The Textbook Case for Industrial Policy: Theory Meets Data*

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Abstract

The textbook case for industrial policy is well understood. If some sectors are subject to external economies of scale, whereas others are not, a government should subsidize the first group of sectors at the expense of the second. The empirical relevance of this argument, however, remains unclear. In this paper we develop a strategy to estimate sector-level economies of scale and evaluate the gains from such policy interventions in an open economy. Our benchmark results point towards significant and heterogeneous economies of scale across manufacturing sectors, but only modest gains from industrial policy, below 1% of GDP on average. Though these gains can be larger in some of the alternative environments that we consider, they are always smaller than the gains from optimal trade policy.

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1 Introduction

The textbook case for industrial policy is well understood. In sectors subject to external economies of scale, private marginal costs of production are lower than social ones. This creates a rationale for Pigouvian subsidies equal to the difference between the two, with the associated welfare gains equal to the area of the Harberger triangle located between the demand and social marginal cost curves, as illustrated in Figure 1.

The empirical relevance of the previous considerations is another matter. In his original discussion of optimal industrial policy, Pigou (1920) already noted: "Attempts to develop and expand [these theoretical results] are sometimes frowned upon on the ground that they cannot be applied to practice. For, it is argued, though we may be able to say that [...] economic welfare would be increased by granting bounties to industries falling into one category and by imposing taxes on those falling into another category, we are not able to say which of our categories the various industries of real life belong."

One hundred years later, the challenges that Pigou identified remain obstacles to the pursuit of industrial policy. The goal of our paper is to narrow this gap between theory and data. We first show how to estimate economies of scale across sectors using data that is commonly available. Having identified the sectors that should be subsidized at the expense of others, we then explore the welfare gains from optimal industrial policies as well as how trade openness, and the access to trade policy instruments, may affect the design of industrial policy and its welfare implications. Our main finding is that even under an optimistic scenario where governments aim to maximize social welfare and have full knowledge of the structure of externalities across sectors, gains from industrial policies appear relatively modest, somewhat smaller than those from optimal trade policy.

Section 2 presents our theoretical framework. We study a Ricardian economy with multiple sectors, each subject to external economies of scale. Our focus on this environment is motivated by its long intellectual history, dating back to Marshall (1920), Graham's (1923) famous argument for trade protection, and the formal treatment of external economies of scale in Chipman (1970) and Ethier (1982), as well as the recent emergence of Eaton and Kortum's (2002) Ricardian model as a workhorse model for quantitative work. Within each sector, external economies of scale may affect both the physical productivity of firms as well as the quality of the goods that they produce. In a competitive equilibrium, firms do not internalize the fact that when they increase sector size they raise its quality-adjusted productivity. In the presence of the optimal trade policy, the

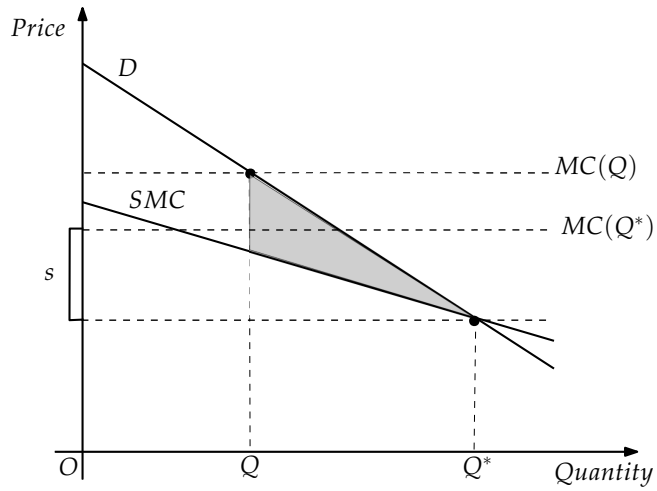


Figure 1: The Textbook Case for Industrial Policy

Notes: Due to external economies of scale in a sector, social marginal cost SMC does not equal private marginal cost MC and so output Q is less than the social optimum Q^*. The optimal industrial policy is a subsidy $s = MC(Q^*) - SMC(Q^*)$, which would give rise to gains equal to the area of the grey triangle.

optimal production subsidy is equal to the elasticity of productivity with respect to size and exactly compensates the firm for the marginal effect of its output decision on sector productivity.

Section 3 turns to identification. We show that external economies of scale can be non-parametrically identified in this environment from standard data on international trade flows. The starting point of our empirical strategy is the observation that in each destination and within each sector, trade flows from different origins reflect the optimal demand for labor services from these countries. Provided that this demand system is invertible, changes in trade flows therefore reveal changes in the effective prices of these services. Once the prices of labor services have been revealed, we can estimate external economies of scale by measuring the extent to which an exogenous increase in sector size lowers such prices.

Section 4 imposes parametric restrictions to implement the previous general strategy with trade and production data that are commonly available. Within each sector, we assume: (i) that productivity is a log-linear function of size, so that we have constant *scale elasticities*; and (ii) that the demand for labor services from different countries takes the Constant Elasticity of Substitution (CES) form, so that we have constant *trade elasticities*.[1]

[1]These parametric restrictions are satisfied by the multi-sector gravity models analyzed in Kucheryavyy et al. (2017), a set that includes models with perfect competition and external economies of scale, as in this paper, but also models with monopolistic competition and free entry, in which case scale effects arise from product differentiation and love of variety within industries, as in Krugman (1980).

Under these restrictions, the (log of the) price of labor services from a country is proportional to (the log of) its sector size, with a slope given by the scale elasticity; and the revealed (log of the) price of labor services is proportional to (the log of) its bilateral exports, with a slope given by the inverse of the trade elasticity. Given existing estimates of sector-level trade elasticities in the literature, we can therefore estimate sector-level scale elasticities using a log-linear regression of bilateral exports, adjusted by the trade elasticity, on sector size.

Since idiosyncratic productivity differences across countries and sectors affect both sector size and bilateral exports, identification requires a demand-side instrumental variable (IV) that is positively correlated with sector size yet uncorrelated with productivity shocks. To construct such an instrument, we first estimate the upper-level elasticity of substitution between goods from different sectors. Given an estimate of this elasticity, we then compute the demand residuals that rationalize observed expenditure shares across sectors and countries. Under the assumption that these demand residuals are uncorrelated with idiosyncratic productivity shocks, the product of demand residuals, in each country-sector pair, and population, in each country, provides a valid (and, in practice, strong) instrument for sector size at the country level. Importantly, our identification strategy deliberately draws on cross-sectional variation alone, so as to isolate the long-run notion of scale economies that animates the textbook case for industrial policy.

Drawing on a dataset comprising 61 of the world's largest countries from 1995-2010, our results point to statistically significant scale elasticities in every 2-digit manufacturing sector, with an average of 0.13. There is also substantial heterogeneity, with sector-level estimates ranging from 0.07 to 0.25. Interestingly, the previous numbers are below the inverse of the trade elasticity in all sectors, implying that our estimated scale elasticities are weaker than those implicitly assumed in trade models with monopolistic competition à la Krugman (1980) or Melitz (2003).[2]

Three auxiliary findings lend support to the validity of these estimates. First, consistent with expected simultaneity bias in an open economy under elastic demand, in which sector size responds positively to productivity, in every sector we find that our demand-based IV estimate is lower than its corresponding OLS estimate. Second, consistent with our demand-based IV, these results are largely invariant to the inclusion of flexible supply-side controls. And finally, while our baseline estimates are obtained from pooling across multiple cross-sections, we obtain very similar estimates from each cross-

[2] Costinot and Rodríguez-Clare (2013) and Kucheryavyy, Lyn and Rodríguez-Clare (2017) offer detailed discussions of the relationship between trade elasticities and scale effects in Krugman (1980) and Melitz (2003).

section separately.

Section 5 uses our empirical estimates to evaluate the gains from industrial policy and to compare them to the gains from trade policy. We focus on the case of an economy that is large enough to affect the price of its own good relative to goods from other countries, but too small to affect relative prices in the rest of the world as well as other countries' employment and expenditure across sectors. For such a small open economy, the optimal policy consists of a mix of trade and industrial policy: sector-specific export taxes—equal to the inverse of one plus the trade elasticity—to improve the country's terms-of-trade, as well as sector-specific production subsidies—equal to the scale elasticity—to address external economies of scale.

We define the gains from industrial and trade policy as the difference between welfare when both optimal trade taxes and production subsidies are in place and welfare when only the other policy, either the export tax or the production subsidy, is in place. Despite large and pervasive external economies of scale, we find that gains from industrial policy in our baseline calibration are hardly transformative. They range from 0.40% of GDP for the United States to 1.36% for Luxembourg, with larger gains for more open economies. On average, gains from optimal industrial policy are equal to 0.69%. To put this number in perspective, the average gains from optimal trade policy that we estimate in the same environment are equal to 0.95% of GDP.[3]

Consistent with the importance of terms-of-trade considerations, we also find that pure Pigouvian taxes may backfire, with Ireland, for instance, experiencing a welfare loss of 1.49% when Pigouvian taxes are not accompanied by optimal export taxes. This tension reflects the fact that our empirical estimates of scale elasticities tend to be negatively correlated with trade elasticities. As a result, sectors whose output should be expanded, for Pigouvian reasons, are also those whose exports should be contracted, for market power reasons.

Section 6 explores the sensitivity of these conclusions to the values of various structural parameters, including scale and trade elasticities, as well as more substantial departures from our baseline Ricardian model. Among other things, we allow for multiple factors of production and input-output linkages across sectors. Though some of these extensions predict significantly larger gains from policy interventions, they all point towards gains from industrial policy that are modest relative to the gains from trade policy.

Because of the prominence of industrial policy in accounts of development and un-

[3]These numbers refer to the welfare change in the country implementing the policy in question. Of course, from a global standpoint, trade policy is a beggar-thy-neighbour policy, as improvements in one country's terms-of-trade necessarily occur at the expense of another country, whereas industrial policy is not.

derdevelopment, a number of theoretical and empirical papers have discussed the rationale and potential consequences of industrial policy, as reviewed in Harrison and Rodríguez-Clare (2010). This includes recent reduced-form work on the consequences of the Napoleonic blockade (Juhasz, 2018), South Korea's transition to a military dictatorship (Lane, 2017), and a place-based manufacturing investment subsidy in the UK (Criscuolo et al., 2019), as well as theoretical work on optimal industrial policy in the presence of financial frictions (Itskhoki and Moll, 2019 and Liu, 2018). There is, however, a dearth of work that has tried to combine both theory and empirics in order to estimate the benefits that textbook industrial policy could achieve in practice.

A notable exception is Lashkaripour and Lugovskyy (2018), which studies a monopolistically competitive environment à la Krugman (1980) where the elasticity of substitution between domestic varieties may differ from the elasticity of substitution between domestic and foreign varieties. In this model, the scale elasticity is indirectly determined by the elasticity of substitution between domestic varieties, whereas the trade elasticity is determined by the elasticity of substitution between domestic and foreign varieties, so estimates of these two demand elasticities, obtained from monthly exchange rate variation in Colombia, can be used to calculate the effects of optimal policy. In contrast, our empirical strategy directly identifies scale elasticities from the responses of sector-level productivity, as revealed by exports, to changes in sector size caused by long-run variation in domestic demand.

Our estimates also relate to a large literature that uses gravity models for counterfactual analysis. As discussed by Costinot and Rodríguez-Clare (2013) and Kucheryavyy et al. (2017), the quantitative predictions of these models hinge on two key elasticities: trade elasticities and scale elasticities. While the former have received significant attention in the empirical literature, as discussed in Head and Mayer (2013), the latter have not. Scale economies, when introduced in gravity models, are instead indirectly calibrated using information about the elasticity of substitution across goods in monopolistically competitive environments; see e.g. Balistreri, Hillberry and Rutherford (2011). One of the goals of our paper is to offer more direct and credible evidence about scale elasticities for use in quantitative multi-sector gravity models.

Finally, our methods for estimating sector-level scale economies build on a large empirical literature concerned with estimating production functions in industrial organization and macroeconomics—see Ackerberg et al. (2007) and Basu (2008) for reviews. Compared to the former, we make no attempt at estimating internal economies of scale at the firm-level. Rather, we focus on external economies at the sector level, which sector-level trade flows reveal. Our focus on economies of scale at the sector level is therefore closer

in spirit to Caballero and Lyons (1992) and Basu and Fernald (1997). A key difference between our approach and theirs is that we do not rely on measures of real output, or price indices, collected by statistical agencies. Instead, we use estimates of the demand for foreign factor services, as in Adao, Costinot and Donaldson (2017), to infer the effective prices of those services. This provides a theoretically-grounded way to adjust for quality differences across origins within the same sector, as well as an approach that works symmetrically for a large set of countries around the world. We come back to these issues in Section 3.2.

