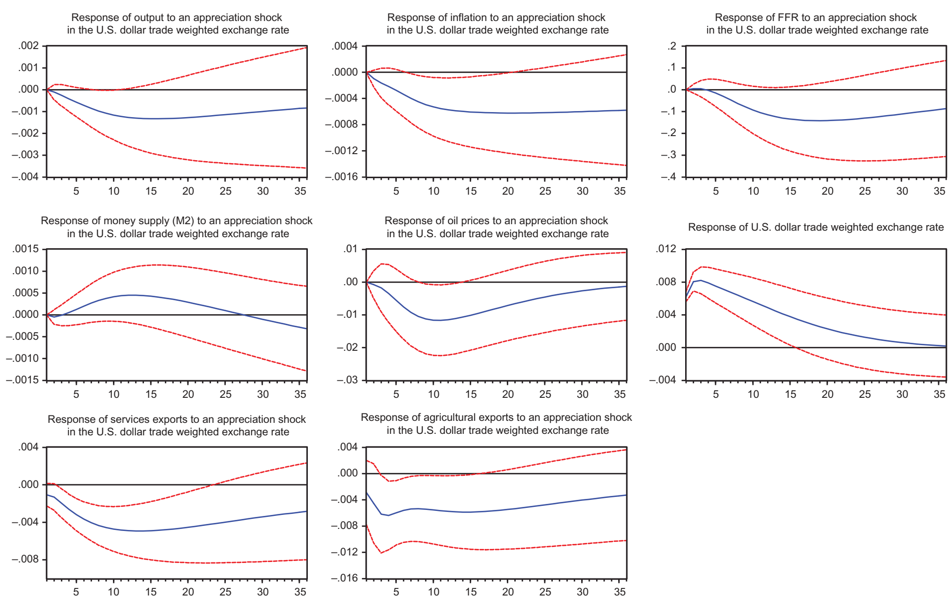


**FIGURE 2** Impulse responses to a positive innovation (appreciation) in the U.S. dollar trade weighted exchange rate.

recursive identification structure. The impulse responses show that services and agricultural exports are negatively affected by an appreciation shock in the trade weighted exchange rate. Output falls following an appreciation shock in the exchange rate. However, the dynamic movements of exports in the two sectors show remarkable differences in terms of the magnitude of the impact response and the persistence of the shock. The recursive identification structure, however, does not fully capture the structural relationships among major economic variables in the system. Despite a clear negative relationship between sectoral exports and trade weighted exchange rates consistent with what the theories on exchange rate determination would predict, the results in Figure 2 only present an entry point toward a more plausible identification strategy.

## Effects of Exchange Rate Shocks under the Non-Recursive Identification Restrictions

The results of using the non-recursive or overidentified VAR to investigate the effects of exchange rate appreciation shocks on key macro variables are presented in Figure 3.[6] In Figure 3, every variable in the system is shocked and the response for each variable to every shock in the system is generated. Since there are eight variables in the VAR, that would result in 64 panels for the impulse response functions. Careful understanding and interpretation need to be accorded to the results presented in Figure 3 in terms of where the shocks are originating and how the variables in the system are responding to the different shocks.

However, the main interest is in regard to how the shocks in exchange rates, oil prices, and monetary policy variables propagate to affect the real exports of agriculture and services. Therefore, we need to locate which panels in Figure 3 represent the position where the shocks to those three variables are originating. To locate the position where the shock originates is like reading the (x, y) coordinates of a graph, where one reads the x-coordinate first followed by the y-coordinate to locate a point on the graph. Since the exchange rate is the sixth variable in the VAR ordering, it implies that the panel that represents the origin of the exchange rate shock involves counting six panels across, starting at the top left corner of Figure 3, and then six panels down the column. The responses of all variables in the system to the exchange rate shock are located in the same column where the shock originates (that is, column 6 of Figure 3).

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[6] Note that the data on exchange rate are expressed as the inverse of U.S. dollar trade weighted exchange rate. Therefore, a positive innovation in the exchange rate signifies an appreciation in the U.S. dollar against a broad range of major trading partners' currencies weighted by the size of bilateral trade between the U.S. with each trading partner.

