The Impact of Domestic and Foreign Macroeconomic Variables on U.S. Meat Exports

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This paper examines the impact of domestic and foreign macroeconomic variables on U.S. meat exports, including beef, pork, turkey, and chicken, in the context of an open economy. The results show that foreign macroeconomic variables exert more significant and persistent effects on U.S. meat exports than domestic macroeconomic variables. The implication is that the U.S. can increase its meat exports more effectively by expending efforts on international macroeconomic policy coordination rather than on domestic sectoral policy. The results also suggest that macroeconomic models of the agricultural sector should include foreign variables and should not be limited only to domestic ones.

With ever-expanding international trade, the national economies of the world and their related sectors have become closely intertwined. U.S. agriculture presents no exception; its financial health, growth prospects, and employment are strongly linked to levels of imports and exports, which depend on the macroeconomic performances of both the U.S. and other trading nations. The importance of examining the agricultural sector within the context of an open macro economy was first pointed out by Schuh, who investigated the impact of exchange rates on U.S. farm prices. Subsequently, Chambers and Just developed a structural econometric model for the U.S. crop subsector and found significant exchange rate impacts on crop exports. Barnett, Bessler, and Thompson constructed a reduced-form vector autoregression (VAR) model and identified a Granger-type causal relationship between the U.S. money supply and agricultural prices. In a more elaborate VAR framework, Orden and Bradshaw and Orden studied relationships among the money supply, exchange rates, agricultural prices, and crop exports.

This paper analyzes the dynamic impact of domestic and foreign macroeconomic variables on U.S. meat exports, with special reference to the effects of monetary policy and exchange rate movements. Growth in meat exports represents expansion in an important value-added market for U.S. agriculture. The value of livestock and poultry exports made up about 15 percent of all U.S. agricultural exports in 1989, and was 59 percent larger compared to 1980 (Wisner and Wang). With high-income countries such as Japan, South Korea, and Taiwan significantly easing their import restrictions on meat products, further expansion in this area is very likely.

While previous research has investigated the impact of macroeconomic variables on the U.S. agricultural sector and in some cases on the crop subsector, this study focuses exclusively on U.S. meat exports. An understanding of macroeconomic effects on meat exports could facilitate economic forecasting and policy analysis within the meat subsector. This paper also addresses the potential bias that might result from the modelling strategy of previous work, which assumed that the simple inclusion of exchange rates could capture all the linkages to the foreign sector. For example, if foreign macroeconomic variables are important to the U.S. agricultural sector, their exclusion from the model simulation would result in inflated impacts of the included domestic macroeconomic and exchange rate variables. The model estimated in this paper includes a set of foreign macroeconomic variables such as aggregate output and price levels. Our results show that not only are foreign macroeconomic variables important but, in most cases, they exert more influence on U.S. meat exports than their U.S. counterparts.

The approach taken in this study is VAR. The VAR approach has become quite popular among

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researchers interested in sorting out the dynamic relationship between macroeconomic and agricultural variables interacting in a rather complicated open economy. Developed by Sims (1980), the VAR approach estimates reduced-form equations with the same set of lagged dependent variables, which can be viewed as a flexible approximation to the reduced form of a correctly specified but unknown dynamic structure. Hence, it represents a reconciliation to our lack of precise knowledge on how the variables interact over time. In estimating the VAR model, this study adopts the recently developed "error correction" method to account for cointegrations which typically occur among economic time series. When variables are cointegrated, conventional VAR models result in either biased or inefficient estimates (Engle and Granger). This is because, while capable of capturing the short-term dynamics of a system, the conventional VAR model ignores the long-term equilibrium relationship among variables implied by the cointegration.

In the next section, an open economy macro sector is first presented, from which the macro VAR model is derived. Following a discussion of the meat VAR model, the data is described and the estimations are presented. Finally, the policy simulation results are discussed.

The Open Macro Economy

The macro sector is composed of three markets: the goods market, the foreign-exchange market, and the money market. The goods market includes the demand, supply, and equilibrium condition of goods and services. The demand for goods and services of the home country (the U.S.) is specified as consisting of two parts: domestic absorption and current account. For given levels of government expenditure (G) and taxes (T), domestic absorption (da) is specified as a function of real output (y) and the interest rate (r), as they affect consumption and investment.[1] That is

$$da = da\,(y,\, r \mid G,\, T). \tag{1}$$

The current account (ca) measures the country's net exports of goods and services and is specified as a function of the relative price level (ep*/p) and real outputs (y and y*) of the domestic and foreign countries, given the tax levels (T and T*). Here, the foreign country is taken as the G6, including Canada, France, Germany, Japan, Italy, and the United Kingdom. The exchange rate (e) is measured in terms of number of dollars per unit of foreign currency and is trade-weighted. Thus:

$$ca = ca\,(ep^*/p,\, y,\, y^* \mid T,\, T^*). \tag{2}$$

The inverse supply of goods and services for the home country is specified as

$$p = p\,(y,\, m \mid PO). \tag{3}$$

Here, the nominal price (p) is expressed as a function of real output (y) and the nominal money supply (m), given the price of oil (PO). Real output captures the impact on price of the real sector, while the money supply captures the impact of the monetary sector. The price of oil is included as a proxy for production costs and is treated as exogenous to the model.

At the equilibrium, supply equals demand:

$$y = da + ca. \tag{4}$$

Given the exogenous variables (G, T, T*, and PO) and foreign endogenous variables (p* and y*), equations (1) through (4) can be used to solve for the domestic price and quantities (p, da, ca, and y), if the exchange rate (e) and interest rate (r) can also be determined. This leads us to the specification of the foreign-exchange market and money market.

