Missing Gains from Trade?

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The theoretical result that there are gains from trade is a central tenet of international economics. Assuming perfect competition and no market failures, trade acts like a technological improvement that expands the set of feasible allocations and enables Pareto superior outcomes to be achieved. A recent body of research has sought to quantify the magnitude of these welfare gains. In a class of standard trade models that satisfy a "gravity equation," the welfare gains from trade can be computed using only aggregate data: The open economy domestic trade share and the elasticity of trade with respect to variable trade costs (see Arkolakis, Costinot and Rodriguez-Clare 2012). One of the main findings from this literature is that the welfare gains from trade are relatively modest. For example, in a study of 19 OECD countries, Eaton and Kortum (2002) find that the welfare cost of moving to autarky ranges from 10.3-0.8 percent.

Many extensions to this quantitative approach have been considered, including the introduction of input-output linkages (e.g. Caliendo and Parro 2012) and multiple sectors (e.g. Ossa 2012). Some of these extensions can substantially increase the predicted welfare gains from trade, as surveyed in Costinot and Rodriguez-Clare (2013), which reports a range of potential values for the welfare gains from trade.

In this paper, we suggest a channel for welfare gains that the standard quantitative approach typically abstracts from: trade-induced changes in domestic productivity. Since domestic productivity directly affects welfare in both the closed and open economy (separately from trade flows and relative prices) it provides an additional potential channel for trade to affect welfare. We provide a simple example in which the contribution of this additional channel to the overall welfare gains from trade can be large.

The remainder of the paper is structured as follows. Section I reviews a simple version of the standard quantitative approach and highlights its abstraction from trade-induced changes in domestic productivity. Section II develops a simple extension in which trade leads to endogenous changes in domestic productivity through a re-organization of production. Section III concludes.

I. Quantifying the Gains from Trade

We consider an Armington model of international trade in which goods are differentiated by country of origin. The world consists of a number of countries indexed by $i, n \in \{1, \ldots, N\}$. Each country is endowed with a measure $\bar{L}_n$ of labor. The utility of the representative consumer in each country n is linear in the consumption of a non-traded final good (C_n): $\mathbb{U}_n = C_n$. This non-traded final good is produced with traded intermediate inputs according to a constant elasticity of substitution (CES) production technology:

$$(1) \qquad Y_n = \left[\sum_{i=1}^{N} (\lambda_i y_{ni})^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}},$$

where Y_n is output of the non-traded final good; y_{ni} is the quantity of the traded intermediate input from country i used by country n; and λ_i parameterizes the quality or productivity of the traded intermediate input from country i.

Shipping traded intermediate inputs from country i to country $n \neq i$ incurs iceberg

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variable trade costs of $d_{ni} > 1$, where $d_{nn} = 1$. Cost minimization implies that the share of traded intermediate inputs from country i in costs in country n is:

$$\pi_{ni} = \frac{(d_{ni}p_i/\lambda_i)^{1-\sigma}}{\sum_{k=1}^{N}(d_{nk}p_k/\lambda_k)^{1-\sigma}}, \tag{2}$$

and the dual unit cost function for final goods production is:

$$G_n = \left[\sum_{i=1}^{N}\left(\frac{d_{ni}p_i}{\lambda_i}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}. \tag{3}$$

Perfect competition and constant returns to scale imply that the price of the final good equals its unit cost ($P_n = G_n$). Traded intermediate inputs are produced with labor according to the following constant returns to scale technology under conditions of perfect competition:

$$y_n = \varphi_n L_n. \tag{4}$$

Perfect competition and constant returns to scale imply that 'free on board' intermediate input prices equal unit cost: $p_n = w_n/\varphi_n$. Using the unit cost function (3) and trade share (2) together with prices, welfare can be expressed in terms of the domestic trade share and parameters: $\mathbb{W}_n = w_n/P_n = b_n\pi_{nn}^{-1/(\sigma-1)}$, where $b_n = \varphi_n\lambda_n$ is a composite measure of productivity in final and intermediate production. The welfare gains from trade are:

$$\frac{\mathbb{W}_n^T}{\mathbb{W}_n^A} = \frac{b_n^T}{b_n^A}\left(\pi_{nn}^T\right)^{-\frac{1}{\sigma-1}} = \left(\pi_{nn}^T\right)^{-\frac{1}{\sigma-1}}, \tag{5}$$

where we denote the open economy by T and the closed economy by A; $\pi_{nn}^A = 1$; and

$$\pi_{nn}^T = \frac{(d_{nn}w_n^T/b_n^T)^{1-\sigma}}{\sum_{k=1}^{N}(d_{nk}w_k^T/b_k^T)^{1-\sigma}} < 1.$$

To assess the rough magnitude of the implied welfare gains from trade, suppose that the domestic trade share is 80 percent (not unusual for a large country such as the United States) and the trade elasticity is 4 (a central value among existing empirical estimates). For these values, the above formula predicts welfare gains from trade relative to autarky of around 6 percent.