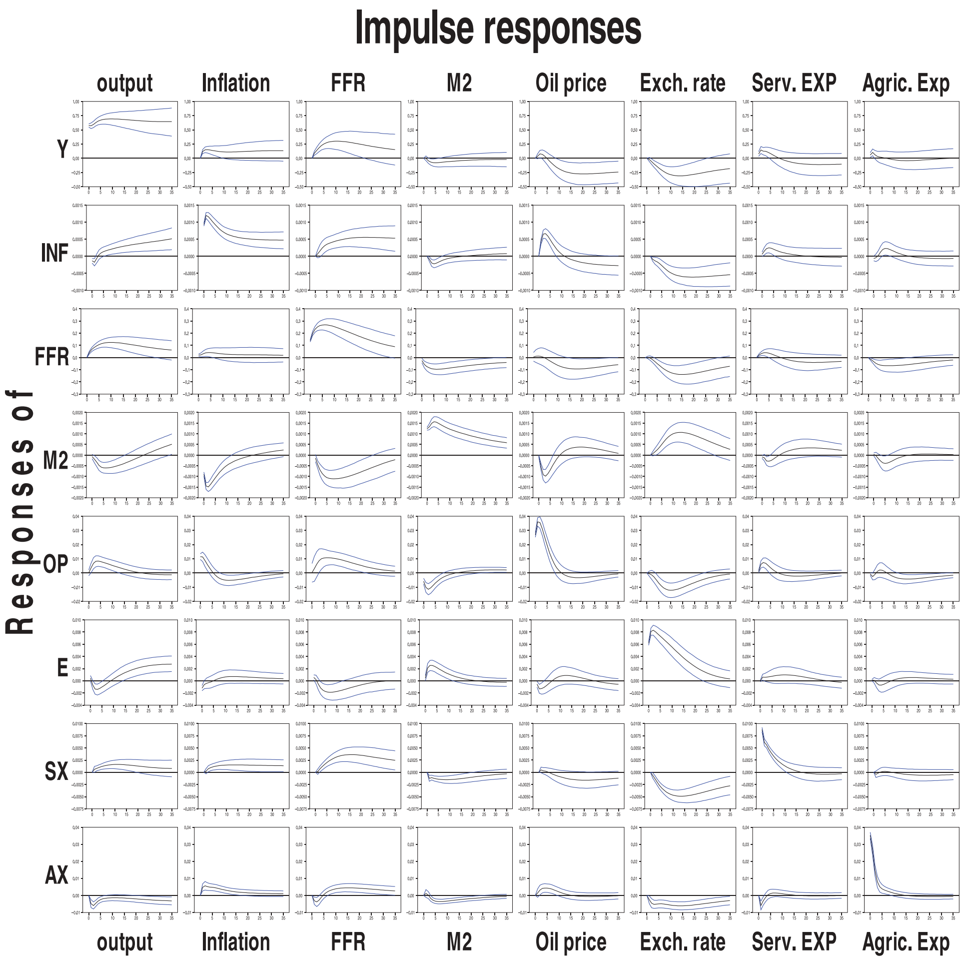


**FIGURE 3** Impulse responses to shocks in the model's endogenous variables with a broader money supply, M2.

The results indicate that an appreciation shock in the trade weighted exchange rate impacts negatively the exports of agriculture and services. Real domestic output subsequently falls. The shock impacts services more than agricultural exports, suggesting that the services sector is more sensitive to the trade weighted exchange rates relative to agricultural sector.[7] However, the shock also seems more persistent on services exports, indicating a slower recovery of services exports from such an impulse relative to agricultural

[7] All variables except the Federal funds rate are expressed in log differences (growth rates). However, one would get the initial impression that agricultural exports are impacted more following an exchange rate shock because of the scale differences. It is then shown using the variance decomposition that the exchange rate accounts for most of the variations in services forecast error variance in both the short- and long-term horizon than they do on agricultural exports.

exports. However, the impact of exchange rate in the two sectors, especially on agricultural exports, is quite small. This finding is important and consistent with what is observed in the two sectors.

## Impulse Responses

The small and statistically insignificant response of agricultural exports to the trade weighted exchange rate shock is expected for two main reasons. First, due to the long gestation period experienced within the agricultural sector relative to services sector, agricultural sector participants are unlikely to respond contemporaneously (within a period) to an exchange rate shock. Second, as the role of agriculture in the overall U.S. GDP diminishes over time, the elasticity of agricultural exports to any given change in international pricing, including exchange rate, decreases. Consequently, the response to the U.S. agricultural export demand by foreigners to any relative price or exchange rate shock is relatively small.