The foreign-exchange market is in equilibrium when deposits of home and foreign currencies offer the same expected rate of return. The expected rate of return on home deposits is simply the home interest rate, while that on foreign deposits is the sum of the foreign interest rate (r*) and expected rate of home currency depreciation (as the foreign investments have to be repatriated eventually). The equilibrium condition can be written as

$$r = r^* + (e^e - e)/e, \tag{5}$$

where e^e is the expected exchange rate and is proxied by a trade-weighted futures rate.[2] To account for the simultaneous determination of the spot and future rates, the expected exchange rate is treated as endogenous and specified as a function of the spot rate:

$$e^e = e^e\,(e). \tag{6}$$

The money market is in equilibrium when the

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[1] Specifically, domestic absorption includes consumption, investment, and government purchases. Consumption is a function of disposable income which, in turn, depends on real output and taxes. Investment is specified as a function of real output and interest rate. To limit the scope of the problem, government expenditure and tax are treated as exogenous.

[2] The arbitrage equation in (5) is often referred to as the "interest rate parity" condition.

money supply set by the central bank equals the aggregate money demand:

$$(7) \qquad m/p = l(r, y),$$

where m/p is the real money supply and l is the real money demand expressed as a function of interest rate and real output. Following Blanchard and Watson, money supply is specified as a function of real output and price, as the monetary authority is assumed to target the levels of the two variables by adjusting its supply of money. Accordingly,

$$(8) \qquad m = m(y, p).$$

Equations (1) through (8) describe the domestic macro economy. The model is consistent with the basic spirit of the mainstream exchange rate determination models, such as Dornbusch's overshooting and Mussa's monetary approach models. The foreign variables (except T*) appearing in the above equations are also treated as endogenous. However, rather than modeling the foreign economy explicitly, each of the foreign variables is simply specified as a function of domestic macroeconomic variables and the exchange rate, because shocks in the macro sector are more or less correlated across countries (Blanchard and Watson).[3]

With the required substitutions, a nine equation system emerges (see Appendix A). This structure facilitates the choice of variables to be included in the empirical macro VAR model.[4] The nine endogenous macro variables are: domestic and foreign outputs, prices, and money supplies, as well as the exchange rate variables (i.e., da, ca, y*, P, P*, m, m*, e, and e^e). In addition to the lagged values of the nine endogenous variables, the preceding theoretical discussion also suggests that the macro VAR model include as explanatory factors the following exogenous variables: G, T, T*, and PO. Additionally, to account for seasonality in the data, three quarterly dummy variables are included.

The Meat Model

Turning to the meat export model, both export volumes and prices are considered. There are eight endogenous variables in the meat VAR model: export volumes of beef, pork, turkey, and chicken (EBEEF, EPORK, ETURK, and ECHIC, respectively), and their retail prices (PBEEF, PPORK, PTURK, and PCHIC, respectively). As far as meat exports are concerned, it would be preferable to consider export prices, rather than domestic retail prices. However, data limitations preclude this specification.

To account for seasonality, the meat VAR model also contains three seasonal dummy variables. Further, to capture the impact of the macro sector, the nine endogenous macro variables are included in each of the eight meat VAR equations as explanatory factors. However, based on previous research findings that agricultural variables exert little influence on the macro sector (Barnett et al.; Robertson and Orden; and Saunders), a recursive structure in which the meat model follows the macro model is assumed. Notice that, given this simplifying assumption, the macro VAR model does not contain the meat variables and can be estimated without any regard to the meat model. A detailed technical discussion on the two models and the overall combined model can be found in Appendix A [the macro VAR and meat VAR models are presented in (A7) and (A9), respectively, while the overall model is presented in (A10).]

The Data

Quarterly data on the macroeconomic variables and meat variables for the period 1971:1 through 1988:4 are used in the estimation. With the exception of the current account balance, all variables are transformed to natural logs before estimation. Since the current account variable contains both positive and negative values, it is not transformed. Most of the macro data come from the Economic Report of the President (ERP) and Main Economic Indicators (MEI). Data for all the meat variables come from the Livestock and Poultry Situation and Outlook Report. For a detailed discussion on data sources, data compilations, and treatments of occasional missing data, see Liu et al.

Nominal domestic price (p) is the CPI for all items and nominal domestic money supply (m) is the M1, both reported in MEI. Real domestic absorption (da), current account (ca), government expenditures (G), and tax (T) are taken from ERP. The spot nominal exchange rate (e) is the trade-weighted nominal exchange rate reported in ERP. Nominal foreign price (p*) is computed by the definition $q \equiv ep^*/p$, where q is the trade-weighted real exchange rate reported in ERP. Real foreign

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[3] The data requirements would be unyielding if the foreign economy were modeled explicitly because it includes several other major trading nations.

[4] The structure is also used in policy simulation to orthogonalize the contemporaneously correlated variance-covariance matrix of residuals in the macro VAR model (Blanchard and Watson, Orden and Fackler, and Sims, 1986). A detailed discussion on the orthogonalization procedure can be found in Appendix A.

Table 1. Dickey and Fuller Unit Root Test[a]

Macro Variables	One-Lag Model		Four-Lag Model		Meat Variables	One-Lag Model		Four-Lag Model	
	τ_μ	τ_τ	τ_μ	τ_τ		τ_μ	τ_τ	τ_μ	τ_τ
da	−0.41	−2.16	−0.24	−3.02	EBEEF	−0.33	−3.27	−0.40	−3.33
ca	−1.00	−1.77	−1.28	−2.39	EPORK	−2.75	−2.86	−2.68	−2.95
p	−1.49	−0.94	−1.86	−1.73	ETURK	−4.44#	−4.51#	−2.43	−2.67
m	1.11	−1.73	0.81	−2.02	ECHIC	−5.79#	−7.16#	−2.02	−2.57
y*	−0.96	−1.36	−1.61	−2.10					
p*	−0.90	−1.10	−1.19	−2.86	PBEEF	−1.82	−1.66	−1.51	−2.04
m*	−0.90	−1.96	−0.56	−2.43	PPORK	−2.71	−3.07	−2.55	−2.62
e	−1.73	−1.74	−2.23	−2.19	PTURK	−2.25	−3.43	−2.34	−2.87
e^e	−2.06	−2.21	−1.97	−2.16	PCHIC	−2.00	−3.57#	−2.30	−3.85#