Finally, the general idea of using trade data to infer economies of scale bears a direct relationship to empirical tests of the home-market effect; see e.g. Head and Ries (2001), Davis and Weinstein (2003), and Costinot et al. (2019). Indeed, the home-market effect—that is, a positive effect of demand on exports—implies the existence of economies of scale at the sector level. Our empirical strategy is also closely related to previous work on revealed comparative advantage; see e.g. Costinot, Donaldson and Komunjer (2012) and Levchenko and Zhang (2016). The starting point of these papers, like ours, is that trade flows contain information about relative costs of production, a point also emphasized by Antweiler and Trefler (2002).

2 Theory

2.1 Environment

Consider an economy comprising many countries, indexed by i or $j = 1, ..., I$, and many sectors, indexed by $k = 1, ..., K$. Each sector itself comprises many goods, indexed by ω.

Technology. Technology is Ricardian. In any origin country i, the same composite factor, equipped labor, is used to produce all goods in all sectors.[4] We let L_i denote the fixed supply of labor in country i. For any sector k, output of good ω in country i that is available for consumption in country j is given by

$$q_{ij,k}(\omega) = A_{ij,k}(\omega) l_{ij,k}(\omega),$$

[4]This rules out cross-sectoral differences in either factor intensity or input-output linkages in our baseline analysis. We introduce both of these features in Section 6.2.

where $l_{ij,k}(\omega)$ denotes the amount of labor used by firms from an origin country i to produce and deliver good ω to a destination country j.[5] Transportation costs, if any, are reflected in $A_{ij,k}(\omega)$. In turn, these productivities are given by

$$A_{ij,k}(\omega) = \alpha_{ij,k}(\omega) A_{ij,k} E_k^A(L_{i,k}).$$

Here $\alpha_{ij,k}(\omega)$ and $A_{ij,k}$ are exogenous while $E_k^A(L_{i,k})$ captures economies of scale as a function of total sector-level employment, $L_{i,k} = \sum_j \int l_{ij,k}(\omega) d\omega$. For expositional purposes, we shall simply refer to $L_{i,k}$ as sector size.[6]

Preferences. There is a representative agent with weakly separable preferences in each country. The utility of the representative agent in a destination country j is given by

$$U_j = U_j(U_{j,1}, .., U_{j,K}),$$

with $U_{j,k}$ the subutility associated with goods from sector k,

$$U_{j,k} = U_{j,k}(\{B_{ij,k}(\omega) q_{ij,k}(\omega)\}_{i,\omega}).$$

In this expression, $q_{ij,k}(\omega)$ denotes the total amount of good ω from sector k produced in country i and sold to consumers in country j and $B_{ij,k}(\omega)$ is an origin-destination-sector-specific taste shock that captures quality differences. We assume that subutility $U_{j,k}$ is homothetic, that standard Inada conditions hold, and that demand for goods within a sector satisfies the connected substitutes property, as defined in Arrow and Hahn (1971). This will guarantee the invertibility of the demand for labor services in the rest of our analysis. Finally, just as with productivity, we allow quality to be affected by sector size,

$$B_{ij,k}(\omega) = \beta_{ij,k}(\omega) B_{ij,k} E_k^B(L_{i,k}).$$

Below we let $E_k(L_{j,k}) \equiv E_k^A(L_{j,k}) E_k^B(L_{j,k})$ denote the joint effect of external economies of scale operating on the supply and demand sides.

[5]The above specification assumes constant returns to scale at the level of goods ω but does not require constant returns to scale at the level of firms. As is well understood, constant returns to scale at the good level may reflect the free entry of heterogeneous firms, each subject to decreasing returns to scale, as in Hopenhayn (1992). Appendix A.1 makes that point explicitly; we return to it in Section 3.2.

[6]To keep the focus of our analysis on the textbook case for industrial policy, we restrict external effects to occur within a given sector in a country and rule out the possibility of external effects that spill over across sectors or countries.

Taxes. There are three types of taxes in all countries. Production in a given sector k may be subject to an ad-valorem production subsidy, $s_{j,k}$, which creates a wedge between the prices faced by firms and consumers in country j. Imports and exports in a given sector k may also be subject to an import tariff, $t^m_{ij,k}$, and an export tax, $t^x_{ji,k}$. The first trade tax creates a wedge between the price paid by consumers in country j and the price received by firms in country $i \neq j$, whereas the second creates a wedge between the price received by firms in country j and the price paid by consumers in country i. Net revenues from taxes and subsidies are rebated through a lump-sum transfer, T_j, to the representative agent in country j.

2.2 Competitive Equilibrium

We focus on a competitive equilibrium with external economies of scale. In equilibrium, consumers maximize utility taking as given good prices, wages, taxes, and the size of each sector; firms maximize their profits, also taking as given good prices, wages, taxes, and the size of each sector; and all markets clear. The formal definition of a competitive equilibrium can be found in Appendix A.2.

To prepare our analysis of optimal policy, it is convenient to focus on the exchange of labor services between countries, as in Adao et al. (2017). Let $L_{ij,k}$ denote the demand, in efficiency units, for labor from country i in country j within a given sector k, and let $V_j(\{L_{ij,k}\}_{i,k})$ denote the utility of the representative agent in country j associated with a given vector of labor demand,

$$\begin{aligned} V_j(\{L_{ij,k}\}_{i,k}) \equiv \max_{\{\tilde{q}_{ij,k}(\omega),\tilde{l}_{ij,k}(\omega)\}_{i,j,k,\omega}} & U_j(\{U_{j,k}(\{\beta_{ij,k}(\omega)\tilde{q}_{ij,k}\}_{i,\omega})\}_k) \\ \tilde{q}_{ij,k} \leq \alpha_{ij,k}(\omega)\tilde{l}_{ij,k}(\omega) & \text{ for all } \omega,\ i, \text{ and } k, \\ \int \tilde{l}_{ij,k}(\omega)d\omega \leq L_{ij,k} & \text{ for all } i \text{ and } k. \end{aligned}$$

In a competitive equilibrium, the labor services demanded by country j from different origins and sectors, $\{L_{ij,k}\}_{i,k}$, the labor services exported by country j towards different

destinations, $\{L_{ji,k}\}_{i\neq j,k}$, and the sector sizes in country j, $\{L_{j,k}\}_k$, must solve

$$\max_{\{\tilde{L}_{ij,k}\}_{i,k},\{\tilde{L}_{ji,k}\}_{i\neq j,k},\{\tilde{L}_{j,k}\}_k} V_j(\{\tilde{L}_{ij,k}\}_{i,k}) \tag{1a}$$

$$\sum_{i\neq j,k} c_{ij,k}(1+t^m_{ij,k})\tilde{L}_{ij,k} \leq \sum_{i\neq j,k} c_{ji,k}(1-t^x_{ji,k})\tilde{L}_{ji,k} + T_j, \tag{1b}$$

$$\sum_i \eta_{ji,k}\tilde{L}_{ji,k} \leq (1+s_{j,k})E_{j,k}\tilde{L}_{j,k}, \text{ for all } k, \tag{1c}$$

$$\sum_k \tilde{L}_{j,k} \leq L_j, \tag{1d}$$

where $E_{j,k} \equiv E_k(L_{j,k})$ measures external economies of scale; $\eta_{ji,k} \equiv 1/(A_{ij,k}B_{ij,k})$ captures systematic productivity and quality differences; and $c_{ij,k} \equiv \eta_{ij,k}w_i/[(1+s_{i,k})(1-t^x_{ij,k})E_{i,k}]$ corresponds to the effective price of labor from country i in country j and sector k—that is, the wage w_i adjusted by the export tax $t^x_{ij,k}$, the production subsidy $s_{i,k}$, the systematic productivity and quality differences $\eta_{ij,k}$, and the external economies of scale $E_{i,k}$.

Equation (1b) is the trade balance condition. It states that the value of labor services imported by country j is no greater than the value of its exports. Equations (1c) captures technological constraints; it states that total demand for labor services across destinations i, adjusted by the bilateral exogenous efficiency term $\eta_{ji,k}$, can be no greater than the total supply, in efficiency units, in country j and sector k. The term $E_{j,k}$ reflects the fact that because of economies of scale, an increase in sector size leads either to larger quantities or higher quality goods being produced with a given amount of labor, and hence an increase in the amount of labor services supplied in efficiency units. Since firms do not internalize this effect, $E_{j,k}$ is taken as given in the above problem. Finally, equation (1d) is the labor market clearing condition; it states that the sum of labor allocated across sectors k can be no greater than the total labor supply in country j.

For future reference, we let $x_{ij,k} = [(1+t^m_{ij,k})c_{ij,k}L_{ij,k}]/(\sum_{i'}[(1+t^m_{i'j,k})c_{i'j,k}L_{i'j,k}])$ denote the share of expenditure in destination j on labor services from country i in sector k. In a Ricardian environment, this also corresponds to the share of expenditure on goods from sector k produced in country i. In what follows, we shall simply refer to $\{x_{ij,k}\}$ as trade shares. As shown in Appendix A.3, trade shares in a perfectly competitive equilibrium are given by

$$x_{ij,k} = \chi_{ij,k}((1+t^m_{1j,k})c_{1j,k}, ..., (1+t^m_{Ij,k})c_{Ij,k}), \tag{2}$$

where the function $\chi_{j,k} \equiv (\chi_{1j,k}, ..., \chi_{Ij,k})$ is homogeneous of degree zero, invertible, and determined by $U_{j,k}$, $\{\alpha_{i,k}(\omega)\}$ and $\{\beta_{ij,k}(\omega)\}$.

2.3 Optimal Policy

We now turn to the analysis of optimal policy. By optimal, we mean the vector of trade and production taxes or subsidies that maximize the utility of the representative agent in a given country j, taking as given policies in other countries. We further assume that country j is small in the sense that it can only affect the price of its own good relative to goods from other countries: relative prices, sector-level employment, and sector-level expenditure in the rest of the world are all taken as exogenously given by its government. As argued below, this restriction is irrelevant for the structure of optimal industrial policy, which is our main focus in this paper.

We proceed in two steps. First, we consider the problem of a government that can directly choose consumption and production in order to maximize utility in country j. Second, we show how the solution to that planning problem can be decentralized through sector-level production and trade taxes.

Government Problem. The problem of country j's government is

$$\max_{\{\tilde{L}_{ij,k}\}_{i,k},\{\tilde{L}_{ji,k}\}_{i\neq j,k},\{\tilde{L}_{j,k}\}_k} V_j(\{\tilde{L}_{ij,k}\}_{i,k}) \tag{3a}$$

$$\sum_{i\neq j,k} c_{ij,k}\tilde{L}_{ij,k} \leq \sum_{i\neq j,k} c_{ji,k}(\tilde{L}_{ji,k})\tilde{L}_{ji,k}, \tag{3b}$$

$$\sum_i \eta_{ji,k}\tilde{L}_{ji,k} \leq E_k(\tilde{L}_{j,k})\tilde{L}_{j,k}, \text{ for all } k, \tag{3c}$$

$$\sum_k \tilde{L}_{j,k} \leq L_j. \tag{3d}$$

There are two key differences between problems (1) and (3).

First, country j's government internalizes sector-level economies of scale, $E_k(\tilde{L}_{j,k})$, whereas firms and consumers do not. This explains why $E_k(\tilde{L}_{j,k})$ in equation (3c) depends on the choice variable, $\tilde{L}_{j,k}$, rather than its equilibrium value, $L_{j,k}$, as in equation (1c). This creates a rationale for Pigouvian taxation—that is, production subsidies, $\{s_{j,k}\}$—that may be non-zero at the optimum.

Second, the government recognizes its market power on foreign markets, whereas firms and consumers do not. In the small open economy case that we focus on, country j's government takes import prices, $c_{ij,k} \equiv \eta_{ij,k}w_i/[(1+s_{i,k})(1-t^x_{ij,k})E_{i,k}]$, as given for any origin country $i \neq j$. But it internalizes the fact that export prices, $c_{ji,k}(L_{ji,k})$, are a function

of its own exports, $L_{ji,k}$, with this function implicitly given by the price $c_{ji,k}$ that solves

$$\chi_{ji,k}((1+t^m_{1i,k})c_{1i,k},...,(1+t^m_{Ii,k})c_{Ii,k}) = \frac{(1+t^m_{ji,k})c_{ji,k}L_{ji,k}}{\sum_{i'\neq j}(1+t^m_{i'i,k})c_{i'i,k}L_{i'i,k}+(1+t^m_{ji,k})c_{ji,k}L_{ji,k}}, \quad (4)$$

with the equilibrium costs of other exporters, $\{c_{i'i,k}\}_{i'\neq j}$, as well as their exports of labor services, $\{L_{i'i,k}\}_{i'\neq j}$, taken as given. The fact that firms and consumers ignore such effects creates a rationale for export taxes, $\{t^x_{ji,k}\}_{i,k}$, that manipulate country j's terms-of-trade.