What about the movements in monetary variables following a trade weighted exchange rate shock? Figure 3 also indicates that there is a lag decrease in the interest rates and the money supply expands following an appreciation shock in the exchange. The results are consistent with a majority of models on exchange rates. The exchange rate appreciation shock also leads to a decline in the oil prices, and this result is expected because oil prices are designated in dollars. Because the Federal Reserve responds only with a lag to changes in the exchange rates, changes in the oil price could impact the overall prices in the economy.

## Effects of an Oil Price Shock

In Figure 3, the panel that represents the shock in oil prices is located by counting five panels across, beginning from the top left corner, followed by five panels down the column. The panel where the oil price shock originates indicates that a positive innovation in the real price of oil leads to an increase in inflation in the U.S. As inflation rises, the ensuing result is depreciation in the dollar relative to the currencies of major U.S. trading partners. There are two explanations for such a result. One possibility is that, since the U.S. is a net importer of oil, any surge in the oil price weakens the U.S. terms of trade with the rest of the world and lowers the trade weighted value of the dollar.

The second explanation is that the supply shock resulting from a surge in the oil price can potentially cause stagflation, leading to depreciation. Another important point worth noting from these results is that there is evidence of a two-way causality between the trade weighted value of the U.S. dollar and the oil price. An appreciation shock in the trade weighted exchange rate leads to a substantial decline in oil prices. On the other hand, a positive innovation in oil prices leads to depreciation in the dollar. This is not surprising because the price of oil is designated in dollars; an increase in oil prices implies more dollars are needed to buy an equivalent quantity of oil consumed previously. The result is that the supply of dollars must increase and this drives down its exchange value. The positive innovation in oil prices could potentially boost exports of services and agricultural products as the dollar depreciates with an oil price increase. However, as illustrated in Figure 3, this positive impact on services and agricultural exports following a positive innovation in oil prices is quite small and insignificant.

## The Impact of a Monetary Policy Shock

If one identifies monetary policy as a positive innovation in the money supply—M2, as indicated in Figure 3—the resulting impact is a reduction in the interest rate. Again, the result is consistent with the theory and there is no evidence of a liquidity puzzle. However, there is no statistically significant impact on sectoral exports, real output, and prices. Following a shock in the monetary aggregate, there is almost an immediate appreciation in the exchange rate and the problem of a delayed overshooting or forward discount bias puzzle is drastically resolved. The effect of a shock in monetary aggregate, *M*2, leads to a small but statistically insignificant effect on services and agricultural exports. When monetary policy is identified as a positive innovation in the federal funds rate, as illustrated in Figure 3, the proximate effect is a reduction in the money supply. Such a monetary contraction should also lead to almost an immediate increase in the price level if agents do interpret such a movement in the interest rate as a signal to higher future prices. However, the results in Figures 3 and 4 indicate that the increase in the federal funds rate leads to a price puzzle. The monetary contraction could have a greater effect on real activities if such movements in the interest rate cause changes in the exchange rates and the real interest rate in the same direction. However, the results regarding the response of output to a monetary contraction in Figure 3 is counterintuitive to theory. Output increases but begins to show signs of decline after 2-3 lags. Yet one would expect almost a lagged decline, not increase, in output due to a positive innovation in the federal funds rate. However, this output puzzle could arise because we are using monthly data on industrial production rather than quarterly data in which realistic GDP numbers are reported. Gordon and Leeper (1994) argue, in contrast to Bernanke and Blinder (1992), that the identification of monetary policy using the federal funds rate sometimes is at odd with the theory of monetary economics. One possibility could be that the Fed could have been reacting to the behavior of the private sector. Also, and more importantly, the U.S. economy grew at a much faster rate in the 1990s and inflation was almost at its lowest levels, comparable to conditions in the 1950s and 1960s, in that any attempt to slow down the economy through contractionary monetary policy would be attenuated due to longer inside and outside lags in the policy variables. Due to limitation in the dataset in some of the variables used in this article, my analysis only begins with monthly data from 1992 until 2009, a period when the U.S. macroeconomic performance had been fairly stable in terms of limited variability in output, employment, and consumer prices. It would be interesting to look at the behavior of monetary variables with a much longer time series that captures the periods of high volatility of the 1970s and the great moderation periods that began in the mid-1980s, and also check the results with quarterly data.