[a] Numbers for τ_μ are t-statistics on β_0 in the regression $\Delta x_t = \alpha + \beta_0 x_{t-1} + \Sigma_{j=1}^{K} \beta_j \Delta x_{t-j}$. Numbers for τ_τ are t-statistics on β_0 in the regression $\Delta x_t = \alpha_0 + \alpha_1 t + \beta_0 x_{t-1} + \Sigma_{j=1}^{K} \beta_j \Delta x_{t-j}$. Superscript # indicates rejection of the null hypothesis of unit root at the 5% level. The number of usable observations in the estimation was 70. For the sample size of 50, 1%, 5%, and 10% critical values are 3.58, 2.93, and 2.60 for the τ_μ test and 4.15, 3.50, and 3.18 for the τ_τ test. For the sample size of 100, the corresponding critical values are 3.51, 2.89, and 2.58 for the τ_μ test and 4.04, 3.45, and 3.15 for the τ_τ test.

output (y*) accounts for the output of the G6, with data for individual countries taken from MEI. Real foreign tax (T*) accounts for the tax of the G6, with data for individual countries mainly taken from International Financial Statistics. In the compilation of the above two aggregate series, variables for individual countries are deflated by their own CPI's and, before summing up, converted to U.S. dollars through multiplying appropriate spot exchange rates. (The individual country's CPI and exchange rate are taken from MEI.) Nominal foreign money supply (m*) is arrived at by aggregating individual M1's of the G6 taken from MEI. The aggregation involves converting an individual country's M1 to U.S. dollars and then summing up. The expected exchange rate (e^e) is proxied by a trade-weighted one-quarter-ahead futures rate. Due to data limitations, this compilation includes only the US-UK rate, US-Japan rate, and US-Germany rate. Data for the three currency futures are taken from the Wall Street Journal and are weighted by the trade volumes of the three countries as reported in MEI. Finally, the price of oil (PO) is taken from the CRB Commodity Year Book.

Estimation

Since the correct specification of a VAR model depends on whether the variables involved are stationary or not, the Dickey and Fuller unit root test was first conducted for each individual series. Table 1 presents the results. Tests are conducted against two common alternatives: one consistent with fluctuations around a constant mean (τ_μ test), the other with stationary fluctuations around a deterministic linear trend (τ_τ test). Both tests entertain a one lag difference and four lag differences to account for serial correlation in the error term. The hypothesis of a unit root is not rejected for any of the nine endogenous macro variables. As for the meat variables, unit root is rejected only for turkey exports, chicken exports, and chicken price. However, the rejection of unit root for turkey and chicken exports occurs only under the one-lag specification, while that for chicken price occurs only under the τ_τ test. Accordingly, all the variables are taken as nonstationary and their first differences are used in the subsequent estimation.

As pointed out by Engle and Granger, even though individual economic time series are not sta-

Table 2. Likelihood Ratio Test on VAR Lag Length

lag.[a] (n vs. n+1)	Macro VAR		Meat VAR	
	Likelihood Ratio	p-Value	Likelihood Ratio	p-Value
1 vs. 2	153	0.00#	80	0.09#
2 vs. 3	86	0.33	64	0.48
3 vs. 4	102	0.05#	83	0.08#
4 vs. 5	87	0.30	69	0.30

[a] Reject the null hypothesis that the coefficients for lag n + 1 are zero at the α% significance level if the p-value for the test statistic is less than α. Superscript # indicates rejection of the null hypothesis of zero coefficients for lag n + 1 at the 10% significance level.

Table 3. Johansen Cointegration Test

	Macro Model			Meat Model		5% Critical Value	
H_0	Trace[a]	λ max[b]	H_0	Trace[a]	λ max[b]	Trace[c]	λ max[c]
$r \le 8$	1.51	1.51	$r \le 7$	0.02	0.02	8.18	8.18
$r \le 7$	7.81	6.30	$r \le 6$	5.22	5.20	17.96	14.90
$r \le 6$	21.52	13.71	$r \le 5$	16.70	11.48	31.53	21.07
$r \le 5$	47.22	25.71	$r \le 4$	$51.31^{\#}$	$34.61^{\#}$	48.28	27.14
$r \le 4$	$82.97^{\#}$	$35.75^{\#}$	$r \le 3$	$94.30^{\#}$	$42.99^{\#}$	70.60	33.32
$r \le 3$	$129.42^{\#}$	$46.45^{\#}$	$r \le 2$	$148.52^{\#}$	$54.21^{\#}$	95.18	39.43
$r \le 2$	$201.32^{\#}$	$71.89^{\#}$	$r \le 1$	$232.67^{\#}$	$84.16^{\#}$	124.25	44.91
$r \le 1$	$290.53^{\#}$	$89.21^{\#}$	$r = 0$	$341.97^{\#}$	$109.30^{\#}$	157.11	51.07
$r = 0$	$427.59^{\#}$	$137.06^{\#}$				192.84	57.00

[a] Superscript # indicates rejection at the 5% level of the null hypothesis of at most r stationary linear combinations of the series against the alternative of possible stationarity of all series.
[b] Superscript # indicates rejection at the 5% level of the null hypothesis of at most r stationary linear combinations of the series against the alternative of at most r + 1 such combinations.
[c] Critical values are from Osterwald-Lenum.

tionary, linear combinations of them can be, because equilibrium forces tend to keep such series together in the long run. When this happens the variables are said to be cointegrated, and some error correction terms have to be included in the conventional first-differenced VAR model to account for short-term deviations from the long-run equilibrium relationship implied by the cointegration. Before moving on to the testing of cointegration, the order of the VAR model has to be determined. The selection criterion used in this study is the likelihood ratio test developed by Sims (1980). Based on the test statistics presented in Table 2, a fourth-order specification is chosen for both the macro and meat VAR models.

In testing for cointegration and estimating the error corrected VAR model (EC-VAR), the maximum likelihood procedure developed in Johansen is adopted. Results from the cointegration test are presented in Table 3. Johansen's trace and λ_{max} tests indicate that there are five cointegrating relationships for the nine endogenous macro variables and for the eight endogenous meat variables. Thus, five error correction terms are constructed and included in the maximum likelihood estimation of the macro EC-VAR model. Similarly, another five error correction terms are included in the meat EC-VAR model.