Implementation. To characterize the structure of optimal policy, we compare the solutions to (1) and (3) and derive necessary conditions on production subsidies and trade taxes such that the two solutions coincide.

Consider first the solution to (3). The first-order conditions with respect to $\{\tilde{L}_{j,k}\}_k$, $\{\tilde{L}_{ji,k}\}_{i\neq j,k}$, and $\{\tilde{L}_{ij,k}\}_{i,k}$ imply

$$\begin{aligned}
[E'_k(L_{j,k})L_{j,k}+E_k(L_{j,k})]\rho_{j,k} &= \rho_j,\\
\lambda_j[c'_{ji,k}(L_{ji,k})L_{ji,k}+c_{ji,k}(L_{ji,k})] &= \eta_{ji,k}\rho_{j,k},\\
dV_j(\{L_{ij,k}\}_{i,k})/dL_{ij,k} &= \lambda_j c_{ij,k}, \text{ if } i\neq j,\\
dV_j(\{L_{ij,k}\}_{i,k})/dL_{ij,k} &= \eta_{ij,k}\rho_{j,k}, \text{ if } i=j.
\end{aligned}$$

where λ_j, $\{\rho_{j,k}\}$ and ρ_j denote the values of the Lagrange multipliers associated with constraints (3b)-(3d) at the optimal allocation.

Now suppose that the same allocation arises at the solution to (1). The first-order conditions associated with this problem imply

$$\begin{aligned}
(1+s_{j,k})E_k(L_{j,k})\rho^e_{j,k} &= \rho^e_j,\\
\lambda^e_j(1-t^x_{ji,k})c_{ji,k}(L_{ji,k}) &= \eta_{ji,k}\rho^e_{j,k},\\
dV_j(\{L_{ij,k}\}_{i,k})/dL_{ij,k} &= \lambda^e_j(1+t^m_{ij,k})c_{ij,k}, \text{ if } i\neq j,\\
dV_j(\{L_{ij,k}\}_{i,k})/dL_{ij,k} &= \eta_{ij,k}\rho^e_{j,k}, \text{ if } i=j,
\end{aligned}$$

where λ^e_j, $\{\rho^e_{j,k}\}_k$ and ρ^e_j denote the values of the Lagrange multipliers associated with constraints (1b)-(1d). A comparison of these two sets of first-order conditions leads to the following proposition.

Proposition 1. *For a small open economy j, the unilaterally optimal policy consists of a combi-*

nation of production and trade taxes such that, for some $s_j, t_j > -1$,

$$1 + s_{j,k} = (1 + s_j)(1 + \frac{d \ln E_k}{d \ln L_{j,k}}), \textit{for all } k,$$
$$1 - t^x_{ji,k} = (1 + t_j)(1 + \frac{d \ln c_{ji,k}}{d \ln L_{ji,k}}), \textit{for all } i \textit{ and } k,$$
$$1 + t^m_{ij,k} = 1 + t_j, \textit{for all } i \textit{ and } k.$$

The two shifters, s_j and t_j, reflect two distinct sources of tax indeterminacy. First, since labor supply is perfectly inelastic, a uniform production tax or subsidy s_j only affects the level of factor prices in country j, but leaves the equilibrium allocation unchanged. Second, a uniform increase in all trade taxes again affects the level of prices in country j, but leaves the trade balance condition and the equilibrium allocation unchanged, an expression of Lerner Symmetry. In the rest of our analysis, we normalize both s_j and t_j to zero. Hence optimal trade policy only requires export taxes, whereas optimal industrial policy only requires production subsidies.

It is worth noting that while we have focused on the case of a small open economy, this restriction is only relevant for the structure of optimal trade policy, which would depend, in general, on the entire vector of imports and exports by country j. The optimal Pigouvian tax, in contrast, is always given by $\frac{d \ln E_k}{d \ln L_{j,k}}$. Formally, this derives from the fact that the technological constraints (1c) and (3c) are unchanged in the case of a large open economy, as described in Appendix A.4.

3 Identification

Section 2 highlights the importance of two structural objects for optimal policy design: (i) $\chi_{j,k}$, which determines trade shares in the rest of the world and, in turn, export prices for country j; and (ii) E_k, which determines external economies of scale across sectors. Under the assumption that demand in each sector satisfies standard Inada conditions and the connected substitutes property, $\chi_{j,k}$ is invertible and non-parametrically identified from variation in $c_{ij,k}$ under standard orthogonality conditions, as discussed in Adao, Costinot and Donaldson (2017). Our goal in this section is to provide conditions under which, given knowledge of $\chi_{j,k}$, E_k is non-parametrically identified as well.

The basic idea is to start by inverting demand in order to go from the trade shares, which are observed, to the effective prices of labor services, which are not. Once the prices have been inferred, we can then estimate external economies of scale by measuring

the extent to which an exogenous increase in sector size lowers such prices.

3.1 Non-Parametric Identification of External Economies of Scale

Formally, let $\chi^{-1}_{ij,k}(x_{1j,k}, ..., x_{Ij,k})$ denote the effective price of the labor services from country i in country j and sector k, up to some normalization. For any pair of origin countries, i_1 and i_2, and any sector k_1, equation (2) implies

$$\ln \frac{\chi^{-1}_{i_1j,k_1}(x_{1j,k_1}, ..., x_{Ij,k_1})}{\chi^{-1}_{i_2j,k_1}(x_{1j,k_1}, ..., x_{Ij,k_1})} = \ln \frac{E_{k_1}(L_{i_2,k_1})}{E_{k_1}(L_{i_1,k_1})} + \ln \frac{w_{i_1}}{w_{i_2}} + \ln \frac{\tilde{\eta}_{i_1j,k_1}}{\tilde{\eta}_{i_2j,k_1}},$$

with $\tilde{\eta}_{ij,k} \equiv [\eta_{ij,k}(1 + t^m_{ij,k})]/[(1 - t^x_{ij,k})(1 + s_{i,k})]$. Taking a second difference relative to another sector k_2, we therefore have

$$\begin{aligned} \ln \frac{\chi^{-1}_{i_1j,k_1}(x_{1j,k_1}, ..., x_{Ij,k_1})}{\chi^{-1}_{i_2j,k_1}(x_{1j,k_1}, ..., x_{Ij,k_1})} - \ln \frac{\chi^{-1}_{i_1j,k_2}(x_{1j,k_2}, ..., x_{Ij,k_2})}{\chi^{-1}_{i_2j,k_2}(x_{1j,k_2}, ..., x_{Ij,k_2})} \\ = \ln \frac{E_{k_1}(L_{i_2,k_1})}{E_{k_1}(L_{i_1,k_1})} - \ln \frac{E_{k_2}(L_{i_2,k_2})}{E_{k_2}(L_{i_1,k_2})} + \ln \frac{\tilde{\eta}_{i_1j,k_1}}{\tilde{\eta}_{i_2j,k_1}} - \ln \frac{\tilde{\eta}_{i_1j,k_2}}{\tilde{\eta}_{i_2j,k_2}}. \end{aligned} \tag{5}$$

Given two origin countries, i_1 and i_2, two sectors, k_1 and k_2, and a destination country j, equation (5) is a nonparametric regression model with endogenous regressors and a linear error term,

$$y = h(l) + \epsilon,$$

where the endogenous variables, y and l, the function to be estimated, $h(\cdot)$, and the error term, ϵ, are given by

$$\begin{aligned} y &\equiv \ln \frac{\chi^{-1}_{i_1j,k_1}(x_{1j,k_1}, ..., x_{Ij,k_1})}{\chi^{-1}_{i_2j,k_1}(x_{1j,k_1}, ..., x_{Ij,k_1})} - \ln \frac{\chi^{-1}_{i_1j,k_2}(x_{1j,k_2}, ..., x_{Ij,k_2})}{\chi^{-1}_{i_2j,k_2}(x_{1j,k_2}, ..., x_{Ij,k_2})}, \\ l &\equiv (L_{i_1,k_1}, L_{i_2,k_1}, L_{i_1,k_2}, L_{i_2,k_2}), \\ h(l) &\equiv \ln \frac{E_{k_1}(L_{i_2,k_1})}{E_{k_1}(L_{i_1,k_1})} - \ln \frac{E_{k_2}(L_{i_2,k_2})}{E_{k_2}(L_{i_1,k_2})}, \\ \epsilon &\equiv \ln \frac{\tilde{\eta}_{i_1j,k_1}}{\tilde{\eta}_{i_2j,k_1}} - \ln \frac{\tilde{\eta}_{i_1j,k_2}}{\tilde{\eta}_{i_2j,k_2}}. \end{aligned}$$

Economically speaking, the endogeneity of the regressors, $E[\epsilon|l] \neq 0$, simply reflects the fact that sectors with higher productivity, higher quality, or lower trade costs in a given origin country will also tend to have larger sizes. The identification of $h(\cdot)$ therefore

requires a vector of instruments.

Newey and Powell (2003) provide general conditions for nonparametric identification in such environments. Specifically, if there exists a vector of instruments z that satisfies the exclusion restriction, that $E[\epsilon|z] = 0$, as well as the completeness condition, that $E[g(l)|z] = 0$ implies $g = 0$ for any g with finite expectation, then $h(\cdot)$ is nonparametrically identified. As shown in Appendix A.5, once $h(\cdot)$ is identified, both E_{k_1} and E_{k_2} are also identified, up to a normalization that is irrelevant for policy analysis. In the next section, we will propose such a vector of instruments and use it to estimate sector-level external economies of scale.

3.2 Discussion

Before turning to our empirical analysis, we briefly discuss the robustness of our approach as well as some of the relative costs and benefits of this approach as compared to alternative methods for estimating scale economies.

Perfect versus Imperfect Competition. The nonparametric identification of external economies of scale above is conducted under the assumption of perfect competition, in which prices are equal to unit costs. This assumption allows us to infer how variation in sector sizes affects costs, and hence economies of scale, by estimating how the variation in sector sizes affects prices, as revealed by trade shares. While this might suggest that perfect competition is critical for our empirical strategy, this is not the case, as an example (developed formally in Appendix A.6) illustrates. Suppose that we introduce an imperfectly competitive retail sector that buys goods at their marginal costs and sells these goods at a profit. In this economy, retailers will impose different markups on different goods, but markups in sector k and country j will still be a function of $(c_{1j,k}, ..., c_{Ij,k})$, and hence we can still express trade shares as a function of these prices, $\chi_{j,k}(c_{1j,k}, ..., c_{Ij,k})$, as well as estimate this function from variation in $c_{ij,k}$. Hence, external economies are nonparametrically identified under the same conditions as under perfect competition, regardless of whether good prices are equal to their marginal costs or not.[7]

[7]This establishes that perfect competition is not critical for our empirical strategy, not that there does not exist imperfectly competitive models under which variation in markups would affect our inferences about the magnitude of external economies of scale. Costinot et al. (2019) discuss one such example. In their model, an increase in the number of firms producing in a given origin country and sector lowers the markup charged by those firms everywhere, leading to a decrease in the prices faced by importing countries, absent any external economies of scale.

Internal versus External Economies of Scale. As we have already noted, our model is consistent with the existence of internal economies of scale at the firm-level, provided that there is free entry in the production of each good, as in Hopenhayn (1992) and Appendix A.1. If so, as the total number of workers employed to produce a good ω increases, the measure of entering firms increases in a proportional manner, while the number of workers per firm remains unchanged, making firm-level economies of scale irrelevant for our results. Absent free entry, production functions at the good level may no longer be constant returns and economies of scale estimated at the sector level may therefore reflect a mixture of both internal and external economies of scale. This concern offers an additional motive for estimating demand and scale functions, as we do below, through the use of relatively long-run variation, in which the assumption of free entry is more appropriate.

Alternative Methods for Estimating External Economies of Scale. We have established above how one can use data on trade shares, $\{x_{ij,k}\}$, and sector sizes, $\{L_{i,k}\}$, to identify external economies of scale E_k. An obvious benefit of this empirical strategy is that trade data are easily available for a large number of countries, sectors, and years. An obvious cost is that identification relies on knowledge of the $\chi_{j,k}$ system. While $\chi_{j,k}$ is also required, independently from E_k, for the design and evaluation of optimal policy, if one were interested in E_k alone then alternative estimation methods would also be available. We discuss such alternatives here.

In many settings researchers have access to micro-level data. On the production side, such data can be used to estimate firm-level production functions such as,

$$q = E_k^A(L_{i,k})F(l, \phi),$$

where ϕ is an index of productivity that may vary across firms producing the same good ω in country i and sector k, as discussed further in Appendix A.1. This would amount to first estimating $F(l, \phi)$ and then estimating $E_k^A(L_{i,k})$ by investigating how firms' productivity residuals relate to sector size, with a similar need for instrumental variables as discussed in Section 3.1. Similarly, with micro-level data on consumption and prices one could estimate the (potentially extremely high-dimensional) *within*-sector demand system for all goods and then infer $E_k^B(L_{i,k})$ by estimating how firms' demand residuals are affected by exogenous increases in sector size. Our approach instead folds the estimation of these two micro-level functions, production functions and demand systems, into a single macro-level function, the effective demand (in any destination j) for factor services

from country i in sector k given by $\chi_{ij,k}$. One downside of this approach is that it does not allow us to separately identify $E_k^A(L_{i,k})$ and $E_k^B(L_{i,k})$, but it does identify the combination, $E_k(L_{i,k}) = E_k^A(L_{i,k})E_k^B(L_{i,k})$, which is all that will matter for optimal industrial policy.

