Estimating the welfare costs of autarky: a sufficient statistics approach

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Abstract

This paper uses the Jeffersonian Embargo enacted in 1807 to estimate the welfare costs of autarky. I use an Armington trade model to compute the welfare losses using two sufficient statistics: the share of expenditures on domestic goods and the elasticity of substitution between domestic and imported goods. I use historical data from 1792 to 1807 to estimate the Armington elasticity, using import tariffs as instrument for relative prices. The empirical findings suggest welfare losses of 2.83-8.14% of real income.

Keywords: Autarky, Welfare losses, Armington elasticity
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1 Introduction

During the Napoleonic Wars, American ships were seized by the French and British navies, violating U.S. neutrality. To protect U.S. ships, in December 1807 the Jefferson administration enacted an Embargo. The Embargo, one of the rare cases of autarky in the history, lasted until March 1809, when Jefferson decided to re-open the US ports. This paper exploits such policy shock to estimate the welfare losses from autarky.

I first set up a two-country Armington (1969) trade model, where each country produces a differentiated good that cannot be substituted by production in another country. I follow Arkolakis et al. (2012) and show that the change in welfare following a shock can be computed using only two sufficient statistics: the share of expenditures on domestic goods and the elasticity of substitution between domestic and imported goods.

I estimate the Armington elasticity of substitution using historical data from 1792 to 1807 on imports, domestic production and prices. I instrument the relative price of imports with ad-valorem tariffs. The empirical findings document a median elasticity of 3.64. I use this elasticity and the observed change in the domestic trade share to compute the welfare cost of the Embargo. The preferred specification suggests a welfare loss of 2.83-8.14% of real income, a striking number given that the Embargo lasted only 14 months.

Few empirical works have studied the implications of autarky, such as Bernhofen and Brown (2004), Irwin (2005) and Etkes and Zimring (2015). This paper provides an exact measure of the welfare losses from autarky, using a framework commonly employed by economists to evaluate trade policies (see e.g. Costinot and Rodríguez-Clare (2013)). Moreover, my approach relies only on two sufficient statistics, thus reducing the impact of measurement error on the estimates, which is a typical concern with historical data.

Lastly, to my knowledge, this paper is the first to estimate, for the early 19th century, the Armington elasticity, a key parameter in international economics (see Broda and Weinstein (2006) and Feenstra et al. (2018)). Therefore, my estimates could be used in other empirical works that focus on the same historical period.

2 The Embargo

During the Napoleonic Wars, American ships were seized as contraband of war by the British and French navies. In response to these violations of U.S. neutrality, in December 1807 US President Jefferson imposed a general Embargo. Since the Embargo was the direct response of the US government to a policy carried out by the European countries, it can be considered an exogenous shock to the US economy. The Embargo lasted until March

Figure 1: US Trade, 1792-1808

Source: North (1960). Data are in millions of dollars.

1809, after mounting domestic opposition, and generated a 73% drop in exports and a 48% reduction in imports, as shown in Figure 1.

3 The Armington Model

I set up a general equilibrium Armington (1969) model that will be used to calculate the welfare costs of the Embargo. The model assumes that each country produces, using labor, a differentiated good that cannot be substituted by production in another country. This is consistent with the evidence that, at the time of the Embargo, a large fraction of US imports consisted of goods, such as tea, coffee, spices, and wine, that US firms could not produce, due to climate and land constraints.

3.1 Environment

Two countries, US and Rest of the World, produce a differentiated good using labor, under perfect competition. In each country, a representative agent maximizes the following CES utility function:

$$U_j = \left[\alpha q_{Uj}^{\frac{\sigma-1}{\sigma}} + (1-\alpha) q_{Rj}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

$$\text{s.to } q_{Uj}p_{Uj} + q_{Rj}p_{Rj} \leq w_j L_j$$

where q_{ij} is the quantity of country i' s good consumed by country j, L_j is the population, $\sigma > 1$ is the elasticity of substitution between domestic and imported goods, and $\alpha > 0$ is a preference parameter. Solving the consumer's problem implies that US total imports equal

$$X_{RU} \equiv q_{RU}p_{RU} = (1-\alpha)^{\sigma}\left(\frac{p_{RU}}{P_U}\right)^{1-\sigma} w_U L_U, \tag{2}$$

where P_U is the price index:

$$P_U = \left[\alpha^{\sigma}(p_{UU})^{1-\sigma} + (1-\alpha)^{\sigma}(p_{RU})^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{3}$$

and $E_U = w_U L_U$ are total expenditures. To ship a good from i to j, producers incur in iceberg costs $\tau_{ij} \geq 1$, equal to 1 for $j = i$. Perfect competition implies that $p_{ij} = \tau_{ij} w_i$.