Detailed results on the estimated equations are reported in Liu et al. Diagnostic test statistics for the estimated macro and meat EC-VAR models are presented in Table 4. The reported $\bar{R}^2$ are not unreasonable, given that all the variables are first differenced. The low mean absolute percentage in-sample forecasting errors reported in the table indicate that the equations fit the data well. Further, Ljung-Box Q statistics indicate that the estimated equations are free from serial correlation problems, except for the exchange rate equation. The null hypothesis of no serial correlation is rejected for the exchange rate equation at the 5% significance level, but not at the 1% level. Additionally, heteroscedasticity does not appear to be a problem for any of the equations.[5] However, the result of the Jarque-Bera normality tests indicate that the estimated residuals are not normal in any but one of the equations.[6]

Policy Simulations

The estimated macro and meat EC-VAR models are used to investigate the dynamic impacts of domestic and foreign macroeconomic variables on U.S. meat exports. Forecast error variance decomposition is conducted over a thirty-quarter period to assess the extent to which endogenous macro variables affect meat exports over time. The procedure involves decomposing the forecasting error variance of each of the meat export variables into the part due to each of the shocks in the system (Doan). If the movement of an endogenous macroeconomic variable is important to the meat export variable in question, shocks in the equation pertaining to that macroeconomic variable should

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[5] Each residual series were split into three parts and the variances associated with the first and third parts computed and compared. This procedure is similar to the Goldfeld-Quandt test.

[6] A more detailed examination of the Jarque-Bera statistics indicates that the nonnormality result is in large part due to low values for the Kurtosis coefficients; skewness does not appear to be the problem. Clearly, in examining the subsequent policy simulation results, one should bear in mind this estimation drawback.

Table 4. Diagnostic Tests for the Macro and Meat EC-VAR Models

Equation[a]	$\bar{R}^2$	Mean Absolute[b] Percentage Error (%)	Ljung-Box[c] Q-Statistic	Jarque-Bera[d] Normality Test
Domestic Absorption (da)	0.67	0.10	16.62	15.46
U.S. Current Account (ca)	0.42	6.44	19.47	14.05
Domestic Price (p)	0.81	0.28	19.08	11.20
Domestic Money Supply (m)	0.78	0.19	13.14	8.95
Foreign Output (y*)	0.52	0.49	21.91	14.46
Foreign Price (p*)	0.38	0.09	24.26	7.04
Foreign Money Supply (m*)	0.45	1.40	22.16	14.37
Exchange Rate (e)	0.60	1.10	32.42	15.17
Exchange Rate Expectation (e^e)	0.93	0.37	14.99	13.25
Beef Exports	0.30	0.11	16.12	13.19
Pork Exports	0.70	6.38	26.21	21.44
Turkey Exports	0.64	3.89	20.49	15.07
Chicken Exports	0.73	0.58	18.57	9.55
Beef Price	0.38	0.73	20.82	15.22
Pork Price	0.36	1.81	10.77	11.38
Turkey Price	0.70	1.62	19.39	13.50
Chicken Price	0.36	1.70	14.66	9.62

[a] All the equations are estimated in first differences.

[b] Based on dynamic in-sample-forecasts with forecasting period ranging from 1972:2 through 1988:4.

[c] Ljung-Box Q-statistic is distributed as χ^2 (17). The null hypothesis of no serial correlation is rejected at the 5% significance level if the Q-statistic is larger than 30.19.

[d] Jarque-Bera statistic is distributed as χ^2 (2). The null hypothesis of normality is rejected at the 5% significance level if the test statistic is larger than 7.38.

account for a large proportion of the unexpected variation in the meat variable.[7]

Table 5 presents the results of the decomposition of the meat export variables.[8] Columns 1 and 2 report the percentages of the unexpected variations in each of the four meat export variables contributed by a shock in domestic and foreign money supply equations, respectively. Column 3 sums up the percentages of the unexpected variations contributed by shocks in domestic output and price (da, ca, and p). Similarly, column 4 contains the contribution made jointly by shocks in foreign output and price (y* and p*). Results pertaining to the exchange rate shock are in Column 5. The impacts of shocks in the meat variables on meat exports are reported in columns 6 through 9.[9]

The first column of Table 5 indicates that domestic money supply shock exerts a very insignificant impact on all four meat export variables. For example, it accounts for only 1.10% of the unexpected beef export variation in the first period and explains, on average, only 0.55% of the variations over the thirty simulated periods. Though the domestic money effect is trivial, the impact of foreign money supply shock is very significant for all the meat export variables except beef. Column 2 indicates that foreign money supply shock, on average, accounts for 8.62%, 26.97%, 32.31%, and 27.37%, respectively, of the unexpected variations in beef, pork, turkey and chicken exports.

Given the results of earlier studies (Orden, Lapp), it is not too surprising that the domestic money effect on the agricultural variables is weak. However, it is not clear why the foreign money supply shock would exert more influence on U.S. meat exports than the domestic money shock. In a related vein, why would these foreign variable shocks impact pork, turkey and chicken exports more than beef? Insights on the first issue may come from distinguishing between the price and income effects of the money supply shock. A shock in the foreign money supply results in a

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[7] As pointed out by a reviewer, the terminology "shock" should be interpreted with caution. This is because the structural equations developed in this paper are, in fact, what might be called quasi-reduced form equations and, hence, their error terms cannot be clearly identified as being behavioral shocks of specific agents. For example, (5) is not a behavioral equation of a specific agent. Rather, it is the equilibrium condition being played out by various types of agents involved in the foreign-exchange market. Hence, each shock in the system should be interpreted as an innovation to a specific VAR equation, rather than to a specific endogenous variable. That is, it reflects the error left unexplained by the equation.

[8] See Liu et al. for results of the decomposition of meat price variables.

[9] For conciseness, the percentage of the unexpected variations in meat exports contributed by shock in the exchange rate expectation is not reported in the table. Percentages of the contribution made by all shocks in the system add up to 100.