However, when monetary policy is identified with a shock in the federal funds rate with M1 instead of M2 as illustrated in Figure 4, the problem of longer lags of output response to a contractionary policy is drastically reduced. Output still rises somewhat, but falls significantly afterwards.

To check the robustness in all of the results, a seven-variable VAR was used in which the exports of services and agriculture enter one at a time while preserving our initial identifying restrictions. The results (not reported here) are consistent with the eight-variable VAR case regarding the impact of exchange rate and monetary policy shocks on sectoral exports. This implies that the choice of ordering of variables in the VAR plus the structural identifying restrictions imposed here are plausible.

How else can one explain the propagation mechanism of an exchange rate shock to services and agricultural exports? The analysis on the behavior of sectoral exports to an exchange rate shock is extended by considering the forecast error variance decomposition of services and agricultural exports. An analysis of this sort provides insights of the propagation mechanisms of exchange rate shocks to services and agricultural export sectors. This exercise is accomplished by examining the contribution of exchange rates and other endogenous variables in the system to the error variation for the sector in question at both short- and long-run forecast horizons.

Tables 1 and 2 present the variance decompositions of exports from services and agricultural sectors, respectively, for the recursive identification.[8] It is observed that the short-term total forecast error variance is greater in services export sector than it is under agricultural export sector. In period 1, the total forecast error variance is 91.98% for services exports in Table 1 and 89.29% for services exports in Table 2, of which the exchange rate accounts for 1.387 and 0.065%, respectively, for these variations.

By looking at the longer forecast horizons, such as in period 18, the total forecast error variance of service exports in Table 1 falls to 23.84%, of which exchange rate accounts for 37.444%. However, the total forecast error variance of agricultural exports in Table 2 also falls to 58.21% for a longer

[8] The forecast error decompositions of the two sectors were also generated with the non-recursive identification, and the results not indicated here are similar regarding the proportion of the forecast error variance of the two sectoral exports explained by exchange rates at both short and longer time horizons.