Another approach would draw on macro-level data on sector-level quantity indices $Q_{i,k}$. Provided that these indices have been constructed so as to correctly adjust for quality and variety differences, an estimate of how exogenous changes in sector sizes, $L_{i,k}$, affect $Q_{i,k}$ would also identify E_k. The key difference between this macro approach and ours therefore boils down to the the nature of the quality adjustment. In our case, this adjustment derives from the estimation of demand for factor services from different countries and the associated residuals. In the case of the macro-data approach, it is left to the statistical agency in charge of computing price deflators.[8]

4 Estimation

The characteristics of textbook industrial policy hinge on the extent of external economies of scale. In Section 2, we have shown how optimal industrial policy can be constructed given knowledge of $E_k(\cdot)$. In Section 3, we have further demonstrated how knowledge of this function could be obtained, nonparametrically, from conventional data and exogenous variation in sector size. In this section we describe the empirical procedure that we use to obtain estimates of this function, before using them in Section 5 to assess the consequences of industrial policy.

4.1 Parametric Restrictions

The identification results presented in Section 3 are asymptotic in nature. They reveal conditions under which, in theory, one could point-identify external economies of scale, E_k, in all sectors with a dataset that includes an infinite sequence of economies. In this context, we have established that, given an exogenous shifter of sector sizes, one can identify external economies of scale by tracing out the impact of changes in sector sizes on prices, as revealed by changes in equilibrium trade shares.

[8]While the appropriate exact price index is only obtainable with knowledge of the entire within-sector demand system, in many contexts one can more easily construct a first-order approximation to that index, such as Laspeyres or Paasche. However, in the economic environment that we consider in Section 2.1, there may not exist a single-output technology at the country-sector level because, within a sector, different goods may be sold by the same country to different destinations. In such cases, there is no theoretically grounded expenditure function that the measured price index would be a first-order approximation to. Focusing on trade in factor services circumvents this concern.

In practice, researchers have limited data variation from which to learn about the relatively aggregate and long-run phenomena involved in external economies of scale. For example, as we discuss below, the dataset we use here includes only four time periods and 61 countries. So, estimation inevitably needs to proceed parametrically. In the rest of our analysis, we impose the following functional-form assumptions on the factor demand system $\chi_{ij,k}$ and external economies of scale E_k at all times t:

$$\chi_{ij,k}((1+t^{m,t}_{1j,k})c^t_{1j,k},...,(1+t^{m,t}_{Ij,k})c^t_{Ij,k}) = \frac{((1+t^{m,t}_{ij,k})c^t_{ij,k})^{-\theta_k}}{\sum_{i'}((1+t^{m,t}_{i'j,k})c^t_{i'j,k})^{-\theta_k}}, \tag{6}$$

$$E_k(L^t_{i,k}) = (L^t_{i,k})^{\gamma_k}. \tag{7}$$

These choices have the advantage of focusing our empirical analysis on the elasticities that matter for the design of optimal policy. Equation (6) states that bilateral trade shares between an origin country i and a destination j in any sector k satisfy a gravity equation with trade elasticity θ_k. Costinot et al. (2012) describe a multi-sector extension of Eaton and Kortum (2002) that provides micro-theoretical foundations for such a functional form. The same micro-foundations can be invoked in the presence of external economies of scale, as in Kucheryavyy et al. (2017). Equation (7) allows external economies of scale to vary across sectors, as is critical for industrial policy considerations, but restricts the elasticity of external economies γ_k to be constant within each sector.

In addition, for the purposes of assessing the welfare gains from optimal policy, which also depends on the sector-level elasticity of demand, as Figure 1 illustrates, we must specify the upper-level utility function U_j. This also plays a role in our instrumental variable estimation procedure below. We do so under the assumption that the elasticity of substitution across manufacturing sectors is constant as well. Hence, we can express country j's share of expenditure on a manufacturing sector $k \in M$, across all origins, as

$$x^t_{j,k} = \frac{\exp(\varepsilon^t_{j,k})(P^t_{j,k})^{1-\rho}}{\sum_{l\in M}\exp(\varepsilon^t_{j,l})(P^t_{j,l})^{1-\rho}}, \tag{8}$$

where ρ is the elasticity of substitution between sectors, $\varepsilon^t_{j,k}$ is an exogenous preference parameter, and $P^t_{j,k}$ is sector k's price index in country j given by

$$P^t_{j,k} \equiv \left[\sum_i((1+t^{m,t}_{ij,k})c^t_{ij,k})^{-\theta_k}\right]^{-1/\theta_k}. \tag{9}$$

One feature to note about the functional forms in equations (6)-(9) is that all level-shifters can change over time, but the elasticities $\{\theta_k\}$, $\{\gamma_k\}$, and ρ cannot. This implies that, while we use data from multiple time periods, this is not necessary for estimation; we could proceed instead with data from just one time period. Choosing the former over the latter merely allows us to take advantage of the increased statistical precision that comes from pooling the data from multiple cross-sections.

4.2 Empirical Strategy

We now discuss our procedure for obtaining estimates of scale elasticities γ_k.

Baseline Specification. Let $x^t_{ij,k}$ denote the trade share of exporter i for importer j in sector k and period t. Given equations (6) and (7), equation (5) simplifies into

$$\frac{1}{\theta_{k_2}} \ln\left(\frac{x^t_{i_1 j,k_2}}{x^t_{i_2 j,k_2}}\right) - \frac{1}{\theta_{k_1}} \ln\left(\frac{x^t_{i_1 j,k_1}}{x^t_{i_2 j,k_1}}\right) = \gamma_{k_1} \ln\left(\frac{L^t_{i_2,k_1}}{L^t_{i_1,k_1}}\right) - \gamma_{k_2} \ln\left(\frac{L^t_{i_2,k_2}}{L^t_{i_1,k_2}}\right) + \ln\left(\frac{\tilde{\eta}^t_{i_1 j,k_1}}{\tilde{\eta}^t_{i_2 j,k_1}}\right) - \ln\left(\frac{\tilde{\eta}^t_{i_1 j,k_2}}{\tilde{\eta}^t_{i_2 j,k_2}}\right).$$

The fixed-effect counterpart of this difference-in-difference specification is

$$\frac{1}{\theta_k} \ln(x^t_{ij,k}) = \delta^t_{ij} + \nu^t_{j,k} + \gamma_k \ln L^t_{i,k} + \epsilon^t_{ij,k}, \tag{10}$$

where δ^t_{ij} and $\nu^t_{j,k}$ represent exporter-importer-year and importer-sector-year fixed effects, respectively, and $\epsilon^t_{ij,k} \equiv -\ln \tilde{\eta}^t_{ij,k}$.[9] Equation (10) will be our baseline specification.

Three features of this specification are worth emphasizing. First, because sector size $L^t_{i,k}$ would respond endogenously to the idiosyncratic productivity shocks that are part of $\epsilon^t_{ij,k}$, ordinary least squares (OLS) estimates of equation (10) would be biased, as already discussed in Section 3. Hence, estimation of the supply-side parameter γ_k requires demand-side instrumental variables for sector size $L^t_{i,k}$. Second, because we aim to es-

[9] Fixing some exporter i_2 and sector k_2, these fixed effects satisfy the following structural relationships:

$$\delta^t_{ij} \equiv \frac{1}{\theta_{k_2}} \ln\left(\frac{x^t_{ij,k_2}}{x^t_{i_2 j,k_2}}\right) - \gamma_{k_2} \ln(L^t_{i,k_2}) + \ln\left(\frac{\tilde{\eta}^t_{ij,k_2}}{\tilde{\eta}^t_{i_2 j,k_2}}\right),$$
$$\nu^t_{j,k} \equiv \frac{1}{\theta_k} \ln(x^t_{i_2 j,k}) - \gamma_k \ln(L^t_{i_2,k}) + \gamma_{k_2} \ln(L^t_{i_2,k_2}) + \ln \tilde{\eta}^t_{i_2 j,k}.$$

timate the long-run scale elasticities γ_k that motivate textbook industrial policy, we deliberately exploit long-run, cross-sectional variation alone; put differently, it is important that exporter-sector fixed effects do not appear in equation (10). Finally, because equation (10) includes exporter-importer-year fixed effects, which are necessary in order to control for the exporter's wage w_i^t and any differences in aggregate productivity, it cannot be estimated separately sector-by-sector. Formally, one should therefore think of the endogenous variables as the entire vector of sector sizes, $\{\ln L_{i,k}^t\}_k$, interacted with a full set of K sector indicators. Identification therefore requires at least K instrumental variables that shift sector sizes in independent directions. We now describe a procedure for constructing such variables.

Construction of Instrumental Variables. To construct demand-side, cross-sectional instruments for sector size, we propose to start from estimates (to be described below) of country-and-sector-level demand shocks, $\exp(\varepsilon_{j,k}^t)$, in equation (8). Because $\{\exp(\varepsilon_{j,k}^t)\}_k$ govern expenditure shares, rather than levels, we then formulate a prediction for the levels of country j's demand for goods from sector k as $\widehat{D}_{j,k}^t \equiv \exp(\widehat{\varepsilon}_{j,k}^t)\overline{L}_j^t$, using data on total population $\overline{L}_j^t$. Finally, given those demand-side estimates, we construct the K instrumental variables for (log) sector size $\ln L_{i,k}^t$, interacted with K sector indicators, as (log) predicted demand $\ln(\widehat{D}_{j,k}^t)$, interacted with the same K sector indicators. This provides a (just-identified) 2SLS system.[10] The exclusion restriction being imposed is that after conditioning on importer-exporter-year and importer-sector-year fixed effects, predicted demand in country i and sector k at year t, $\ln(\widehat{D}_{j,k}^t)$, is mean-independent of the supply-side shocks, $\{\epsilon_{i'j',k'}^{t'}\}$.[11]

To obtain estimates of country-and-sector-level demand shocks, $\hat{\varepsilon}_{j,k}^t$, we use data on sector-level expenditures. Let $X_{j,k}^t \equiv \sum_i X_{ij,k}^t$ denote the expenditure by importer j on all goods (from all origins i) in manufacturing sector k at time t and let $x_{j,k}^t \equiv X_{j,k}^t / \sum_{s \in M} X_{j,s}^t$ be the share of expenditures in sector k as a share of total manufacturing expenditures. If upper-level preferences were Cobb-Douglas ($\rho = 1$), we would directly infer that $\exp(\hat{\varepsilon}_{j,k}^t) = x_{j,k}^t$, up to a normalization. But more generally, we also need estimates of

[10] One unusual feature of our 2SLS estimation system of equations is that the first-stage equation involves a more aggregate level of variation than the (bilateral) second-stage equation. However, this poses no difficulties of interpretation or inference given that we cluster the standard errors in all of the following regressions (first-stage and second-stage) at the exporter-sector level. In addition to correcting for unrestricted forms of serially correlated errors over time, this clustering procedure has the advantage of correcting for the purely mechanical within-group (that is, within-exporter-sector-year) correlation in the first-stage.

[11] We note that in this model 2SLS is a limited-information approach to consistent estimation of the scale elasticity parameters γ_k. But relative to full-information approaches, which would use the full structure of the model to derive an efficient nonlinear estimator, linear 2SLS offers the benefit of simplicity and draws on finite-sample theory that is relatively well understood.

sector-level price indices, $\hat{P}^t_{j,k}$, and the elasticity of substitution, $\hat{\rho}$, to recover the demand residuals in equation (8). Appendix B.1 describes in detail how we obtain those by (i) inferring sector-level price indices, $\hat{P}_{j,k}$, from importer-sector-year fixed effects in a gravity equation and (ii) instrumenting those prices with country population times a full set of sector indicators, drawing on the supply-based logic of our economies of scale model.[12]

4.3 Measurement

To estimate scale elasticities γ_k in equation (10) using predicted demand as instruments, we need measures of trade shares $x^t_{ij,k}$, population $\overline{L}^t_i$, and sector size, $L_{i,t}$. We discuss each of these in turn.