3.2 Welfare changes

Equation (1) and the budget constraint imply that welfare equals real income:

$$W_U = \frac{w_U L_U}{P_U}. \tag{4}$$

Consider a shock to trade costs $\hat{\tau}_{ij} \equiv \frac{\tau'_{ij}}{\tau_{ij}}$, for $j \neq i$. Following Arkolakis et al. (2012), the change in welfare associated with such shock is:[1]

$$\hat{W}_U = \left(\hat{\lambda}_{UU}\right)^{\frac{1}{1-\sigma}}, \tag{5}$$

where λ_{UU} is the share of income spent for domestic goods:

$$\lambda_{UU} \equiv \frac{X_{UU}}{E_U}. \tag{6}$$

[1]The share of expenditures on domestic goods is: $\lambda_{UU} = (\alpha)^{\sigma}\left(\frac{p_{UU}}{P_U}\right)^{1-\sigma}$. In percentage changes it becomes $d\ln(\lambda_{UU}) = (1-\sigma)\left[d\ln(p_{UU}) - d\ln(P_U)\right]$. Setting the US wage as numeraire, and since $d\ln\tau_{UU} = 0$, it holds that $d\ln p_{UU} = 0$. Given that $d\ln(W_U) = -d\ln(P_U)$, we have $d\ln(W_U) = \frac{d\ln(\lambda_{UU})}{1-\sigma}$. Integrating, we obtain equation (5).

The advantage of using the Armington framework is that the welfare changes can be exactly computed using only two sufficient statistics. λ_{UU} can be directly observed in the data, while the elasticity of substitution σ needs to be estimated. The following section will carry out the empirical estimation of σ and compute the welfare losses from the Embargo.

4 An empirical assessment of the Embargo

4.1 Methodology

To estimate the Armington elasticity, I rearrange the F.O.C.s of the consumer as

$$\frac{q_{UU}}{q_{RU}} = \left(\frac{\alpha}{1-\alpha}\right)^{\sigma} \left(\frac{p_{UU}}{p_{RU}}\right)^{-\sigma}. \tag{7}$$

Assuming that the model holds period by period, the above expression can be estimated in logs as:

$$y_t = \beta_0 + \beta_1 x_t + \nu_t, \tag{8}$$

where $y_t \equiv \ln\left(\frac{q_{UU,t}}{q_{RU,t}}\right)$, the log of the ratio between US domestic sales and imports at time t; $x_t \equiv \ln\left(\frac{p_{UU,t}}{p_{RU,t}}\right)$, the log of the ratio between the price of the domestic and imported goods; $\beta_0 = \sigma \ln\left(\frac{\alpha}{1-\alpha}\right)$, and v_t is an econometric error. The elasticity of substitution is simply $\sigma = -\hat{\beta}_1$.

4.2 Data

Given the limits on the availability of data, the empirical analysis is carried out with yearly data from 1792 to 1807.[2]

Domestic sales. Total domestic sales are computed by subtracting total exports (North (1960)) and re-exports (Irwin (2003)), from the GDP estimates in Weiss (1992). For robustness, I use 3 alternative measures: i) starting from the Weiss' estimate in 1793, I recover the GDP series until 1807 using the Davis (2004) Production Index; ii) the GDP series from Gallman (1966), converted into a 1792-1807 series using the Davis Index; iii) the GDP series constructed in Johnston and Williamson (2011).

[2]While prices are available at monthly frequency, sales are available only at the yearly level.