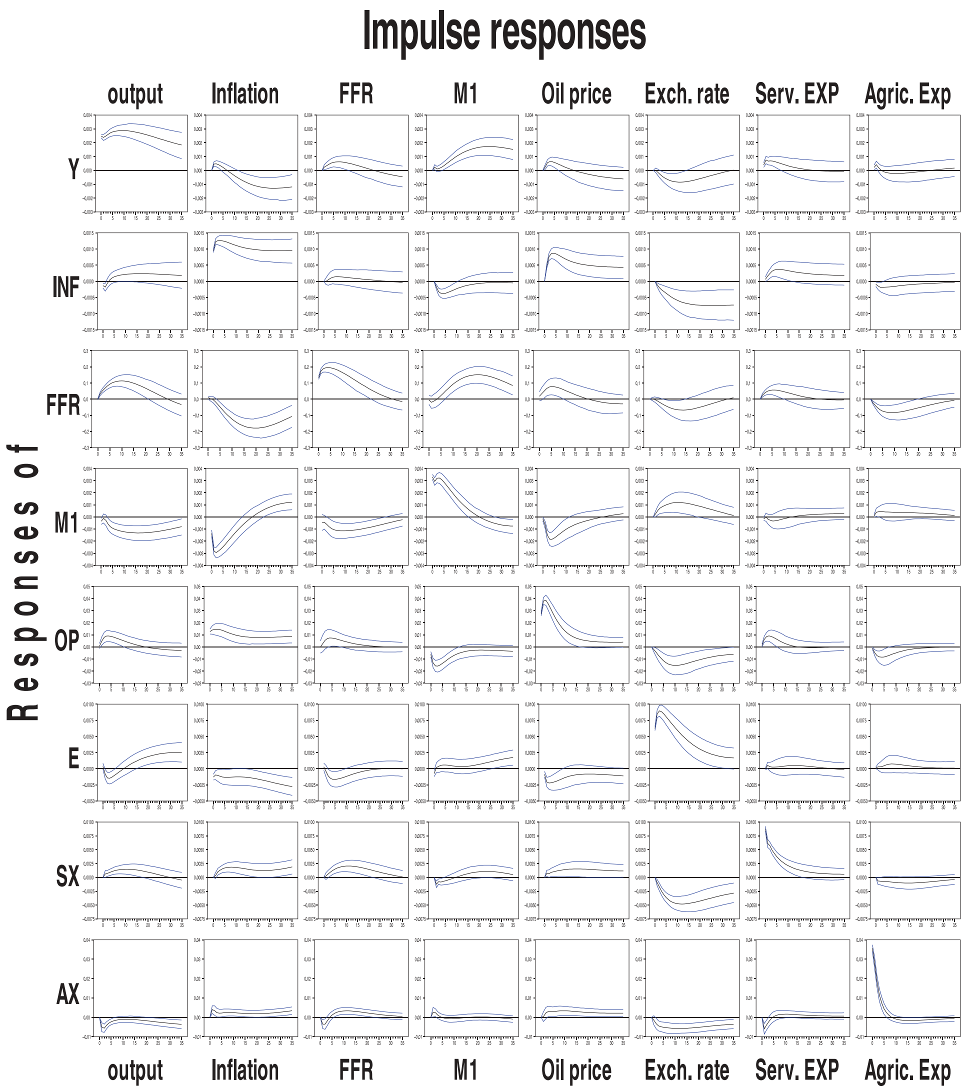


**FIGURE 4** Impulse responses to shocks in the model's endogenous variables with a narrower money aggregate, M1.

forecast horizon in period 18, of which the exchange rates account for only 14.598% for such variations. These results suggest that the exchange rate contribution to the forecast error variance is greater in the services export sector than it is in the agricultural export sector in the longer forecast horizons. Certainly, these results have implications on how exchange rate shocks impact the services sector more in the short term, and also persist more in the services sector at longer time horizons than they do in agricultural exports.

**TABLE 1** Variance Decomposition of Services Exports

| Year | Output | Inflation | Fed. Funds Rate | Money Supply | Oil Price | Exchange Rate | Services Exports | Agric. Exports |
|---|---|---|---|---|---|---|---|---|
| 1 | 2.959 | 0.399 | 0.004 | 2.769 | 0.501 | 1.387 | 91.981 | 0.000 |
| | (2.367) | (1.007) | (0.665) | (2.120) | (1.102) | (1.692) | (3.783) | (0.000) |
| 2 | 4.252 | 0.647 | 0.055 | 5.875 | 1.044 | 2.267 | 85.676 | 0.184 |
| | (3.148) | (1.410) | (0.820) | (3.317) | (1.619) | (2.240) | (5.092) | (0.653) |
| 3 | 5.340 | 1.314 | 0.532 | 6.683 | 1.139 | 3.991 | 80.791 | 0.211 |
| | (3.650) | (2.073) | (1.342) | (3.629) | (1.824) | (3.198) | (6.138) | (0.893) |
| 4 | 5.968 | 1.999 | 1.452 | 7.305 | 1.131 | 6.573 | 75.364 | 0.208 |
| | (3.934) | (2.630) | (2.105) | (3.844) | (1.917) | (4.286) | (7.069) | (1.140) |
| 5 | 6.421 | 2.624 | 2.775 | 7.662 | 1.033 | 9.767 | 69.508 | 0.210 |
| | (4.114) | (3.072) | (2.950) | (3.948) | (1.915) | (5.360) | (7.821) | (1.367) |
| 6 | 6.710 | 3.156 | 4.404 | 7.807 | 0.906 | 13.266 | 63.530 | 0.220 |
| | (4.232) | (3.431) | (3.808) | (3.976) | (1.877) | (6.340) | (8.391) | (1.548) |