Trade Shares. We obtain data on bilateral trade flows $X^t_{ij,k}$ from the OECD's Inter-Country Input-Output (ICIO) tables. This source documents bilateral trade among 61 major exporters i and importers j, listed in Table B.8, within each of 34 sectors k (27 of which are traded, with 15 in manufacturing) defined at a similar level to the 2-digit SIC, and for each year $t = 1995$, 2000, 2005, and 2010. The 15 manufacturing sectors k, listed in Table 1, are those for which we aim to estimate γ_k.[13] Since ICIO tables also include domestic sales $X^t_{ii,k}$ in all sectors, we can measure trade shares directly as $x^t_{ij,k} = X^t_{ij,k} / \sum_l X^t_{lj,k}$.

Population. We take our preferred measure of population $\overline{L}^t_i$ from the "POP" variable in the Penn World Tables version 9.0. In practice this variable is highly correlated with alternative measures such as the total labor force.

Sector Size. According to the baseline model developed here, the total wage bill in a sector is equal to total sales across all destinations, $w^t_i L^t_{i,k} = \sum_j X^t_{ij,k}$, and total employment across sectors is equal to total labor supply, which further implies $w^t_i L^t_i = \sum_k \sum_j X^t_{ij,k}$.

[12] In the presence of $\gamma_k > 0$, we know that a country j's productivity in any sector k will be increasing in $L^t_{j,k}$. While sector size $L^t_{j,k}$ is endogenously determined, a natural candidate to predict such sector scale (especially for the empirically relevant case of low import penetration in most sectors) is the country's overall scale, driven by its population $\overline{L}^t_j$. We expect this overall country size to have a differential impact on productivity, and hence price reduction, across sectors depending on the relative strength of economies of scale γ_k. This suggests constructing IVs from the interaction between $\overline{L}^t_j$ and γ_k. Since γ_k is unknown at this stage—indeed, our procedure for estimating γ_k relies on knowledge of the parameter ρ that is the goal here—we simply construct IVs from the interaction of $\overline{L}^t_j$ and a set of sector indicators. In line with the previous logic, we will later confirm that there is a strong (inverse) correlation between the first stage coefficients here, on each sector interaction variable, and the sector's corresponding estimate of γ_k.

[13] We omit sector 18, Recycling and Manufacturing NEC, from the estimation.

Combining these two observations, and using population $\bar{L}_i^t$ as a proxy for labor supply L_i^t, we can therefore measure sector size $L_{i,k}^t$ as $\left(\frac{\sum_j X_{ij,k}^t}{\sum_{k'} \sum_j X_{ij,k'}^t}\right) \bar{L}_i^t$.[14]

4.4 Estimates of Scale Elasticities

Auxiliary Results. The estimation of scale elasticities γ_k requires estimates of two auxiliary parameters: (i) the elasticity of substitution between manufacturing sectors ρ, to construct our demand-side instruments; and (ii) trade elasticities θ_k in each sector, to construct our dependent variables. We begin with a discussion of these auxiliary estimates.

Our estimate of ρ is reported in Table B.2, with the corresponding first-stage results in Table B.1. The IV estimate is $\widehat{\rho} = 1.47$, which is lower than the OLS estimate (of $\widehat{\rho} = 3.35$) as is consistent with the presence of increasing returns at the sector level. When supply curves slope downwards, positive demand shocks lead to reductions in prices. Hence, the OLS estimate of the impact of prices on expenditure shares, which confounds a truly downward-sloping demand curve with the negative correlation between demand shocks and prices, will be an underestimate of $1 - \rho$, leading to an overestimate of ρ.

Trade elasticities θ_k in manufacturing sectors have already been estimated by various researchers. For our baseline analysis, we take the median estimate, within each sector, from the following recent studies: Bagwell, Staiger and Yurukoglu (2018), Caliendo and Parro (2015), Giri, Yi and Yilmazkuday (2018), and Shapiro (2016). The resulting estimates are described in Table B.3. We explore the sensitivity of our results to using alternative trade elasticities in Section 6.1.

Main Results. OLS estimates of γ_k from equation (10) are reported in column (1) of Table 1. All of these estimates imply precisely-estimated economies of scale (i.e. $\gamma_k > 0$) but, as discussed, we expect OLS to deliver biased estimates of true economies of scale. For this reason we turn to the IV estimation procedure documented in Section 4.2. Recall that this corresponds to a 2SLS system in which there are 15 endogenous variables (the variable $\ln L_{i,k}^t$ interacted with an indicator variable for each sector) and 15 instruments (the variable $\ln\left(\widehat{\varepsilon}_{i,k}^t \overline{L}_i^t\right)$, again interacted with an indicator variable for each sector). While this means that there are 15 first-stage equation estimates to report (each with 15 coefficients), the F-statistic from each of these first-stage equations is large, as reported in columns (4)

[14] Given this measure of sector size, any discrepancy between population and labor supply in efficiency units is therefore also implicitly part of the error term in equation (10). That is, if $L_i^t = \xi_i^t \bar{L}_i^t$, then the error term also includes $\gamma_k \ln \xi_i^t$, with our exclusion applying to this term as well—though, as we describe in Section 4.4, our estimates are robust to the inclusion of controls for per-capita GDP interacted with sector-year dummies, which lends support to this assumption.

Table 1: Estimates of Sector-Level Scale Elasticities (γ_k)

Sector	OLS (1)	2SLS (2)	Reduced-form (3)	First-stage F-stat (4)	SW F-stat (5)
Food, Beverages and Tobacco	0.19	0.16	0.10	87.20	394.3
	(0.01)	(0.02)	(0.02)		
Textiles	0.14	0.12	0.06	56.70	349.9
	(0.01)	(0.01)	(0.02)		
Wood Products	0.13	0.11	0.05	15.50	210.7
	(0.01)	(0.02)	(0.01)		
Paper Products	0.14	0.11	0.05	55.60	661.9
	(0.01)	(0.02)	(0.01)		
Coke/Petroleum Products	0.09	0.07	0.03	14.20	299.1
	(0.01)	(0.01)	(0.01)		
Chemicals	0.23	0.20	0.17	31.10	335.8
	(0.01)	(0.02)	(0.02)		
Rubber and Plastics	0.29	0.25	0.22	39.13	436.0
	(0.02)	(0.03)	(0.03)		
Mineral Products	0.16	0.13	0.08	40.50	405.0
	(0.01)	(0.02)	(0.01)		
Basic Metals	0.13	0.11	0.07	14.40	254.0
	(0.01)	(0.01)	(0.01)		
Fabricated Metals	0.16	0.13	0.07	57.10	421.1
	(0.01)	(0.02)	(0.01)		
Machinery and Equipment	0.15	0.13	0.07	66.40	401.6
	(0.01)	(0.01)	(0.01)		
Computers and Electronics	0.10	0.09	0.04	18.60	290.5
	(0.01)	(0.01)	(0.01)		
Electrical Machinery, NEC	0.11	0.09	0.03	45.90	419.5
	(0.01)	(0.01)	(0.01)		
Motor Vehicles	0.17	0.15	0.15	39.80	390.2
	(0.01)	(0.01)	(0.02)		
Other Transport Equipment	0.17	0.16	0.11	24.00	381.6
	(0.01)	(0.02)	(0.02)		

Notes: Column (1) reports the OLS estimate, and column (2) the 2SLS estimate, of equation (10). Column (3) reports the reduced form coefficients. The instruments are the log of (country population $\times$ sectoral demand shifter), interacted with sector dummies. Column (4) reports the conventional F-statistic, and column (5) the Sanderson-Windmeijer F-statistic, from the first-stage regression corresponding to each row. All regressions control for importer-sector-year fixed-effects and (asymmetric) trading pair-year effects. Standard errors in parentheses are clustered at the exporter-sector level. The number of obserations (unique exporter-importer-sector-years) is 207,542.

and (5), so potential concerns about finite-sample bias from weak instruments seem not to apply here. The first-stage coefficient estimates themselves are summarized in Table B.4.[15]

The 2SLS estimates of γ_k are reported in column (2) of Table 1. These are our preferred estimates of the strength of economies of scale within each of the 15 manufacturing sectors in our sample. The results point to substantial economies of scale—with an average scale elasticity of 0.13—that are statistically significantly different from zero in every sector. At the same time, there is widespread heterogeneity, with estimates ranging from $\gamma_k = 0.07$ in the Coke/Petroleum Products sector to $\gamma_k = 0.25$ in the Rubber and Plastics sector. We can easily reject the hypothesis of coefficient equality at the 1% level. This heterogeneity is important for the scope for industrial policy, as we discuss in Section 5.

Another feature of these estimates is that, in each sector, the OLS estimate of γ_k is larger than its corresponding 2SLS estimate. This downward OLS bias is to be expected in an open economy in which countries specialize in sectors where they have a comparative advantage; further, it is consistent with our finding that the elasticity of substitution between sectors, ρ, is greater than one, which magnifies the impact of productivity differences on specialization.

Finally, column (3) reports the reduced-form parameter estimates of the impact of predicted (log) demand, $\ln(\widehat{D}^t_{i,k})$, on the dependent variable, $\frac{1}{\theta_k}\ln(x^t_{ij,k})$. We see that countries with higher predicted demand in a sector tend to have larger exports in that sector. This is again consistent with the the existence of increasing returns at the sector level, which implies that positive shocks to domestic demand cause lower prices and, in turn, greater exports. This is a manifestation of the home-market effect.[16]

Robustness. The estimates of γ_k in Table 1 are obtained from pooling across four cross-sections: 1995, 2000, 2005 and 2010. As a first robustness check, we consider each of these cross-sections separately. The new estimates of γ_k, displayed in Table B.5, are very similar. The largest relative change in scale elasticities, across all sector and year estimates, is that

[15]Specifically, Table B.4 reports, for each first-stage regression, that the demand residual-based IV for any given sector has a strong correlation with its own sector size and a far weaker correlation with any other sector's size. Consequently, as seen in column (4) of Table 1, the conventional F-statistic from the 15 instruments in each first-stage equation is large and the Sanderson and Windmeijer (2016) F-statistic in column (5), which assesses the extent to which each first-stage is affected by independent variation in the instruments from that in the other 14 first-stages, is considerably larger.

[16]Echoing that view, the first-stage results corresponding to the estimation of the elasticity substitution ρ reported in Table B.1 show that the impact of country size on sector-level prices is negative in all sectors but one. Further, the correlation between these sector-specific first-stage coefficients and the estimates of $\widehat{\gamma}_k$ is -0.94, which is strongly consistent with the negative correlation one would again expect to obtain if sectors with stronger scale economies see larger price reductions due to scale.

for the Mineral Products sector which changes from 0.13 in the baseline to 0.16 for 2005. In addition, the lowest SW F-statistic across these 60 first-stage regressions is 101.8. These findings highlight how it is fundamentally stable, cross-sectional variation that drives our estimates of γ_k.

The 2SLS estimates of γ_k in Table 1 further requires that unobserved determinants of comparative advantage, which are absorbed in the error term $\epsilon^t_{ij,k}$ of equation (10), are orthogonal to our instruments. As an additional robustness check, we now explore the sensitivity of our estimates to controlling for systematic sources of Ricardian comparative advantage.

A prominent source of Ricardian comparative advantage stems from differences in institutions across countries and the differential implications that those institutions have for productivity across sectors; see Nunn and Trefler (2014) for a survey. As proxies for institutional quality, we use a measure of contract enforcement and a measure of financial development, thereby encompassing the sources of comparative advantage stressed in Levchenko (2007) and Nunn (2007) as well as Beck (2002) and Manova (2008).[17] Our controls correspond to interaction terms between exporting country-level measures of institutional quality and sector-year dummies, which hence allows for any form of systematic Ricardian comparative advantage based on contract enforcement or financial development. The results from including this set of controls are reported in Table B.6. We see only minor changes in the estimates of γ_k as compared to our baseline estimates.

To go beyond institutional sources of comparative advantage, we include as additional covariates a set of interactions between the exporter's per capita GDP and sector-year dummies.[18] This controls for any potential reason for relatively rich countries to be differentially productive in certain sectors. Again, referring to Table B.6, including these additional controls has no appreciable effect on our estimates or inference.

Put together, these results imply that our 2SLS strategy utilizes variation in sector size driven by factors that appear to be orthogonal both to sources of Ricardian comparative advantage that have featured in prior work and to sources derived from differences in overall productivity. As we shall see in Section 6.2, this remains true for the cases of comparative advantage driven by Heckscher-Ohlin sources and differential prices of intermediate inputs. This lends credence to the view that our estimates draw only on demand-side variation in order to identify the supply-side scale economies γ_k.

[17] Our measure of contract enforcement is the "rule of law" variable (as measured in 1997-98) due to Kaufmann, Kraay and Mastruzzi (2003), as used in Nunn (2007). And our measure of financial development is the (log of the) ratio of private bank credit to GDP (as measured in 1997), as also used in Nunn (2007).

[18] We obtain data on per-capita GDP by dividing the real output variable, "RGDPO", in the Penn World Tables by $\overline{L}^t_i$.

