Estimating the Trade Elasticity over Time[*]

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Abstract

Using quarterly data on the U.S. imports from its major trading partners and the corresponding trade costs, this paper estimates the trade elasticity by using a panel structural vector autoregressive model that can distinguish between short-run versus long-run elasticity measures in a continuous way and is robust to any endogeneity problem. The estimated trade elasticity measures are highly consistent with studies in alternative literatures, suggesting a short-run value of about 1 (after one quarter), a medium-run value of about 5 (after one year), and a long-run value of about 7 (after five years).

JEL Classification: F13, F14

Key Words: Trade Elasticity; Short-run; Medium-run; Long-run

1 Introduction

The main topic of investigation in international trade is the reaction of trade to changes in trade costs and thus *the trade elasticity*. This elasticity not only measures the effects of a trade policy change (e.g., a change in duties/tariffs) on trade but also connects the changes in home expenditure share of a country to its welfare gains from trade (e.g., see Arkolakis, Costinot, and Rodríguez-Clare (2012)). Accordingly, estimating the trade elasticity is essential for a trade policy evaluation regarding the changes in trade and welfare.

Regarding the value of trade elasticity, the general agreement in the literature is that it is lower in the short run and higher in the long run, both in calibrations (as in Obstfeld and Rogoff (2007) or Alessandria, Choi, and Ruhl (2014)) and in estimations (as in Gallaway, McDaniel, and Rivera (2003) or Alessandria and Choi (2018)). This observation has also been shown to explain several puzzles in international economics such as the international elasticity puzzle (as in Ruhl (2008)), the trade-comovement puzzle (as in Drozd, Philadelphia, Kolbin, and Nosal (2017)), or the missing globalization puzzle (as in Anderson and Yotov (2017)). Despite the agreement in the literature regarding the value of the trade elasticity changing over time, the evidence on the actual estimate of the trade elasticity is mixed.

This paper sheds light on the mixed evidence on the actual estimate of the trade elasticity by using a panel structural vector autoregression (VAR) approach that takes into account any potential endogeneity concern in a dynamic framework by construction. Theoretically, the bilateral-trade variables in the estimation are selected to be consistent with the implications of a large class of general equilibrium trade models as suggested by Allen, Arkolakis, and Takahashi (2018), including quarterly data on the U.S. imports from its major trading part-

ners, the corresponding U.S. import prices (measured at the port of the trading partner), the corresponding actual trade costs (including both duties/tariffs and transportation/shipment costs), and the U.S. real GDP (or the U.S. industrial production as an alternative).

Empirically, the estimation of the trade elasticity is achieved by using its textbook definition, which corresponds to the total percentage changes in trade divided by the total percentage changes in trade costs. In the panel structural VAR framework, this definition corresponds to dividing the cumulative impulse response of trade to the cumulative impulse response of trade costs, both following a trade cost shock. Since the cumulative impulse response can be estimated for any period after the shock, a continuous estimate of the trade elasticity can be achieved over time, which is a key innovation in this paper with respect to the existing literature.

2   Data and Estimation Methodology

We consider the panel structural VAR model for $z_{i,t} = (\Delta y_t, \Delta p_{i,t}, \Delta \tau_{i,t}, \Delta m_{i,t})'$ based on quarterly data , where Δy_t is the percentage change in the U.S. real GDP (or the percentage change in the U.S. industrial production as an alternative), $\Delta p_{i,t}$ is the percentage change in the U.S. import prices from trading partner i (measured at the port of the trading partner), $\Delta \tau_{i,t}$ is the percentage change in gross trade costs for the U.S. imports from trading partner i (where gross trade costs are defined as one plus the sum of *ad valorem* duties/tariffs and transportation/shipment costs), and $\Delta m_{i,t}$ is the percentage change in U.S. imports from trading partner i. The sample period is 2004q1-2018q4, and the estimation is achieved by pooling U.S. imports data from its major trading partners of China, Canada, Mexico,

Germany, France, United Kingdom and Japan.[1] More details about the data are given in the Data Appendix.