| 7 | 6.860 | 3.587 | 6.214 | 7.790 | 0.798 | 16.791 | 57.721 | 0.241 |
| | (4.316) | (3.730) | (4.634) | (3.959) | (1.829) | (7.182) | (8.786) | (1.689) |
| 8 | 6.899 | 3.921 | 8.084 | 7.656 | 0.730 | 20.138 | 52.297 | 0.275 |
| | (4.382) | (3.979) | (5.403) | (3.915) | (1.836) | (7.874) | (9.020) | (1.807) |
| 9 | 6.860 | 4.168 | 9.922 | 7.446 | 0.709 | 23.188 | 47.385 | 0.322 |
| | (4.440) | (4.189) | (6.106) | (3.856) | (1.906) | (8.432) | (9.116) | (1.916) |
| 10 | 6.768 | 4.343 | 11.665 | 7.192 | 0.733 | 25.888 | 43.031 | 0.380 |
| | (4.494) | (4.366) | (6.744) | (3.789) | (2.038) | (8.884) | (9.108) | (2.026) |
| 11 | 6.645 | 4.460 | 13.276 | 6.915 | 0.794 | 28.236 | 39.228 | 0.446 |
| | (4.548) | (4.517) | (7.325) | (3.719) | (2.214) | (9.260) | (9.025) | (2.143) |
| 12 | 6.505 | 4.532 | 14.739 | 6.633 | 0.884 | 30.254 | 35.936 | 0.518 |
| | (4.601) | (4.647) | (7.855) | (3.648) | (2.420) | (9.582) | (8.895) | (2.267) |
| 13 | 6.359 | 4.571 | 16.051 | 6.355 | 0.997 | 31.976 | 33.099 | 0.592 |
| | (4.654) | (4.762) | (8.340) | (3.579) | (2.642) | (9.868) | (8.738) | (2.397) |
| 14 | 6.213 | 4.585 | 17.218 | 6.089 | 1.124 | 33.443 | 30.660 | 0.667 |
| | (4.705) | (4.865) | (8.785) | (3.512) | (2.870) | (10.131) | (8.568) | (2.530) |
| 15 | 6.072 | 4.582 | 18.250 | 5.836 | 1.262 | 34.692 | 28.563 | 0.742 |
| | (4.756) | (4.959) | (9.195) | (3.447) | (3.101) | (10.378) | (8.395) | (2.662) |
| 16 | 5.939 | 4.569 | 19.160 | 5.600 | 1.404 | 35.757 | 26.756 | 0.815 |
| | (4.806) | (5.047) | (9.573) | (3.385) | (3.329) | (10.613) | (8.226) | (2.792) |
| 17 | 5.816 | 4.548 | 19.961 | 5.381 | 1.548 | 36.666 | 25.197 | 0.885 |
| | (4.856) | (5.130) | (9.923) | (3.326) | (3.551) | (10.839) | (8.064) | (2.918) |
| 18 | 5.701 | 4.523 | 20.665 | 5.179 | 1.690 | 37.444 | 23.846 | 0.952 |
| | (4.906) | (5.210) | (10.248) | (3.270) | (3.766) | (11.058) | (7.914) | (3.039) |