However, a crucial assumption behind this expression is that domestic productivity (here a parameter) is constant ($b_n^T = b_n^A$). To the extent that domestic productivity is itself endogenous to trade, this potential source of welfare gains is not captured. If such trade-induced productivity growth is related to the domestic trade share, the above approach can be amended to incorporate this relationship. However, in this case, the functional form relating productivity to the domestic trade share becomes important for evaluating the welfare gains from trade. In the following section, we develop one set of microfoundations for trade-induced domestic productivity growth. But the idea is much more general. It applies to any mechanism through which trade affects domestic productivity: technology adoption, research and development, knowledge spillovers, infrastructure, institutions, and so on.

II. Sequential Production

The model remains exactly the same as in the previous section except that the non-traded final good is produced using a sequence of traded intermediate inputs indexed by their stage of production $s = 1, \ldots, S$. The final good is the output from stage of production S and is produced using the intermediate input from stage $S-1$. The intermediate input from stage $S-1$ is produced using the intermediate input from stage $S-2$, and so on. The intermediate input from stage 1 is produced using a primary input that is manufactured from labor. Each stage of production must be completed for the final good to be produced.[1] The production technology for stage s takes the same form as in (1), where traded intermediate inputs for each stage of production are differ-

[1] Sequential production can have implications for whether economic activities are organized within or beyond the boundaries of the firm, as analyzed in Antràs and Chor (2013).

entiated by country of origin:

$$Y_n^s = \left[\sum_{i=1}^{N} \left(\lambda_i^s Y_{ni}^{s-1} \right)^{\frac{\sigma_s - 1}{\sigma_s}} \right]^{\frac{\sigma_s}{\sigma_s - 1}}, \tag{6}$$

where Y_n^s is country n's output of stage s; Y_{ni}^{s-1} is country n's input of stage $s-1$ output from country i; λ_i^s parameterizes the quality or productivity of the intermediate input from country i for production stage s; the dual unit cost function takes the same form as in (3). We allow iceberg trade costs to differ across stages of production: $d_{ni}^s > 1$ for $n \neq i$ and $d_{nn}^s = 1$. The share of country n's costs for stage of production s on inputs sourced from itself (π_{nn}^s) is:

$$\pi_{nn}^s = \frac{\left(d_{nn} P_n^{s-1} / \lambda_n^s \right)^{1-\sigma_s}}{\sum_{k=1}^{N} \left(d_{nk} P_k^{s-1} / \lambda_k^s \right)^{1-\sigma_s}}. \tag{7}$$

Using this cost share, the unit cost function for stage of production s can be written as:

$$G_n^s = \frac{P_n^{s-1}}{\lambda_n^s} \left[\frac{1}{\pi_{nn}^s} \right]^{\frac{1}{1-\sigma_s}}, \tag{8}$$

where $d_{nn} = 1$. Perfect competition and constant returns to scale imply that the price of each stage of production equals its unit cost: $P_n^s = G_n^s$. Using this result and the expression for the unit cost function (8), we can solve recursively for the price of each stage of production as a function of the price of the previous stage of production:

$$P_n^s = \frac{P_n^{s-1}}{\lambda_n^s} \left[\frac{1}{\pi_{nn}^s} \right]^{\frac{1}{1-\sigma_s}}. \tag{9}$$

Therefore the price of the final good in stage S can be written in terms of the price of the primary input (P_n^0) and the domestic trade share for each stage of production (π_{nn}^s):

$$P_n^S = P_n^0 \prod_{s=1}^{S} \frac{1}{\lambda_n^s} \left[\frac{1}{\pi_{nn}^s} \right]^{\frac{1}{1-\sigma_s}}.$$