The panel structural VAR model is given by:

$$B_o z_{i,t} = b + \sum_{k=1}^{3} B_k z_{i,t-k} + e_{i,t}$$

where $e_{i,t}$ is the vector of serially and mutually uncorrelated structural innovations. For estimation purposes, the model is expressed in reduced form as follows:

$$z_{i,t} = \alpha + \sum_{k=1}^{3} A_k z_{i,t-k} + u_{i,t}$$

where $\alpha = B_o^{-1} b$, $A_k = B_o^{-1} B_k$ for all k, and it is postulated that the structural impact multiplier matrix B_o^{-1} has a recursive structure such that the reduced form errors $u_{i,t}$ can be decomposed according to $u_{i,t} = B_o^{-1} e_{i,t}$, where the sizes of shocks are standardized to negative unity (i.e., the identification is by triangular factorization). The recursive structure imposed on B_o^{-1} requires an ordering of the variables used in the estimation. Since we have four variables $(\Delta y_t, \Delta p_{i,t}, \Delta \tau_{i,t}, \Delta m_{i,t})$, we have in total 24 possible alternative orderings that can be used in the panel structural VAR estimation. For robustness, we achieve panel structural VAR estimations for all of these 24 alternative models.

The estimation is achieved by a Bayesian approach with independent normal-Wishart priors. This corresponds to generating posterior draws for the structural model parameters by transforming each reduced-form posterior draw. In particular, for each draw of the covariance matrix from its posterior distribution, the corresponding posterior draw for B_o^{-1} is

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[1]The sample period and the trading partners are determined by the data availability.

constructed by using by triangular factorization so that the sizes of shocks are standardized to negative unity (e.g., a trade cost shock represents a reduction in trade costs). In the Bayesian framework, for each of the 24 alternative orderings, a total of 2,000 samples are drawn, where a burn-in sample of 1,000 draws is discarded. The remaining 1,000 draws (for each ordering) are used to determine the structural impulse responses that are necessary in the estimation of the trade elasticity, which is introduced next.

2.1   Implications for the Trade Elasticity

Consistent with the implications of a large class of general equilibrium trade models as suggested by Allen, Arkolakis, and Takahashi (2018), the textbook definition of trade elasticity is given by the total percentage change in the U.S. imports from any of its trading partners divided by the total percentage change in the corresponding trade costs (multiplied by negative one):

$$\theta = -\frac{\Delta \text{ in U.S. Imports}}{\Delta \text{ in Trade Costs}} = -\frac{\Delta m_{i,t}}{\Delta \tau_{i,t}} \tag{1}$$

where Δ represents the percentage change of a variable that can be calculated for any time horizon. To connect these percentage changes to the panel structural VAR model, the trade elasticity θ is defined as the cumulative impulse response of $\Delta m_{i,t}$ divided by the cumulative impulse response of $\Delta \tau_{i,t}$, both following a one-time trade cost shock:

$$\theta = -\frac{\text{Cumulative Response of } \Delta m_{i,t}}{\text{Cumulative Response of } \Delta \tau_{i,t}} \quad \text{(after a trade cost shock)} \tag{2}$$

which can be calculated for any period after the trade cost shock. This definition is similar to the one used by Alessandria, Choi, and Ruhl (2014) who consider time-varying trade elasticity measures as in this paper.[2] Since $\Delta\tau_{i,t}$ represents the changes in total trade costs (i.e., the sum of duties/tariffs and transportation/shipment costs), a one-time trade cost shock may represent either a temporary trade barrier (e.g., antidumping, safeguards and countervailing duties as in studies such as by Bown and Crowley (2013)) or a transportation costs shock (e.g., a supply or demand shock in the transportation sector).[3]

In the Bayesian estimation, for each of the 24 alternative orderings, the right hand side of Equation 2 is calculated for each of the 1,000 draws. For robustness, draws that satisfy the intersection of these 1,000 draws across 24 alternative orderings are considered for the estimation of θ.[4] Therefore, the trade elasticity estimates presented below are consistent with each of the 24 alternative orderings. While the median of the distribution (obtained by the intersection of 24 alternative orderings) is considered as the Bayesian estimator of θ, the 16th and 84th quantiles of the same distribution are used to construct the 68 percent credible interval.