*Note:* Standard errors are in parentheses.

Moreover, the analysis using the forecast error variance decomposition is consistent with the impulse responses of the two sectors following an exchange rate shock.

## VI. CONCLUSION

Past research on open economy suggests that there is a weak correlation between exchange rate fluctuations and aggregate exports. The shortcoming

**TABLE 2** Variance Decomposition of Agricultural Exports

| Year | Output | Inflation | Fed. Funds Rate | Money Supply | Oil Price | Exchange Rate | Services Exports | Agric. Exports |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.857 | 0.167 | 0.466 | 0.435 | 0.065 | 0.641 | 7.073 | 89.296 |
| | (1.930) | (0.772) | (1.048) | (0.979) | (0.791) | (1.212) | (3.186) | (4.099) |
| 2 | 1.336 | 0.685 | 1.514 | 0.274 | 0.046 | 1.407 | 4.569 | 90.169 |
| | (1.296) | (1.058) | (1.897) | (0.954) | (0.998) | (1.811) | (2.445) | (3.872) |
| 3 | 1.580 | 1.666 | 2.299 | 0.242 | 0.294 | 2.781 | 3.974 | 87.164 |
| | (1.436) | (1.926) | (2.680) | (1.023) | (1.331) | (2.627) | (2.318) | (4.727) |
| 4 | 1.689 | 2.587 | 2.527 | 0.390 | 0.790 | 4.170 | 3.767 | 84.079 |
| | (1.573) | (2.524) | (3.037) | (1.126) | (1.748) | (3.246) | (2.308) | (5.453) |
| 5 | 1.696 | 3.507 | 2.449 | 0.721 | 1.338 | 5.308 | 3.691 | 81.289 |
| | (1.633) | (2.938) | (3.060) | (1.280) | (2.174) | (3.682) | (2.353) | (5.922) |
| 6 | 1.678 | 4.417 | 2.382 | 1.151 | 1.861 | 6.218 | 3.656 | 78.636 |
| | (1.671) | (3.264) | (2.932) | (1.462) | (2.585) | (4.029) | (2.425) | (6.253) |
| 7 | 1.657 | 5.245 | 2.462 | 1.604 | 2.311 | 6.993 | 3.629 | 76.099 |
| | (1.705) | (3.536) | (2.789) | (1.645) | (2.962) | (4.348) | (2.505) | (6.522) |
| 8 | 1.636 | 5.937 | 2.708 | 2.027 | 2.652 | 7.712 | 3.598 | 73.730 |
| | (1.742) | (3.766) | (2.720) | (1.809) | (3.286) | (4.662) | (2.584) | (6.756) |
| 9 | 1.619 | 6.477 | 3.097 | 2.396 | 2.875 | 8.419 | 3.561 | 71.556 |
| | (1.783) | (3.956) | (2.770) | (1.947) | (3.544) | (4.979) | (2.654) | (6.964) |
| 10 | 1.608 | 6.876 | 3.595 | 2.701 | 2.994 | 9.135 | 3.517 | 69.574 |
| | (1.828) | (4.110) | (2.942) | (2.058) | (3.736) | (5.297) | (2.714) | (7.152) |
| 11 | 1.602 | 7.157 | 4.171 | 2.945 | 3.033 | 9.864 | 3.467 | 67.761 |
| | (1.879) | (4.233) | (3.213) | (2.146) | (3.871) | (5.612) | (2.762) | (7.328) |
| 12 | 1.602 | 7.343 | 4.798 | 3.135 | 3.019 | 10.601 | 3.413 | 66.090 |
| | (1.934) | (4.330) | (3.547) | (2.215) | (3.957) | (5.919) | (2.801) | (7.496) |
| 13 | 1.608 | 7.455 | 5.454 | 3.279 | 2.976 | 11.333 | 3.355 | 64.539 |
| | (1.994) | (4.405) | (3.916) | (2.269) | (4.008) | (6.215) | (2.831) | (7.657) |
| 14 | 1.620 | 7.513 | 6.122 | 3.385 | 2.918 | 12.050 | 3.296 | 63.094 |
| | (2.057) | (4.462) | (4.298) | (2.310) | (4.031) | (6.497) | (2.855) | (7.815) |
| 15 | 1.638 | 7.530 | 6.788 | 3.463 | 2.857 | 12.741 | 3.238 | 61.745 |
| | (2.124) | (4.504) | (4.677) | (2.343) | 4.035) | (6.763) | (2.875) | (7.969) |
| 16 | 1.661 | 7.518 | 7.441 | 3.516 | 2.799 | 13.400 | 3.180 | 60.485 |
| | (2.193) | (4.536) | (5.046) | (2.368) | (4.027) | (7.013) | (2.892) | (8.120) |
| 17 | 1.688 | 7.486 | 8.074 | 3.552 | 2.745 | 14.019 | 3.125 | 59.310 |
| | (2.265) | (4.559) | (5.399) | (2.389) | (4.011) | (7.246) | (2.909) | (8.266) |
| 18 | 1.720 | 7.440 | 8.681 | 3.573 | 2.699 | 14.598 | 3.072 | 58.216 |
| | (2.340) | (4.575) | (5.733) | (2.405) | (3.990) | (7.463) | (2.925) | (8.408) |

*Note:* Standard errors are in parentheses.

of using aggregate exports rather than sectoral exports is that one is unable to account for the fact that different industries or sectors behave differently following an exchange rate shock. In this article, I move down a level in disaggregation of U.S. aggregate exports to investigate the dynamic simultaneous responses of services and agricultural exports following a shock in the exchange rate. Under alternative identifying structures, the VAR analysis in this study offers a novel contribution regarding the differences in the dynamic simultaneous responses of U.S. services and agricultural exports to a dollar trade weighted exchange rate shock. The analysis leads to the following conclusions. First, in moving down a level of disaggregation in aggregate exports, the impact of exchange rate shocks on services and agricultural exports is quite small. Second, the shocks tend to impact and persist more in services exports than they do in agricultural exports. I hope that the findings in this article will open more platforms for discussion in the literature regarding exchange rate pass-through mechanisms on sectoral exports.

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