The primary input is produced from labor according to the technology (4). Perfect competition and constant returns to scale imply that price equals unit cost: $P_n^0 = w_n/\varphi_n$. Therefore welfare in country n can be written in terms of the domestic trade share for final goods production (π_{nn}^S) and a composite measure of productivity (B_n):

$$\mathbb{W}_n = \frac{w_n}{P_n} = B_n \left(\pi_{nn}^S \right)^{-\frac{1}{\sigma_S - 1}}, \tag{10}$$

$$B_n = \varphi_n \prod_{s=1}^{S} \lambda_n^s \prod_{s=1}^{S-1} \left[\frac{1}{\pi_{nn}^s} \right]^{\frac{1}{\sigma_s - 1}}.$$

The welfare gains from trade are:

$$\frac{\mathbb{W}_n^T}{\mathbb{W}_n^A} = \frac{B_n^T}{B_n^A} \left(\pi_{nn}^{S,T} \right)^{-\frac{1}{\sigma_S - 1}}, \tag{11}$$

$$\frac{B_n^T}{B_n^A} = \prod_{s=1}^{S-1} \left[\frac{1}{\pi_{nn}^s} \right]^{\frac{1}{\sigma_s - 1}},$$

which takes the same form as (5) except that (11) features an endogenous change in domestic productivity in final goods production because of the gains from trade at each intermediate stage of production.

PROPOSITION 1: *The domestic trade shares $\{\pi_{nn}^s\}$ and the trade elasticities $\{\sigma_s - 1\}$ for each stage of production $s \in \{1, \ldots, S\}$ are sufficient statistics for the welfare gains from trade.*

PROOF:

The proposition follows from (11).

PROPOSITION 2: *The welfare gains from trade ($\mathbb{W}_n^T / \mathbb{W}_n^A$) become arbitrarily large as the number of production stages becomes arbitrarily large ($\lim_{S\to\infty} \mathbb{W}_n^T / \mathbb{W}_n^A = \infty$) or the domestic trade share in any one individual stage of production $r \in \{1, \ldots, S\}$ becomes arbitrarily small ($\lim_{\pi_{nn}^r \to 0} \mathbb{W}_n^T / \mathbb{W}_n^A = \infty$).*

PROOF:

The proposition follows from (11).

Trade has a fractal-like property in this model, in which there are gains from trade at each intermediate stage of production. If one falsely assumes a single stage of production, when production is in fact sequential, these gains from trade at each intermediate stage show up as an endogenous increase in domestic productivity. As the number of production stages converges towards infinity, the welfare gains from trade become arbitrarily large. This captures the idea that trade involves myriad changes in the organization of production throughout the economy and the welfare costs from forgoing this pervasive specialization can be large.

As the domestic trade share for an individual production stage becomes arbitrarily small, the welfare gains from trade also become arbitrarily large. This captures the idea that some countries may have strong comparative advantages in some stages of production and the welfare losses from forgoing this specialization can be large. This result for sequential production has similarities and differences with Ossa (2012)'s result in a multi-sector model that the presence of sectors with low trade elasticities can generate large aggregate welfare gains from trade. In contrast, our result holds even if all production stages have the same trade elasticity, because each production stage has to be completed for the final good to be produced.

Our analysis of sequential production is also related to models of 'roundabout' production, in which intermediate inputs enter a Cobb-Douglas production technology through a single CES aggregate (e.g. Krugman and Venables 1995 and Eaton and Kortum 2002). In 'roundabout' production models, measuring the welfare gains from trade simply involves controlling for aggregate information on the share of intermediate inputs in production. In contrast, in our setting with sequential production, correctly computing the welfare gains from trade requires disaggregated information on domestic trade shares and trade elasticities for all stages of production.

While for simplicity we develop these ideas in an Armington framework, the same analysis can be undertaken in for example the Eaton and Kortum (2002) Ricardian model.

III. Conclusions

Substantial progress has been made in quantifying the welfare gains from trade using a class of theoretical models consistent with the gravity equation. These models are rich enough to speak to first-order features of the data, such as country-size and geography, and yet are parsimonious enough to permit model-based counterfactuals. They typically generate relatively modest welfare gains from trade. In this paper, we highlight a channel for trade to affect welfare that has received relatively little attention in this quantitative literature, namely endogenous changes in domestic productivity. Trade can induce a reorganization of production that elevates domestic productivity. Incorporating such endogenous changes in production organization into a model of sequential production, we show that the welfare gains from trade can become arbitrarily large.

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