We consider θ estimated one period after the shock as *the short-run trade elasticity*, θ estimated one year (four quarters) after the shock as *the medium-run trade elasticity*, and θ estimated five years (twenty quarters) after the shock as *the long-run trade elasticity*. Among

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[2]This approach is also similar to studies such as by Shambaugh (2008) or Forbes, Hjortsoe, and Nenova (2018) who estimate exchange rate pass-through by dividing the percentage change in prices by the percentage change in the exchange rate, both following a common shock in a VAR framework.

[3]These one-time trade cost shocks are different from permanent shocks as in studies such as by Baier and Bergstrand (2007) or Baier, Bergstrand, and Feng (2014) who focus on the effects of economic integration agreements (EIA) on international trade over time. The permanent shocks in such studies even have changing patterns over time, since most EIAs are "phased-in" over 5-10 years as suggested by Baier, Bergstrand, and Feng (2014).

[4]In technical terms, this intersection of draws correspond to trade elasticity measures that are larger than the highest minimum and smaller than the lowest maximum measures (for all periods after the trade costs shock) across 24 alternative orderings.

these alternative definitions, (i) *the short-run trade elasticity* is comparable to (or useful for) international finance/macro studies, since they empirically test their models mostly using quarterly data, (ii) *the medium-run trade elasticity* is comparable to (or useful for) international trade studies, since they empirically test their models mostly using annual data, and (iii) *the long-run trade elasticity* is comparable to (or useful for) economic growth studies, since they empirical test their models using at least five-year long data.

3   Estimation Results

Trade elasticity θ estimates are given in Figure 1a (Figure 1b) when the U.S. real GDP (the U.S. industrial production, IP) is used as a measure of real economic activity, whereas the corresponding short-run, medium-run and long-run estimates are given in Table 1. The vertical axes in figures represent the estimated value, while the horizontal axes represent the periods/horizons (measured in quarters) after the trade cost shock. As is evident, independent of the real economic activity measure used, θ is positive and takes higher values over time, as consistent with studies such as by Gallaway, McDaniel, and Rivera (2003), Alessandria, Choi, and Ruhl (2014) or Alessandria and Choi (2018).

The short-run trade elasticity θ estimate is about 1.110 (0.944) when real GDP (IP) is used, with a range between 0.855 and 1.528 (0.662 and 1.452), which is highly consistent with international finance studies considering quarterly data such as by Reinert and Roland-Holst (1992) with an estimate of about 0.91, Blonigen and Wilson (1999) with an estimate of about 0.81, Heathcote and Perri (2002) with an estimate of about 0.9, Bergin (2006) with

an estimate of about 1.13, and Corsetti, Dedola, and Leduc (2008) with an estimate of about 0.85.

The medium-run trade elasticity θ estimate is about 5.028 (4.692) when real GDP (IP) is used, with a range between 2.288 and 7.081 (2.374 and 6.657), that is highly consistent with international trade studies considering annual data such as by Bernard, Eaton, Jensen, and Kortum (2003), Broda and Weinstein (2006), Simonovska and Waugh (2014a), Simonovska and Waugh (2014b) or Eaton, Kortum, and Kramarz (2011) who suggest average elasticity measures ranging between 4 and 5.

Finally, the long-run trade elasticity θ estimate is about 6.908 (6.541) when real GDP (IP) is used, with a range between 2.898 and 10.512 (2.867 and 10.374), consistent with studies such as by Alessandria, Choi, and Ruhl (2014) and Alessandria and Choi (2018) who have estimated the reaction of trade to a trade cost shock after five years as about 6 and 8, respectively.

4   Conclusion

This paper has estimated the trade elasticity using a panel structural VAR approach that is robust to concerns such as its time-varying nature or endogeneity. The estimation results have distinguished between short-run, medium-run and long-run trade elasticity estimates, and they have been shown to be consistent with existing empirical studies in alternative literatures employing data on alternative frequencies.