Table 1: OLS regression

Log of rel. sales	(1)	(2)	(3)	(4)
Log of rel. prices	-2.483***	-2.084***	-2.141***	-2.119***
	(0.677)	(0.600)	(0.627)	(0.479)
Constant	1.882***	1.845***	1.176***	2.102***
	(0.042)	(0.049)	(0.049)	(0.061)
Observations	16	16	16	16
R^2	0.651	0.570	0.572	0.630

Sample period: 1792-1807. Column (1): GDP from Weiss; column (2): Weiss series adjusted by Davis index; column (3): Gallman series adjusted by Davis index; column (4): Johnston and Williamson series. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Imports. Data on aggregate yearly imports are from North (1960). I subtract the amount of re-exports from Irwin (2003).

Prices. The analysis uses annual weighted averages of the prices of domestic and imported commodities prevailing in Boston (Smith and Cole (1935)), given its economic importance in the early 19th century.

4.3 Results

Table 1 presents the results from an OLS estimation of (8). Since equation (8) is expressed in quantities, both domestic sales and imports were deflated by the appropriate price index. The estimated elasticity is between 2.084 and 2.483, significant at 1% level. To mitigate endogeneity concerns, I follow Arkolakis et al. (2018) and instrument the relative price of imports with the log of average import tariffs (Irwin (2003)). Table 2 shows that the magnitude of the elasticity is larger, as expected, and is between 3.31-3.96, significant at 1% level.[3] The median estimate is 3.64, similar to Feenstra et al. (2018), which estimate the Armington elasticity with recent US data.[4]

4.4 The welfare losses from autarky

The last step is to compute λ_{UU}, the share of expenditures on domestic goods. I compute it

[3]Results are similar if I add average freight rates as instrument (North (1960)).

[4]This number is also close to the trade elasticity estimated in the literature, e.g. Simonovska and Waugh (2014), Adao et al. (2019) and Yilmazkuday (2019).

Table 2: IV regression

Log of rel. sales	(1)	(2)	(3)	(4)
Log of rel. prices	-3.960***	-3.313***	-3.333***	-3.953**
	(0.757)	(0.758)	(0.749)	(1.347)
Constant	1.961***	1.910***	1.239***	2.199***
	(0.079)	(0.076)	(0.078)	(0.070)
Observations	16	16	16	16
R^2	0.421	0.372	0.394	0.158

Sample period: 1792-1807. Same specifications as in Table 1, but the dependent variable is instrumented with average log tariffs. Robust standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

as:

$$\lambda_{UU} = 1 - \frac{IMP_U}{E_U}, \tag{9}$$

where IMP_U are total imports and E_U is total spending (total production plus imports and minus exports). To compute the welfare losses, I plug into equation (5) $\hat{\sigma} = 3.64$ - the median Armington elasticity; $\lambda_{UU} = 0.83$ - the share of expenditure on domestic goods before the Embargo, in 1807; $\lambda'_{US,US} = 0.91$ - the share in 1808.[5] Simple algebra delivers $\hat{W} = 0.964$, and thus welfare losses of 3.6% of real income. Allowing for trade imbalances and tariff revenues, the losses are 4.3%.[6] Lastly, I use the standard error in column (1) in Table 2 to provide bounds on the welfare losses, which are between 2.83% and 8.14% of real income.

5 Conclusions

The analysis presented in this paper captures the short-run effects of moving to autarky. The study has shown that the impact of the Embargo on US welfare was sizable. It must be recognized that the Armington is a simplified model: the number of products is fixed and there are no intermediate inputs, hence the gains from trade may be underestimated. Nevertheless, the advantage of using a parsimonious framework is that only two sufficient statistics are needed to estimate the welfare losses, an appealing feature since we lack detailed historical data for the early 19th century.

[5]This is not 1 because smuggling activities allowed some trade to persist during the Embargo.

[6]Replace $E_U = w_U L_U + R_U + T_U$ into $\hat{W}_U = \frac{E'_U/P'_U}{E_U/P_U}$, so $\hat{W}_U = \left(\hat{\lambda}_{UU}\right)^{\frac{1}{1-\sigma}} A\hat{D}J_U$, with $A\hat{D}J_U = \frac{1+\left(R'_U+T'_U\right)/\left(w'_U L'_U\right)}{1+(R_U+T_U)/(w_U L_U)} = 0.99$ from North (1960). See also Esposito (2019).

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