5 The Gains from Industrial Policy

5.1 The Calibrated Economy

Throughout our quantitative exercise, we maintain the parametric restrictions imposed in equations (6) and (7). Thus, scale elasticities are given by γ_k, whereas trade elasticities are given by θ_k. To calibrate γ_k, we use the 2SLS estimates reported in column (2) of Table 1 for all manufacturing sectors and set $\gamma_k = 0$ for all non-manufacturing sectors. This implies that there are welfare gains from reallocating resources from non-manufacturing to manufacturing sectors which have $\gamma_k > 0$, and so the overall gains from industrial policy will be higher than if we had set γ_k in non-manufacturing to some positive value. We consider alternative cases in the sensitivity analysis of Section 5.3. To calibrate θ_k, we use the median values of the trade elasticities from recent studies reported in column (5) of Table B.3 for each manufacturing sector, in line with the empirical analysis of Section 4, and we set $\theta_k = 6.85$ for all non-manufacturing sectors, which is the median elasticity throughout manufacturing.

Following the theoretical analysis of Section 2.3, we treat each country as a small open economy and impose the normalization $s_j = t_j = 0$. By Proposition 1, optimal industrial and trade policy are therefore given by

$$s_{j,k} = \gamma_k, \text{ for all } k, \tag{11}$$

$$t^x_{ji,k} = \frac{1}{1+\theta_k}, \text{ for all } k \text{ and } i \neq j, \tag{12}$$

$$t^m_{ij,k} = 0, \text{ for all } k \text{ and } i, \tag{13}$$

where the second expression uses $d\ln c_{ji,k}/d\ln L_{ji,k} = -(1 - d\ln\chi_{ji,k}/d\ln c_{ij,k})^{-1}$, by equation (4).

To quantify the welfare gains from these policies, we also need to take a stand on the upper-level utility function, U_j, that determines expenditures and the elasticity of substitution across sectors. Like in Section 4, we assume that upper-level preferences are CES with elasticity of substitution ρ across all sectors,

$$U_j(U_{j,1},..,U_{j,K}) = [\sum_k (\exp(\varepsilon_{j,k}))^{\frac{1}{\rho}} (U_{j,k})^{\frac{\rho-1}{\rho}}]^{\frac{\rho}{\rho-1}}.$$

In our baseline exercise, we set $\rho = 1.47$, in line with the 2SLS estimate for manufacturing sectors reported in column (2) of Table B.2. This implies the same elasticity of substitution between manufacturing and non-manufacturing sectors as within manufacturing

sectors. As we discuss further below, this leads to higher gains from industrial policy than if we had assumed an elasticity of substitution between manufacturing and non-manufacturing below one, as estimated in some recent studies, e.g., Comin, Lashkari and Mestieri (2015) and Cravino and Sotelo (2019). Overall, our calibration choices are on the more aggressive side, to give a chance for industrial policy to yield high gains—as we see below, even with these choices, the gains are on the low side.

Finally, as in Dekle, Eaton and Kortum (2008), we compute counterfactual equilibria under optimal policies using exact hat algebra under the assumption that the initial equilibrium observed in the data (corresponding to 2010, the final year in our dataset) features neither taxes nor subsidies and that trade deficits D_i correspond to transfers across countries, with $\sum_i D_i = 0$. The full non-linear system of equations that determines these counterfactual changes can be found in Appendix A.7.

5.2 Baseline Results

Table 2 shows the gains from optimal trade and industrial policy for a subset of countries as well as the average across countries, both unweighted and weighted by GDP. Results for each of the 61 countries in our dataset can be found in Table B.8.

Column (1) reports the gains from the fully optimal policy, i.e., export taxes equal to $1/(1+\theta_k)$ and production subsidies equal to γ_k, whereas columns (2) and (3) report the gains from using only one of these two policy instruments.[19] We define the gains from optimal trade policy as the gains from introducing export taxes $1/(1+\theta_k)$ conditional on having optimal production subsidies γ_k in place. These gains are equal to the difference between columns (1) and (2), which is displayed in column (4). Analogously, we define the gains from optimal industrial policy as the gains from introducing production subsidies γ_k conditional on the presence of optimal export taxes $1/(1+\theta_k)$, which correspond to the difference between column (1) and (3) displayed in column (5).

The policy in column (2) optimally addresses domestic distortions but on the whole is suboptimal because it does not consider the terms-of-trade implications of industrial policy. Similar considerations apply to the policy in column (3): it internalizes the terms-of-trade externality, but ignores external economies of scale. In both cases, welfare losses are possible, as policies that only target one of the two distortions may aggravate the other.[20] In contrast, the results in columns (4) and (5) are always positive because they

[19] That is, in column (2) export taxes are set to zero, whereas production subsidies are equal to γ_k. And in column (3) production subsidies are set to zero, whereas export taxes are equal to $1/(1+\theta_k)$.

[20] As an extreme example, imagine an economy that: (i) exports all of its output, so that production subsidies and export taxes are perfect substitutes; and (ii) features $\gamma_k\theta_k = 1$ for all k. In this case the

Table 2: Gains from Optimal Policies, Selected Countries

Country	Optimal Policy (1)	Ind. Policy Only (2)	Trade Policy Only (3)	Gains from Trade Policy (4)	Gains from Ind. Policy (5)
United States	0.55%	0.21%	0.15%	0.34%	0.40%
China	0.66%	0.36%	0.15%	0.30%	0.51%
Germany	0.91%	-0.13%	0.18%	1.04%	0.73%
Ireland	1.56%	-1.49%	0.26%	3.05%	1.31%
Vietnam	1.41%	0.44%	0.62%	0.97%	0.79%
Avg., Unweighted	**1.05%**	**0.10%**	**0.36%**	**0.95%**	**0.69%**
Avg., GDP-weighted	**0.71%**	**0.14%**	**0.20%**	**0.57%**	**0.51%**

Notes: Each column reports the gains, expressed as a share of initial real national income, that could be achieved by each type of policy. See the text for detailed descriptions of the exercises. Column (4) equals the difference between columns (1) and (2); likewise, column (5) is defined as the difference between columns (1) and (3).

bring the economy towards full efficiency. In particular, the optimal Pigouvian tax γ_k cannot decrease welfare because terms-of-trade externalities are already internalized through the export taxes $1/\left(1+\theta_k\right)$, in the same way that such trade policy would prevent immiserizing growth.

The results in Table 2 reveal that the gains from optimal policy (column 1) are on average 1.05%. The gains from optimal industrial policy (column 5) are smaller than those from optimal trade policy (column 4): focusing on the unweighted average across countries, these gains are 0.69% and 0.95%, respectively. Going back to the textbook case for industrial policy illustrated in Figure 1, these modest average gains from industrial policy are broadly in line with those predicted by the areas of Harberger triangles. Expressed as a fraction of total income, the sum of the Harberger triangles associated with production subsidies s_k across all manufacturing sectors is

$$\frac{\Delta W}{Y} = \frac{1}{2} \sum_{k \in M} \left(\frac{L_k}{L} \right) \frac{s_k^2}{\epsilon_k^d + \epsilon_k^s},$$

where ϵ_k^d and ϵ_k^s are the inverse of the demand and supply elasticities in sector k, respectively. Following the logic in the Introduction, we can approximate the gains from industry policy by the Harberger triangles associated with production subsidies $s_k = \gamma_k$

optimal policy is laissez-faire, because $(1+\gamma_k)(1-\frac{1}{1+\theta_k}) = 1$. Then both columns (2) and (3) would report welfare losses.

across manufacturing sectors. As a simple back-of-the-envelope calculation, we set L_k/L to 0.28, the average share of manufacturing in gross output, s_k to 0.13, the average of scale elasticities that we have estimated for manufacturing sectors, ϵ_k^s to $-0.13/(1+0.13)$, in line with $p_k \propto Q_k^{-\gamma_k/(1+\gamma_k)}$, and ϵ_k^d to $1/1.47$, in line with our estimate of $\rho = 1.47$.[21] This implies that

$$\frac{\Delta W}{Y} = \frac{1}{2} \times (0.28) \times \frac{(0.13)^2}{(1/1.47) - (0.13/1.13)} \simeq 0.42\%,$$

not too far from the 0.69% (unweighted world average) estimated taking into account general equilibrium effects and trade. Intuitively, for gains from industrial policy to be large, there must be either a large subsidy γ_k—which increases the height of the triangle—or a large quantity response of employment to the subsidy, due to either a high initial level of employment or large demand and supply elasticities—which increases the base of the triangle. Empirically, this is not what we observe.

Our quantitative results exhibit substantial heterogeneity across countries. Smaller countries, in particular, gain more from optimal trade and industrial policy than larger ones. This is revealed by the fact that, for each of columns (1), (4), and (5), the simple average is higher than the corresponding GDP-weighted average. As an example, Ireland has gains from optimal policy that are almost three times higher than those of the United States (1.56% vs 0.55%). The gap is particularly large for the gains from trade policy (3.05% vs 0.34%), but the pattern also holds for the gains from industrial policy (1.31% vs 0.40%). The reason why smaller countries gain more from optimal trade policy is simple: such a policy improves a country's terms-of-trade, and since small countries tend to trade more, they benefit more from that improvement.[22]

Being more open also explains why smaller countries gain more from optimal industrial policy. This is illustrated in Figure 2, which shows a scatter plot of the gains from industrial policy (vertical axis) against openness measured as exports plus imports over gross output (horizontal axis). Intuitively, inelastic domestic demand exerts a weaker restraint on labor reallocation in more open economies, and so there is more scope for industrial policy to generate gains. One way to see this formally is to consider the utility associated with domestic employment in an open economy. Compared to a closed

[21] The Harberger formula displayed above implicitly assumes quasi-linear preferences and autarky. Under these assumptions, our empirical estimate of $\rho = 1.47$ corresponds to the (common) elasticity of demand in each manufacturing sector.

[22] In our model, like in any standard gravity model, all countries face the same trade elasticity. Under our small open economy assumption, this implies that all countries have the same ability to manipulate their terms-of-trade. More generally, absent the small open economy assumption, larger countries would have a greater ability to manipulate their terms-of-trade. However, within the class of standard gravity models, Costinot and Rodríguez-Clare (2013) find that this channel is extremely weak even for the largest countries.

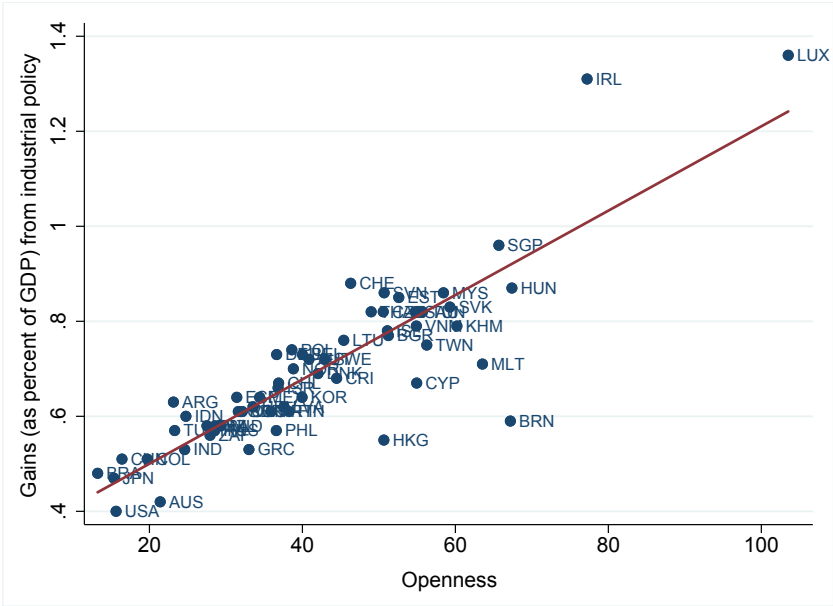


Figure 2: Gains from Optimal Industrial Policy and Openness

economy, this utility no longer corresponds to that derived from domestic factor services alone, since some of those services can be exported and foreign factor services can be imported. We therefore expect the demand for domestic factor services to be more elastic in the open economy, a version of Le Châtelier's Principle.[23] If so, the areas of Harberger triangles should be bigger as well, leading to greater gains from industrial policy.[24]

5.3 Gains from Industrial Policy in the Presence of Trade Agreements

The previous quantitative results assume that countries are free to pursue their unilaterally optimal trade policies. In practice, explicit trade agreements or implicit threats of

[23]Formally, one can express the utility associated with domestic employment in an open economy as

$$V_j^{open}(\{\{L_{j,k}\}_k\}) \equiv \max_{\{\tilde{L}_{ij,k}\}_{i,k},\{\tilde{L}_{ji,k}\}_{i\neq j,k}} V_j(\{\tilde{L}_{ij,k}\}_{i,k})$$
$$\sum_{i\neq j,k} c_{ij,k}\tilde{L}_{ij,k} \leq \sum_{i\neq j,k} c_{ji,k}(\tilde{L}_{ji,k})\tilde{L}_{ji,k},$$
$$\sum_i \eta_{ji,k}\tilde{L}_{ji,k} \leq E_k(L_{j,k})\tilde{L}_{j,k}, \text{ for all } k.$$

Since V_j^{open} is given by the upper-envelope, the associated indifference curves must be less convex than the indifference curves associated with V_j.