The continuous estimates of the trade elasticity increasing over time in this paper can also be connected to several well-established theories in the literature. In particular, they can

be connected to theories that imply trade elasticity measures increasing over time by having alternative frictions such as order/delivery lags, bottlenecks, dock strikes, and transitory changes in trade policies as in Hooper, Johnson, and Marquez (2000); firm-level entry costs and uncertainties on future productivities as in Ruhl (2008) or Alessandria and Choi (2018); durable stocks that cannot be adjusted quickly in response to price changes as in Engel and Wang (2011); search frictions as in Drozd and Nosal (2012); difference between the adjustments in extensive and intensive margins of trade as in Arkolakis, Eaton, and Kortum (2012); fixed versus variable trade costs or investments in reducing future export costs as in Alessandria, Choi, and Ruhl (2014); the speed of adjustment of capital in the distribution sector as in Crucini and Davis (2016); adjustment of capacity in bilateral network links as in Anderson and Yotov (2017); plant-level irreversibility in the structure of inputs used in production as in Ramanarayanan (2017); fixed and sunk costs of export participation as in Fitzgerald and Haller (2018); or adjustment frictions in factor markets as in Steinberg (2018). The results of this paper are not only consistent with these frictions but also provide actual estimates of the trade elasticity over time for which evidence has been mixed in the literature.

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5   Data Appendix

The U.S. real GDP y_t as a measure of real economic activity (Real Gross Domestic Product, Billions of Chained 2012 Dollars, Quarterly, Seasonally Adjusted Annual Rate), the U.S. industrial production as an alternative measure of real economic activity (Industrial Production Index, Index 2012=100, Monthly, Seasonally Adjusted) and the price of U.S. imports from its major trading partners (e.g., Import Price Index: China - All commodities, Index Dec 2003=100, Monthly, Not Seasonally Adjusted) have been obtained from Federal Reserve Economic Data (FRED). The considered trading partners of China, Canada, Mexico, Germany, France, United Kingdom, and Japan have been determined by data availability of the U.S. import prices.

The monthly U.S. industrial production and U.S. imports price indexes that are quoted Free On Board Foreign Port (i.e., it excludes duties, insurance and other extra charges to bring a good into the U.S.) have been converted into quarterly terms represented by y_t and $p_{i,t}$, respectively, by taking the average of the corresponding three months.

The U.S. imports from its trading partners of China, Canada, Mexico, Germany, France, United Kingdom and Japan ($m_{i,t}$'s, All Import Commodities: Customs Value) and the corresponding trade costs of $\tau_{i,t}$'s have been obtained from the U.S. International Trade Commission. In particular, for each trading partner i, gross trade costs $\tau_{i,t}$ are obtained as one plus the sum of "All Import Commodities: Charges, Insurance, and Freight" and "All Import Commodities: Calculated Duties" divided by "All Import Commodities: Customs Value."

The quarterly sample period of 2004q1-2018q4 is chosen to be consistent with data availability. In the panel structural VAR estimation, all variables are represented in demeaned annual percentage changes (as the quarterly year-on-year log changes that are robust to any seasonality concern).

6 Tables

Table 1 - Trade Elasticity θ Estimates

	REA	Estimate	Lower Bound		Upper Bound
Short-run Trade Elasticity	GDP	1.110	[0.855	,	1.528]
(after one quarter)	IP	0.944	[0.662	,	1.452]
Medium-run Trade Elasticity	GDP	5.028	[2.288	,	7.081]
(after one year)	IP	4.692	[2.374	,	6.657]
Long-run Trade Elasticity	GDP	6.908	[2.898	,	10.512]
(after five years)	IP	6.541	[2.867	,	10.374]

Notes: REA stands for the measure of real economic activity used in estimations.

Lower and upper bounds represent the 68 percent credible intervals.