Table 5. Decomposition of Forecast Error Variances: Meat Exports (in Percentage)

Step-ahead	Domestic Money Supply (m)	Foreign Money Supply (m*)	Domestic Output & Price (da,ca,p)	Foreign Output & Price (y*,p*)	Exchange Rate (e)	Own Meat Exports	Own Meat Price	Other Meat Exports	Other Meat Prices
On Beef Exports:									
1	1.10	0.03	18.10	0.29	4.82	66.79	0.00	0.00	0.00
4	0.48	5.30	18.14	8.25	6.09	43.11	1.05	6.77	6.39
8	0.32	7.17	15.50	8.46	3.94	46.82	1.21	6.49	6.24
12	0.35	9.51	13.83	11.37	3.75	42.72	1.79	6.01	6.04
24	0.64	10.81	9.86	11.93	4.14	42.30	1.48	6.86	5.54
average[a]	0.55	8.62	13.02	10.37	4.16	44.42	1.33	5.96	5.85
On Pork Exports:									
1	0.18	0.33	26.53	18.66	1.57	46.62	0.00	4.20	0.00
4	0.50	18.85	17.14	9.40	16.75	12.71	7.13	6.76	7.17
8	0.75	28.82	11.40	24.24	12.03	5.06	4.64	7.05	4.38
12	1.24	30.63	7.50	25.47	11.31	3.65	5.09	9.65	3.60
24	1.38	29.30	6.55	23.03	10.08	3.85	3.93	15.23	3.35
average[a]	1.10	26.97	9.39	21.93	10.98	7.40	4.41	11.74	3.59
On Turkey Exports:									
1	0.08	42.77	8.09	10.67	19.49	18.29	0.00	0.54	0.00
4	0.27	32.81	7.43	15.47	14.26	14.96	1.15	4.93	8.30
8	0.74	32.56	6.84	21.36	12.33	9.40	0.97	6.40	7.75
12	0.79	33.40	6.69	21.83	11.90	7.63	0.88	7.72	7.25
24	0.78	29.71	7.41	21.10	10.24	6.96	1.82	11.62	6.73
average[a]	0.68	32.31	7.12	20.12	11.87	9.00	1.30	8.53	6.80
On Chicken Exports:									
1	0.24	0.30	12.53	12.34	0.80	69.47	0.00	4.28	0.00
4	0.21	15.38	7.31	25.11	4.17	28.23	2.98	9.56	4.66
8	0.54	30.26	5.67	27.77	8.08	10.95	1.32	7.79	6.01
12	0.94	31.12	5.22	28.32	8.46	8.44	1.40	9.01	5.79
24	1.19	31.13	6.03	26.94	8.87	6.85	1.26	10.83	5.44
average[a]	0.87	27.37	6.42	26.67	7.72	13.35	1.40	9.44	5.20

[a] average over 30 periods.

change in the foreign interest rate which, in turn, affects both the exchange rate and foreign output. Accordingly, foreign money supply shocks affect not only the price that foreign buyers have to pay for U.S. meat products, but also their ability to pay. On the other hand, the only direct consequence of a domestic money supply shock on the foreign excess demand for U.S. meat products is due to a price effect induced by the exchange rate change.

The differential impact of the foreign money supply shock on U.S. beef exports versus other meat exports may be explained partially by the Japanese beef import restrictions. Prior to recent liberalizations, beef imports in Japan have been restricted through a complex framework of quotas (Khan et al.). Since Japan accounts for nearly three-fourths of all U.S. beef exports (Wisner and Wang), its rigid quotas must have left little room for U.S. beef exports to react to most shocks in the system. Further evidence on this point is that the only shock that is important to U.S. beef exports is the one pertaining to the export variable itself (Column 6, Table 5). Effects of the beef export shock are persistent and, on average, account for 44.42% of the unexpected variations in beef exports. On the other hand, while important in the first period or two, the effects of other own meat export shocks on their respective export variables decline quickly over time.[10]

Turning to the shocks in aggregate output and prices, in comparing columns 3 and 4 in Table 5, it is evident that shocks in foreign output and price, in general, exert more influence on the meat export variables than shocks in their domestic counterparts. The average impact of foreign shocks is 10.37%, 21.93%, 20.12%, and 26.67%, respectively, for beef, pork, turkey and chicken; com-

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[10] Japan eliminated import quotas for pork in 1971, and does not have import quotas for poultry (Khan et al.).

Table 6. Decomposition of Forecast Error Variances: Exchange Rate Variables (in Percentage)

Step-ahead	Foreign Money Supply (m*)	Foreign Output (y*)	Foreign Price (p*)	Sum of m*,y* and p*	Domestic Money Supply (m)	Domestic Output & Price (da,ca,p)	Exchange Rate (e)
On Exchange Rate (e):							
1	50.81	4.56	0.53	55.89	0.58	3.68	39.68
4	42.41	5.92	5.16	53.49	0.22	8.86	36.20
8	27.99	13.89	8.15	50.03	0.28	16.82	31.79
12	23.18	12.40	9.87	45.45	0.24	24.07	29.22
24	15.60	8.72	12.52	36.84	0.17	39.27	23.02
average[a]	24.47	9.54	9.71	43.72	0.22	27.02	28.16

[a]average over 30 periods.

pared with 13.02%, 9.39%, 7.12%, and 6.42% for domestic shocks. Shocks in foreign aggregate output and prices can affect U.S. meat exports because they result in income and price effects in the foreign macro economy and, hence, an income effect on the excess demand for U.S. meat products. Similarly, shocks in domestic output and price can affect U.S. meat exports because they result in income and price effects in the domestic macro economy and, hence, an income effect on the excess supply of U.S. meat products. The result that the foreign impact outweighs the domestic impact may be explained in part by the difference in income elasticities for meat products in the domestic and foreign countries.[11] Another feasible explanation is that agricultural trade is more or less an excess demand driven phenomenon, rather than an excess supply driven event.