[24]The Harberger formula above also suggests that countries with higher employment in sectors with stronger scale economies should benefit more from industrial policy. Our quantitative results are also consistent with this prediction: countries with a higher correlation between L_k/L and γ_k do indeed have higher gains from optimal industrial policy. However, compared to the variation in openness across countries, this channel only explains a small fraction of the variation in the gains from industrial policy.

foreign retaliation may prevent countries from doing so. How would such considerations affect the gains from industrial policy?

We address this issue under two benchmark scenarios. In the first case, countries are forced to set zero trade taxes, but still face incentives to manipulate their terms-of-trade using industrial policy, as in Lashkaripour and Lugovskyy (2018). In the second, we assume that, despite the availability of other policy instruments, trade agreements have been designed to internalize terms-of-trade externalities and restore global efficiency, as in Bagwell and Staiger (2001).

Under the first scenario, we numerically find the production subsidies that maximize utility in a given country conditional on zero trade taxes. As mentioned above, these constrained-optimal production subsidies involve a compromise between the textbook Pigouvian motive of internalizing production externalities and the goal of improving the country's terms-of-trade.[25] Column (2) of Table 3 reports the gains from industrial policy under this first scenario.[26] For convenience, column (1) reports again the gains from industrial policy when trade policy is unconstrained as well, i.e., column (5) of Table 2. On average, the gains from this type of constrained industrial policy are a bit lower than those from the optimal industrial policy reported in our baseline, with the unweighted world average decreasing from 0.69% to 0.56%, but the basic message is the same: the gains are smaller than those from optimal trade policy, and are higher for more open countries.

Under the second scenario, we assume that production subsidies are chosen in a Pareto-efficient manner, with lump-sum transfers between countries available if necessary. Hence, only the Pigouvian motive remains and all countries set production subsidies equal to the scale elasticities: $s_{i,k} = \gamma_k$ for all i, k. The gains from industrial policy (gross of lump-sum transfers between countries, if any) in this case are reported in column (3) of Table 3. The GDP-weighted average of the gains associated with this policy is 0.22%, but with (gross of transfer) gains of 1.36% in Vietnam and losses of 1.81% in Ireland. Such welfare losses derive from adverse terms-of-trade effects: larger production subsidies in sectors with high scale elasticities cause an expansion of these sectors and a deterioration of the terms-of-trade of countries specializing in them.[27]

[25] As an example, consider again an economy that exported all its output, as in footnote 20, but now without imposing $\gamma_k \theta_k = 1$ for all k. In this case production subsidies would perfectly replicate the effect of both the production subsidies and export taxes in the unconstrained policy case, with the subsidies now equal to $(1 + \gamma_k) \frac{\theta_k}{1+\theta_k} - 1$. As long as there is some sector in which part of domestic production is sold at home, however, the constrained-optimal production subsidies will deviate from those and the corresponding gains will be strictly lower than those when policy is unconstrained.

[26] Results for all countries in our dataset can be found in Table B.9.

[27] The correlation between the gains from industrial policy in column (3) of Table 3 and the comparative advantage of countries in high scale elasticity sectors (which we measure simply as the correlation, within

Table 3: Gains from Constrained and Globally Efficient Industrial Policies, Selected Countries

Country	Baseline Industrial Policy (1)	Constrained Industrial Policy (2)	Globally Efficient Industrial Policy (3)
United States	0.40%	0.31%	0.42%
China	0.51%	0.41%	0.21%
Germany	0.73%	0.36%	-0.36%
Ireland	1.31%	0.83%	-1.81%
Vietnam	0.79%	0.80%	1.36%
Avg., Unweighted	**0.69%**	**0.56%**	**0.29%**
Avg., GDP-Weighted	**0.51%**	**0.38%**	**0.22%**

Notes: Each column reports the gains, expressed as a share of initial real national income, that could be achieved by each type of policy. See the text for detailed descriptions of the exercises.

6 Sensitivity Analysis

We conclude by exploring the sensitivity of our findings regarding the magnitude of the gains from industrial policy. In Section 6.1, we start by considering alternative values for the main parameters used in our quantitative exercise: scale elasticities γ_k, trade elasticities θ_k, and the elasticity of substitution between sectors ρ. We then turn in Section 6.2 to a more significant departure from our baseline Ricardian framework that allows for multiple factors of production and input-output linkages.

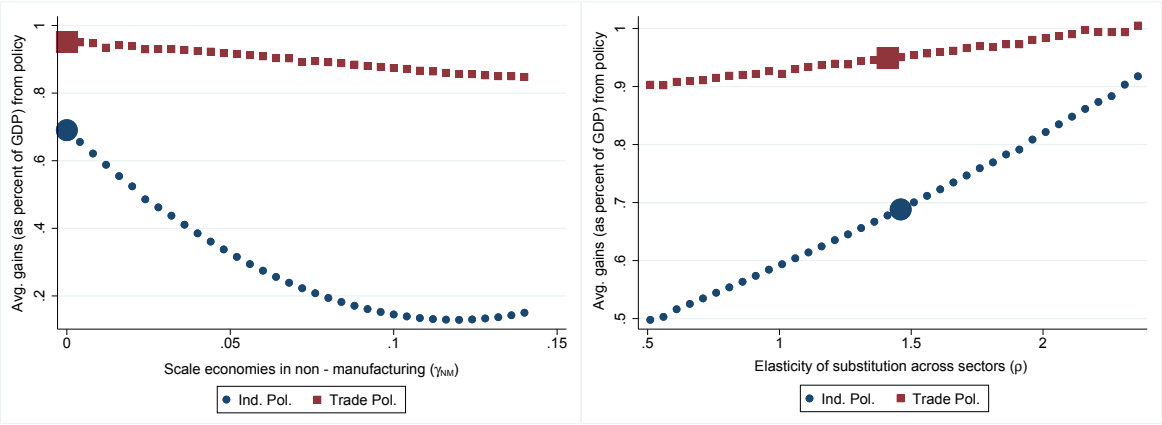
6.1 Alternative Elasticities

Scale Economies in Non-Manufacturing. We begin with the implications of the value of scale economies in non-manufacturing sectors, a parameter that we denote γ_{NM}. Our baseline assumption of $\gamma_{NM} = 0$—in which economies of scale are the province of the manufacturing sectors alone—might correspond to the traditional view behind industrial policy. But in the absence of strong evidence to suggest that industrial sectors have superior economies of scale, it seems important to explore the quantitative implications of this assumption.

To shed light on this issue, Figure 3a plots the average of the estimated gains from optimal industrial policy (across all countries in the world) as a function of γ_{NM}.[28] Not

each country, between its sector-level net exports and sector scale elasticities), is equal to -0.4.

[28] We continue to calculate the gains from optimal policy as described in equations (11)-(13); that is, now



(a) Scale Elasticity Outside Manufacturing (γ_{NM}) **(b)** Elasticity of Substitution between Sectors (ρ)

Figure 3: Gains from Industrial and Trade Policy, Alternative Values of γ_{NM} and ρ

surprisingly, as we start raising γ_{NM} from zero, the relative size of manufacturing and non-manufacturing sectors in the competitive equilibrium gets closer to its optimal value and the gains from industrial policy fall. Indeed, the gains are minimized when γ_{NM} is equal to 0.12, or approximately equal to the average of the manufacturing sector γ_k values of 0.13. Our baseline finding that the gains from optimal industrial policy are relatively modest therefore appears to hold across a wide range of reasonable values for scale elasticities outside manufacturing. And it continues to be the case that, throughout this range, the gains from trade policy remain substantially larger than the gains from industrial policy.

Elasticity of Substitution Across Sectors. We next consider the role played by the elasticity of substitution ρ. In our baseline analysis, we have used our 2SLS estimate $\rho = 1.47$. Table B.2 reports a 95% confidence interval of $[0.55, 2.39]$. In Figure 3b, we therefore plot the average gains from optimal industrial policy throughout this range. As discussed above, we expect that a higher ρ would lead to larger reallocations in response to optimal industrial policy and, in turn, larger welfare gains. Qualitatively, this is confirmed in Figure 3b. Quantitatively, however, we see that even for $\rho = 2.39$, the average gains from industrial policy are only 0.93%, still below the gains from trade policy.

Trade Elasticities. Trade elasticities play a dual role in our analysis: first, they affect the inverse factor demand system that we use to estimate scale elasticities γ_k in equation

that $\gamma_{NM} > 0$ the optimal policy includes a production subsidy in non-manufacturing sectors.

Table 4: Gains from Industrial Policy, Alternative Trade Elasticities (θ_k)

Country	Baseline (1)	Shapiro (2)	BSY (3)	CP (4)	GYY (5)	Truncated CP (6)
United States	0.40%	0.56%	0.38%	3.67%	1.33%	1.39%
China	0.51%	0.80%	0.48%	4.24%	1.55%	2.20%
Germany	0.73%	1.02%	0.68%	7.37%	1.92%	3.10%
Ireland	1.31%	2.03%	1.11%	5.20%	3.06%	2.11%
Vietnam	0.79%	1.24%	0.73%	7.99%	1.95%	2.38%
Avg., Unweighted	**0.69%**	**0.92%**	**0.68%**	**4.81%**	**1.84%**	**2.03%**
Avg., GDP-Weighted	**0.51%**	**0.73%**	**0.49%**	**4.26%**	**1.48%**	**1.84%**
Corr. with Baseline	**-**	**0.77**	**0.90**	**0.28**	**0.77**	**0.32**

Notes: Each column reports the gains from industrial policy for the corresponding trade elasticity estimates reported in Table B.3. Column (1) replicates the baseline calculation, which uses the median trade elasticity in each sector across the studies in columns (2)-(5). Columns (2)-(5) reports a similar calculation using trade elasticity estimates from each of these studies (Shapiro, 2016; Bagwell et al., 2018; Caliendo and Parro, 2015; and Giri et al., 2018) individually. Column (6) recalculates column (4) but for trade elasticities that are truncated at the second-lowest and second-highest values. The last row reports the correlation, across countries, of the gains from industrial policy with those in column (1).

(10); and second, they shape the gains from optimal policy for any given value of γ_k. Our baseline estimates used θ_k from prior estimates in the literature, taking the median estimate of θ_k, within each sector, across four recent studies in the literature. We now instead estimate the gains from optimal policy when drawing trade elasticities from each of those four studies in turn. In each case we repeat the entire two-step estimation procedure from Section 4 for the new vector of θ_k values under consideration.[29]

The results of this exercise are shown in Table 4. Each column represents the estimated gains from optimal industrial policy obtained from a given set of trade elasticity estimates, and each row represents a country (or average over all countries). Although there is a wide range of trade elasticity estimates across these four studies (as seen in Table B.3), estimated gains from industrial policy remain fairly similar for three out of four of these studies, ranging from 0.68% to 1.84% on average. The outlier is column (4), which draws on estimates from Caliendo and Parro (2015) that contain a much broader range of trade elasticities across sectors, from 0.4 to 64.9, than the other studies. Using these parameter estimates leads, in turn, to significantly larger gains from industrial policy, equal

[29] In a small number of cases this procedure results in $\gamma_k\theta_k \geq 1$, which leads to multiplicity of equilibria, as pointed out by Kucheryavyy et al. (2017). We therefore cap the value of γ_k such that $\gamma_k\theta_k$ is never higher than 0.975 (since the solution of the counterfactual equilibrium under optimal policy becomes numerically unstable as $\gamma_k\theta_k$ approaches one from below).

to 4.81% on average. The same extreme variation in trade elasticities leads to gains from trade policy that are also much larger, equal to 19.08% on average, almost four times the gains from industrial policy.

As a way to illustrate the importance of extreme values of trade elasticities, the last column of Table 4 presents a case in which we truncate the values of θ_k in Caliendo and Parro (2015). Namely, we use values in the range between 1.45 and 16.52 only, which are the second-lowest and second-highest values respectively, and bottom- and top-code the values outside this range. This results in more modest gains from industrial policy, equal to 2.03% on average, closer to those obtained using the other three studies. Similarly, the average gains from trade policy amount to 3.83% in this case. Our baseline analysis, which focuses on the median of trade elasticities across studies, is purposefully designed to attenuate the potential effects of outliers.

6.2 Beyond Ricardian Economies

In our baseline analysis, we have focused on Ricardian economies with (equipped) labor as the only factor of production. In our final robustness check, we relax this assumption and introduce physical capital as well as input-output linkages, along the same lines as in Caliendo and Parro (2015). The full model is described in Appendix A.8.1.