7 Figures

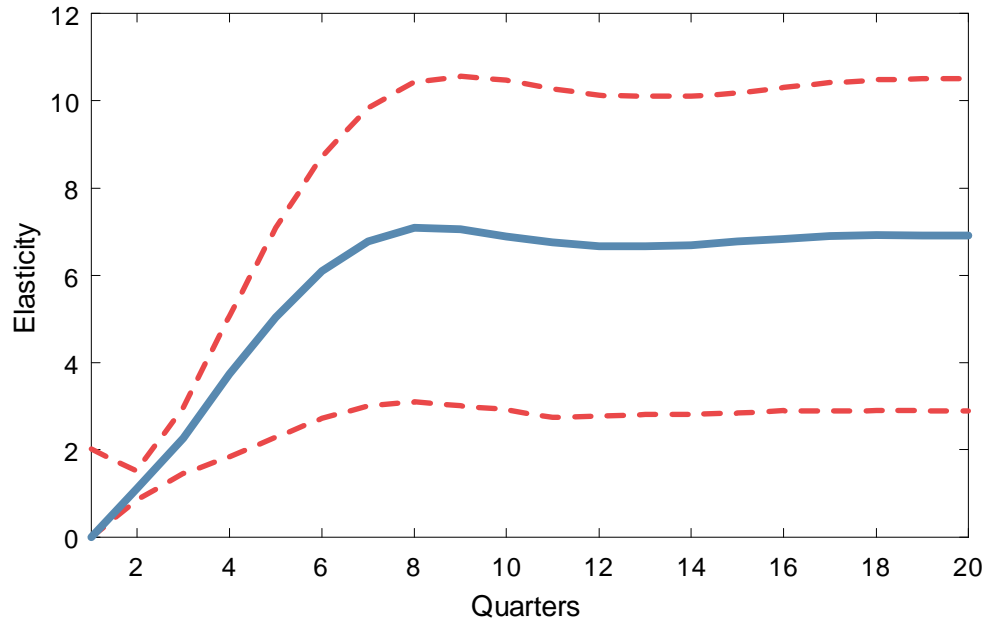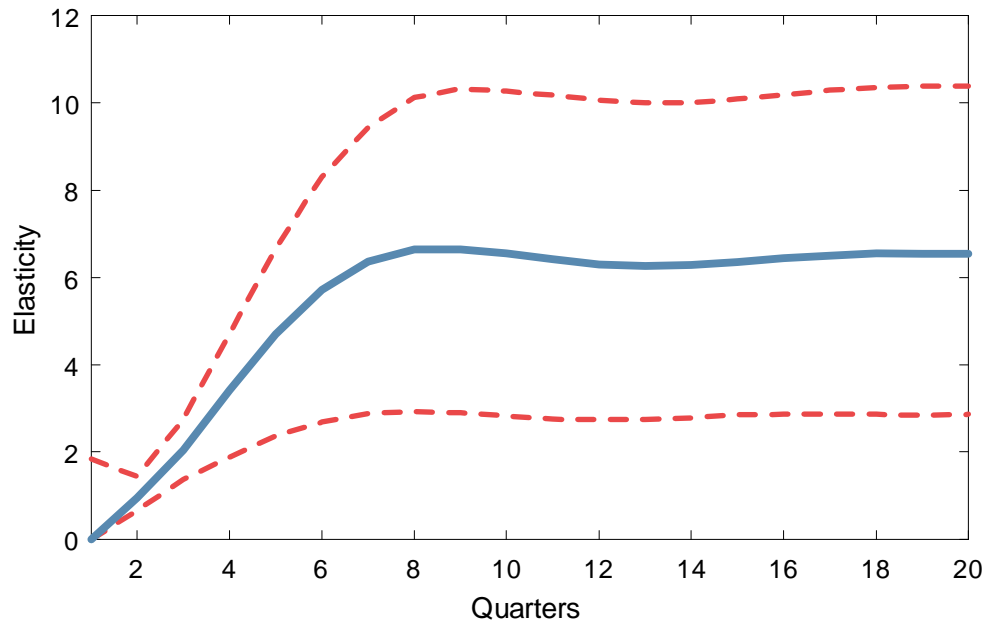**Figure 1a - Trade Elasticity θ Estimates over Time (using real GDP)**

Figure 1b - Trade Elasticity θ Estimates over Time (using IP)

Notes: The solid lines represent the trade elasticity estimates, while dashed lines represent lower and upper bounds that correspond to the 68 percent credible intervals.