Columns 3 and 4 of Table 5 also indicate that the impacts of domestic output and price shocks are relatively more significant in the first period but decrease steadily over time, while those of foreign shocks tend to be delayed but increases over time. In other words, the response of U.S. meat excess supply to shocks in the domestic macroeconomy tends to be relatively more rapid than the response of foreign excess demand to shocks in the foreign macroeconomy. Since shocks in the aggregate output and prices within the macro sector can result in an income effect on the meat exports, the difference in the adjustment speed may be due to differences in short-term and longer-term income elasticities of meat products in the two countries. Alternatively, it may be due to a differential in the dynamic linkage between the macro sector and the meat subsector in the two countries. Further research in this area is needed to provide additional insight toward the multifarious dynamics of the system.

Finally, as reported in column 5 of Table 5, the impact of an exchange rate shock is modest for all meat export variables. On average, this accounts for 4.16%, 10.98%, 11.87%, and 7.72%, respectively, of the unexpected variations in beef, pork, turkey and chicken exports. The modest effect of exchange rates contradicts earlier findings that exchange rate movements are important to the agricultural sector (e.g., Schuh, and Chambers and Just). However, as previous research tended to consider exchange rates as the only linkage to the foreign sector, the omission of other important foreign macroeconomic variables from the model could have inflated the importance of the exchange rate shock.

To gain insight into the relationship between the foreign macroeconomic variables and exchange rate, Table 6 reports the forecast error variance decomposition of the latter. Shocks in the exchange rate variable itself are very important to the movement of the exchange rate; the contribution of the exchange rate shock, on average, accounts for 28.16% of the unexpected variations in the variable. However, to a larger extent, exchange rate movements are affected by shocks in other macroeconomic variables. In particular, a foreign money supply shock explains, on average, 24.47% of the unexpected variations in the exchange rate, and the combined impact of the three foreign macroeconomic variables (m*, y*, and p*) is 43.72%. Obviously, if the three foreign macroeconomic variables had been excluded from the model, at least part of the 43.72% impact would have been attributed incorrectly to a shock in the exchange rate variable.

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[11] For example, the income elasticities for meat products in Japan are rather high; between 1 and 2 for chicken, and 0.5 and 1.5 for pork (Dyck).

Conclusions

Within the context of an open economy, this paper examines the impacts of domestic and foreign macroeconomic variables on U.S. meat exports, including beef, pork, turkey, and chicken. The results show that domestic money supply shock has an insignificant effect on meat exports, while a shock in the foreign money supply is very important. The impact of domestic output and aggregate price shocks is initially significant, but declines over time to a rather modest level. On the other hand, the impacts of foreign output and aggregate price shocks are significant and persistent for most meat export variables. In general, it is found that foreign macroeconomic variables exert more significant and persistent effects on U.S. meat exports than domestic macroeconomic variables. The results are interesting because they suggest that the U.S. can increase its meat exports more effectively by expending efforts on international macroeconomic policy coordination rather than on domestic sectoral policy. The results also highlight the need to include various foreign economy variables in macroeconomic models of the agricultural sector.

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Appendix A: The VAR Models

Given the international focus of the study, the goods market equilibrium condition in (4) is used to eliminate y from the macro model. However, since it is desirable to measure variables in logs and yet retain linearity in the estimation, instead of imposing (4) rigorously, it is specified that:

$$y = y\,(da, ca). \tag{A1}$$

The money market equilibrium condition in (7) is used to eliminate r from the model:

$$\begin{aligned} r &= f\,(y, p, m) \\ &\equiv r\,(da, ca, p, m). \end{aligned} \tag{A2}$$

Similarly, the foreign interest rate can be eliminated from the model by expressing

$$r^* = r^*\,(y^*, p^*, m^*). \tag{A3}$$

Substituting (A1) and (A2) into (1) for y and r, respectively, the domestic absorption equation can be specified econometrically as

$$\begin{aligned} da_t = {} & \alpha^{da} + \beta_1^{da}\, ca_t + \beta_2^{da}\, p_t \\ & + \beta_3^{da}\, m_t + \lambda_1^{da}\, G_t \\ & + \lambda_2^{da}\, T_t + \mu_t^{da}, \end{aligned} \tag{A4.1}$$

where α is the constant term, β's are the coefficients for the endogenous variables, λ's are the coefficients for the exogenous variables, and μ is the error term.

Substituting (A1) into (2) and (3) for y, the current account and price equations can be expressed econometrically as

$$\begin{aligned} ca_t = {} & \alpha^{ca} + \beta_1^{ca}\,(e_t + p_t^* - p_t) \\ & + \beta_2^{ca}\, da_t + \beta_3^{ca}\, y_t^* + \lambda_1^{ca}\, T_t \\ & + \lambda_2^{ca}\, T_t^* + \mu_t^{ca}, \end{aligned} \tag{A4.2}$$

$$\begin{aligned} p_t = {} & \alpha^{p} + \beta_1^{p}\, da_t + \beta_2^{p}\, ca_t \\ & + \beta_3^{p}\, m_t + \lambda_1^{p}\, PO_t + \mu_t^{p}. \end{aligned} \tag{A4.3}$$

Similarly, substituting (A2) and (A3) into (5) for r and r*, respectively, the exchange rate equation can be expressed as

$$\begin{aligned} e_t = {} & \alpha^{e} + \beta_1^{e}\, da_t + \beta_2^{e}\, ca_t + \beta_3^{e}\, p_t \\ & + \beta_4^{e}\, m_t + \beta_5^{e}\, y_t^* + \beta_6^{e}\, p_t^* \\ & + \beta_7^{e}\, m_t^* + \beta_8^{e}\, e_t^{e} + \mu_t^{e}. \end{aligned} \tag{A4.4}$$

The exchange rate expectation in (6) is specified as

$$e_t^{e} = \alpha^{e^e} + \beta_1^{e^e}\, e_t + \mu_t^{e^e}. \tag{A4.5}$$

Substituting (A1) into (8) for y, the domestic money supply equation can be expressed as

$$\begin{aligned} m_t = {} & \alpha^{m} + \beta_1^{m}\, da_t + \beta_2^{m}\, ca_t \\ & + \beta_3^{m}\, p_t + \mu_t^{m}. \end{aligned} \tag{A4.6}$$

There are three foreign endogenous variables (y*, p*, and m*) appearing in (A4.2) and (A4.4). Each of the three foreign variables is specified as a function of domestic real output, price, money supply, and the exchange rate:

$$\begin{aligned} y_t^* = {} & \alpha^{y^*} + \beta_1^{y^*}\, da_t + \beta_2^{y^*}\, ca_t \\ & + \beta_3^{y^*}\, p_t + \beta_4^{y^*}\, e_t \\ & + \beta_5^{y^*}\, m_t + \mu_t^{y^*}, \end{aligned} \tag{A4.7}$$

$$\begin{aligned} p_t^* = {} & \alpha^{p^*} + \beta_1^{p^*}\, da_t + \beta_2^{p^*}\, ca_t \\ & + \beta_3^{p^*}\, p_t + \beta_4^{p^*}\, e_t \\ & + \beta_5^{p^*}\, m_t + \mu_t^{p^*}, \end{aligned} \tag{A4.8}$$

$$\begin{aligned} m_t^* = {} & \alpha^{m^*} + \beta_1^{m^*}\, da_t + \beta_2^{m^*}\, ca_t \\ & + \beta_3^{m^*}\, p_t + \beta_4^{m^*}\, e_t \\ & + \beta_5^{m^*}\, m_t + \mu_t^{m^*}. \end{aligned} \tag{A4.9}$$

The Macro VAR Model

The nine-equation macro structure in (A4.1) through (A4.9) contains nine endogenous variables. Denote those nine endogenous variables by the column vector $x_t \equiv (da_t, ca_t, p_t, m_t, y_t^*, p_t^*, m_t^*, e_t, e_t^e)'$. Theory does not say much about the dynamics of the system. To correct for this limitation, the VAR spirit of Sims (1980) is adopted by augmenting each of the nine equations n lags of the nine endogenous variables $(x_{t-1}', x_{t-2}', \ldots, x_{t-n}')$. The augmented version of the structure can be written in matrix form as:

$$\begin{aligned} Bx_t = {} & \alpha + \Gamma_1\, x_{t-1} + \ldots + \Gamma_n\, x_{t-n} \\ & + \Lambda\, z_t + \mu_t, \end{aligned} \tag{A5}$$

where B is a 9 × 9 matrix containing the structural coefficients of the current variables, β's (notice that there are 36 free parameters in B); α is a 9 × 1 vector containing the constant terms; Γ_i is a 9 × 9 matrix containing lagged coefficients for x_{t-i}; $z_t \equiv (G_t, T_t, T_t^*, PO_t)'$ is a 4 × 1 exogenous vector; Λ is a 9 × 4 matrix containing coefficients for z_t, λ's; and

$$\begin{aligned} \mu_t \equiv {} & (\mu_t^{da}, \mu_t^{ca}, \mu_t^{p}, \mu_t^{m}, \mu_t^{y^*}, \mu_t^{p^*}, \\ & \mu_t^{m^*}, \mu_t^{e}, \mu_t^{e^e})'. \end{aligned}$$

Denote the 9 × 9 variance-covariance matrix of μ_t in (A5) as Σ_μ. It is conventional to assume that the structural error terms in μ_t are mutually and serially independent. Thus, Σ_μ is a diagonal matrix. From (A5), it follows that:

$$\begin{aligned} x_t = {} & B^{-1}\alpha + B^{-1}\Gamma_1\, x_{t-1} + \ldots \\ & + B^{-1}\Gamma_n\, x_{t-n} + B^{-1}\Lambda\, z_t \\ & + B^{-1}\, \mu_t. \end{aligned} \tag{A6}$$

Alternatively, one can write a reduced-form VAR system:

$$\text{(A7)}\quad x_t \equiv \Pi_0 + \Pi_1 x_{t-1} + \ldots + \Pi_n x_{t-n} + \Pi_{n+1} z_t + v_t.$$

Denote the 9 × 9 variance-covariance matrix of v_t in (A7) as Σ_v. Notice that Σ_v equals $B^{-1}\Sigma_\mu B^{-1\prime}$ ($\because v_t = B^{-1}\mu_t$, by construction) and, in general, is not a diagonal matrix; implying the VAR error terms in (A7) are contemporaneously correlated. To disentangle the effect of individual shocks in dynamic policy simulations, it is necessary to perform a transformation of the equation such that the variance-covariance matrix of the transformed innovations is diagonal. Since $v_t = B^{-1}\mu_t$, an appropriate transformation matrix for (A7) is B. Upon transformation, (A7) becomes

$$\text{(A8)}\quad Bx_t = B\Pi_0 + B\Pi_1 x_{t-1} + \ldots + B\Pi_n x_{t-n} + B\Pi_{n+1} z_t + \mu_t.$$

Since the variance-covariance matrix of the error terms in (A8) is diagonal, the equation system can be used directly for policy simulations as long as one knows B, Σ_μ, and Π_i's. The estimates of Π_i's can be obtained from estimating the VAR model in (A7). In doing so, one also obtains estimates of Σ_v. Then, B and Σ_μ can be identified via solving $\Sigma_v = B^{-1}\Sigma_\mu B^{-1\prime}$. In particular, since Σ_v is a 9 × 9 symmetric matrix, it contains 45 distinct elements, which are just enough to identify the 45 free parameters, including the 36 β's in B and the 9 variances in Σ_μ. [Note that $\Sigma_v = B^{-1}\Sigma_\mu B^{-1\prime}$ contains 45 nonlinear equations. In the empirical analysis, this system is solved using Shazam's nonlinear equation routine (NL), with standard defaults. In this process, the macro structural model is first estimated equation by equation using OLS. The resulting preliminary estimates of B and Σ_μ are then used as the initial values for the numerical iterations needed for solving the nonlinear system.]

The Meat VAR Model

With the assumption that the meat subsector "recursively follows" the macro sector, the impacts of macroeconomic variables on meat exports do not depend on the contemporary ordering of the meat variables. Hence, specifying a structure for the meat subsector is not needed, given the purpose of this study. Denote the eight meat variables by an 8 × 1 column vector x^a. Specifying x_t^a as a function of its own lags, some exogenous variables unique to the meat sector (z_t^a), the lagged macro variables, and current macro exogenous variables, one can write:

$$\text{(A9)}\quad x_t^a = \Pi_0^a + \Pi_1^a x_{t-1}^a + \ldots + \Pi_n^a x_{t-n}^a + \Pi_{n+1}^a z_t^a + \Phi_1 x_{t-1} + \ldots + \Phi_n x_{t-n} + \Phi_{n+1} z_t + v_t^a.$$

(Upon using (A7), (A9) can be alternatively specified as:

$$x_t^a = \Pi_0^a + \Pi_1^a x_{t-1}^a + \ldots + \Pi_n^a x_{t-n}^a + \Pi_{n+1}^a z_t^a + \Phi x_t + v_t^a.$$

Obviously, this alternative specification conserves degrees of freedom as the lagged x_t's were replaced by the current x_t.)

Denote the 8 × 8 variance-covariance matrix of v_t^a in (A9) as Σ_{v^a}. Similar to Σ_v in (A7), in general, Σ_{v^a} is not diagonal and, hence, an orthogonalizing transformation for (A9) is needed. However, since the meat variables "recursively follow" the macro variables, the transformation cannot be done in isolation from the latter; it is necessary to consider the overall model.

The Overall Model

Given the macro VAR model in (A7) and the meat VAR model in (A9), the overall VAR model can be written as

$$\text{(A10)}\quad \begin{bmatrix} x_t \\ x_t^a \end{bmatrix} = \begin{bmatrix} \Pi_0 \\ \Pi_0^a \end{bmatrix} + \begin{bmatrix} \Pi_1 & 0 \\ \Phi_1 & \Pi_1^a \end{bmatrix} \begin{bmatrix} x_{t-1} \\ x_{t-1}^a \end{bmatrix} + \ldots + \begin{bmatrix} \Pi_n & 0 \\ \Phi_n & \Pi_n^a \end{bmatrix} \begin{bmatrix} x_{t-n} \\ x_{t-n}^a \end{bmatrix} + \begin{bmatrix} \Pi_{n+1} & 0 \\ \Phi_{n+1} & \Pi_{n+1}^a \end{bmatrix} \begin{bmatrix} z_t \\ z_t^a \end{bmatrix} + \begin{bmatrix} v_t \\ v_t^a \end{bmatrix}.$$

Denote the 17 × 17 variance-covariance matrix of the error terms $(v_t', v_t^{a\prime})'$ in (A10) by

$$\Sigma \equiv \begin{bmatrix} \Sigma_v & \Sigma_*' \\ \Sigma_* & \Sigma_{v^a} \end{bmatrix},$$

with Σ_v and Σ_{v^a} being the variance-covariance matrices of v_t and v_t^a, respectively, and Σ_* containing the cross terms.

Now, a transformation matrix is needed for (A10) such that the variance-covariance matrix of the transformed innovation vector is diagonal, with the first nine diagonal entries being the diagonal elements of $\Sigma\mu$ and each of the last eight diagonal elements being one. That is, one seeks a 17 × 17 transformation matrix,

$$H \equiv \begin{bmatrix} H_1 & H_2 \\ H_3 & H_4 \end{bmatrix},$$

such that the transformed variance-covariance matrix is

$$\text{(A11)} \quad \begin{bmatrix} H_1 & H_2 \\ H_3 & H_4 \end{bmatrix} \begin{bmatrix} \Sigma_v & \Sigma_*' \\ \Sigma_* & \Sigma_{v^a} \end{bmatrix} \begin{bmatrix} H_1' & H_3' \\ H_2' & H_4' \end{bmatrix} = \begin{bmatrix} \Sigma_\mu & 0_{9\times 8} \\ 0_{8\times 9} & I_8 \end{bmatrix}.$$

In accordance with the macro model identification in (A8), $H_1 = B$, which has been identified. In keeping with the recursive assumption between the macro and meat models, H_2 is a zero matrix. Thus,

$$\text{(A12)} \quad H \equiv \begin{bmatrix} H_1 & H_2 \\ H_3 & H_4 \end{bmatrix} = \begin{bmatrix} B & 0_{9\times 8} \\ H_3 & H_4 \end{bmatrix}.$$

Remaining to be found are H_3 and H_4. From (A12), the variance-covariance matrix in (A11) becomes

$$\text{(A13)} \quad \begin{bmatrix} B & 0_{9\times 8} \\ H_3 & H_4 \end{bmatrix} \begin{bmatrix} \Sigma_v & \Sigma_*' \\ \Sigma_* & \Sigma_{v^a} \end{bmatrix} \begin{bmatrix} B' & H_3' \\ 0_{8\times 9} & H_4' \end{bmatrix} = \begin{bmatrix} \Sigma_\mu & 0_{9\times 8} \\ 0_{8\times 9} & I_8 \end{bmatrix}.$$

Upon multiplying out (A13) component by component and focusing on the southwest and southeast corners of the matrices, one obtains

$$\text{(A14)} \quad H_3 = -H_4\Sigma_*\Sigma_v^{-1},$$

$$\text{(A15)} \quad H_3\Sigma_v H_3' + H_4\Sigma_* H_3' + H_3\Sigma_*' H_4' + H_4\Sigma_{v^a} H_4' = I_8.$$

Substituting (A14) into (A15) for H_3,

$$\text{(A16)} \quad -\Sigma_*\Sigma_v^{-1}\Sigma_*' + \Sigma_{v^a} = H_4^{-1}H_4^{-1\prime}.$$

Since the ordering of the meat variables does not matter, H_4 is imposed to be a lower triangular matrix. Accordingly, H_4^{-1} is also a lower triangular matrix, which can be conveniently obtained by applying a Choleski decomposition on the left-hand-side of (A16). Once H_4 is arrived at, H_3 can subsequently be calculated using (A14).