Within this environment, the optimal production subsidies, $s_{j,k}$, and trade taxes, $t^x_{ji,k}$ and $t^m_{ij,k}$, remain as described in Proposition 1, as demonstrated in Appendix A.8.2. The non-parametric identification of external economies of scale can proceed following the same steps as in Section 3 given knowledge of the factor demand system, $\chi_{j,k}$, and the sector-level production function f_k that maps labor, physical capital, and intermediate goods into a country-and-sector specific composite factor.[30]

For our empirical and quantitative analysis, we maintain the same parametric restrictions as in Section 4—that is, $\chi_{ij,k}$ and E_k satisfy equations (6) and (7), respectively—and further assume that f_k is Cobb-Douglas, with average shares consistent with the OECD's ICIO tables. The description of our estimation procedure can be found in Appendix B.3.4, whereas the counterpart of the exact hat algebra of Section 5 used to produce counterfactual scenarios can be found in Appendix A.8.3.

Figure 4 plots the scale elasticities, γ_k, estimated in the model with physical capital and input-output linkages against the scale elasticities estimated in our baseline Ricar-

[30]We maintain the assumption that sector-level production functions, f_k, are constant across countries, but allow for Hicks-neutral differences across countries and sectors. Hence, differences in factor endowments may now also act as a source of comparative advantage. In our simulations, the assumption of a common f_k across countries rules out extreme patterns of international specialization across countries.

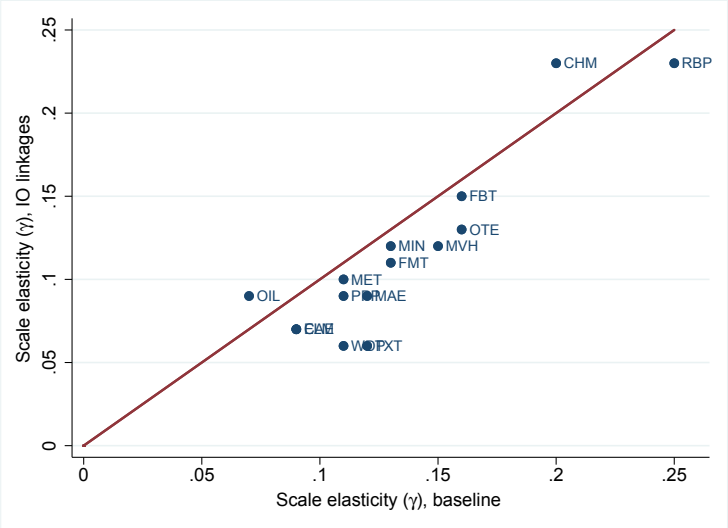


Figure 4: Scale Elasticities, Beyond Ricardian Economies

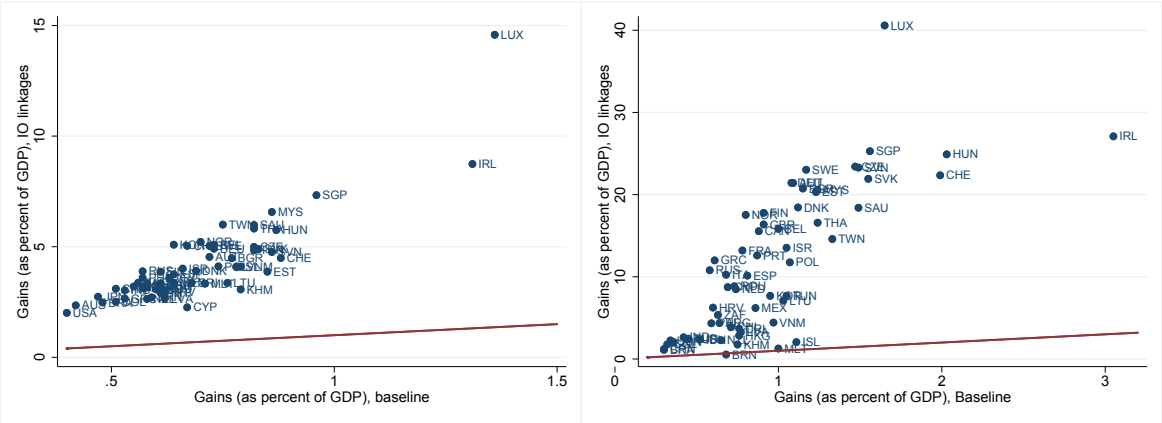
dian model. All observations are close to the 45-degree line (illustrated in red), with a correlation between the scale elasticities estimated using the two models equal to 0.91.[31] This is reassuring, as this suggests little omitted variable bias in our baseline estimation of scale elasticities due to other, non-Ricardian sources of comparative advantage that had not been controlled for in equation (10).

Finally, Figure 5 focuses on the gains from industrial and trade policy. For both policies, we see that the gains in the model with physical capital and input-output linkages are much larger: the average gains from industrial policy are now equal to 4.14%, whereas the average gains from trade policy go all the way to 11.49%. This partly reflects the fact that Harberger triangles are proportional to gross output. Thus, expressed as a share of GDP, the gains from removing such triangles, whatever their origin, are mechanically higher. In addition, the introduction of input-output linkages tends to make supply more elastic, again increasing the size of Harberger triangles and the absolute levels of the gains from policy.[32]

The previous adjustment in absolute levels notwithstanding, the introduction of intermediate goods has little effects on the rest of our conclusions. Across countries, Figure 5 shows that more open economies—such as Ireland, Luxembourg, or Singapore—tend to benefit disproportionately more from both trade and industrial policies. Likewise, across

[31] All estimates of γ_k remain statistically significant at the 5% level and the instruments remain strong by conventional standards (with the lowest first-stage SW F-statistic equal to 203.6). Full estimates are reported in Table B.7.

[32] Interestingly, the adjustment to the gains from combining the optimal industrial and trade policies is only 3.93%, reflecting the fact that only using one of those two policies in isolation tends to generate welfare losses on average.



(a) Gains from Industrial Policy

(b) Gains from Trade Policy

Figure 5: Gains from Industrial and Trade Policy, Beyond Ricardian Economies

policies, Figure 5 shows that gains from industrial policy remain modest relative to the gains from trade policy in the same environment.

7 Concluding Remarks

A major source of skepticism about industrial policy is that governments simply do not know which sectors should be subsidized at the expense of others. In this paper, we have focused on the textbook case for industrial policy, in which the rationale for such policy arises from the existence of external economies of scale; we have shown how, in this environment, one can use commonly available trade and production data to estimate economies of scale at the sector-level; and, in turn, we have characterized the structure and consequences of optimal industrial policy.

Our baseline results are humbling. Empirically, we find that sector-level economies of scale indeed exist and do differ substantially across sectors, ranging from an elasticity of 0.07 to 0.25. Yet, even under our optimistic assumption that governments maximize welfare and have full knowledge of the underlying economy, our baseline analysis points towards gains from optimal industrial policy that are, on average across all countries, equal to just 0.69% of GDP, and only amount to 1.36% for the country that gains the most. These modest gains from industrial policy are slightly smaller than the average gains from optimal trade policy alone, which are equal to 0.95% of GDP.

Intuitively, for gains from industrial policy to be large, one would need production processes that display external economies of scale—such that a nation's productivity in

a given sector is increasing in its scale in that sector—and scale economies that differ in strength across sectors—such that any productivity-enhancing expansion of scale in one sector does not just lead to an equal and opposite contraction of productivity in another sector. These are the conditions that would give rise to a Harberger triangle with a large height in Figure 1. In addition, one would need demand to be elastic or countries to produce highly substitutable and tradable goods—such that a country can simultaneously expand scale in one sector and find useful domestic or foreign substitutes for the sector that it chooses to shrink. These are the conditions that would give rise to a Harberger triangle with a large base in Figure 1. In our baseline calibration, given the low elasticity of demand, the non-trivial gap between social and marginal costs that we have inferred remains too small to generate large gains from industrial policy, even for the most open economies.

While some of our sensitivity exercises, including the introduction of input-output linkages, open the door for significantly larger gains from industrial policy, our analysis consistently points towards gains from industrial policy that are surprisingly modest relative to the gains from trade policy. There may be transformative gains from industrial policy to be realized in practice. Our results, however, offer little support for the notion that these gains can arise from the textbook case based on external economies of scale.

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A Online Theoretical Appendix

A.1 Firm-Level Economies of Scale

In Section 2.1, we have argued that our model, which assumes constant returns to scale at the good level, is consistent with firm-level economies of scale. We now make this point formally.

In any origin country i, suppose that there is a large pool of perfectly competitive firms. Like in Section 2.1, firms can use labor to produce any good in any sector. Unlike in Section 2.1, firms must pay a fixed entry cost, $f_{ij,k}(\omega)$, to start producing in sector k for country j. Once this fixed cost has been paid, firms get access to a production function,

$$q = A_{ij,k} E_k^A(L_{i,k}) F(l, \phi),$$

where l is the amount of labor used by the firm; ϕ is a firm-specific productivity shock, randomly drawn from a distribution, $G_{ij,k}(\cdot|\omega)$; and $F(l, \phi)$ determines the extent of internal economies of scale. We assume that they are such that profits,

$$\pi_{ij,k}(l, \phi, \omega) = p_{ij,k}(\omega) A_{ij,k} E_k^A(L_{i,k}) F(l, \phi) - w_i l,$$

are single-peaked in l.

In a competitive equilibrium with free entry: (i) firms choose l in order to maximize profits taking wages, $\{w_i\}$, and after-tax prices, $\{p_{ij,k}(\omega)(1+s_{i,k})(1-t^x_{ij,k})\}$, as given,

$$\pi_{ij,k}(w_i, L_{i,k}, p_{ij,k}(\omega)(1+s_{i,k})(1-t^x_{ij,k}), \phi) = \max_l p_{ij,k}(\omega)(1+s_{i,k})(1-t^x_{ij,k}) A_{ij,k} E_k^A(L_{i,k}) F(l, \phi) - w_i l;$$

and (ii) expected profits are nonpositive for all goods and zero for all goods with positive output,

$$\int \pi_{ij,k}(w_i, L_{i,k}, p_{ij,k}(\omega)(1+s_{i,k})(1-t^x_{ij,k}), \phi) dG_{ij,k}(\phi|\omega) \leq w_i f_{ij,k}(\omega), \text{ for all } \omega,$$
$$\int \pi_{ij,k}(w_i, L_{i,k}, p_{ij,k}(\omega)(1+s_{i,k})(1-t^x_{ij,k}), \phi) dG_{ij,k}(\phi|\omega) = w_i f_{ij,k}(\omega), \text{ if } q_{ij,k}(\omega) > 0.$$

The two previous observations imply that after-tax producer prices must satisfy

$$p_{ij,k}(\omega)(1+s_{i,k})(1-t^x_{ij,k}) \leq \frac{w_i}{\alpha_{ij,k}(\omega) A_{ij,k} E_k^A(L_{i,k})}, \text{ for all } \omega,$$
$$p_{ij,k}(\omega)(1+s_{i,k})(1-t^x_{ij,k}) = \frac{w_i}{\alpha_{ij,k}(\omega) A_{ij,k} E_k^A(L_{i,k})}, \text{ if } q_{ij,k}(\omega) > 0,$$

where $\alpha_{ij,k}(\omega)$ is a function of, and only of, $f_{ij,k}(\omega)$, $G_{ij,k}(\cdot|\omega)$, and $F(l, \phi)$. The unit cost on the right-hand side is constant and identical to the one that one would obtain starting from the constant returns to scale good-level production function in Section 2.1.

A.2 Competitive Equilibrium

Profit Maximization. For any origin country i, any destination country j, any sector k, and any good ω, profit maximization determines supply,

$$q_{ij,k}(\omega) \in \text{argmax}_{\tilde{q}_{ij,k}(\omega)}[p_{ij,k}(\omega)(1+s_{i,k})(1-t^x_{ij,k}) - \frac{w_i}{\alpha_{ij,k}(\omega)A_{ij,k}E^A_k(L_{i,k})}]\tilde{q}_{ij,k}(\omega), \tag{A.1}$$

with the convention $t^x_{ii,k} = 0$ and sector size in country i and sector k given by

$$L_{i,k} = \sum_j \int \frac{q_{ij,k}(\omega)}{\alpha_{ij,k}(\omega)A_{ij,k}E^A_k(L_{i,k})} d\omega. \tag{A.2}$$

Utility Maximization. For any destination country j and any sector k, utility maximization determines demand,

$$\{q_{ij,k}(\omega)\}_{i,\omega} \in \text{argmax}_{\{\tilde{q}_{ij,k}(\omega)\}_{i,\omega}}\{U_{j,k}(\{\beta_{ij,k}(\omega)B_{ij,k}E^B_k(L_{i,k})\tilde{q}_{ij,k}(\omega)\}_{i,\omega}) \tag{A.3}$$
$$|\sum_i \int p_{ij,k}(\omega)(1+t^m_{ij,k})\tilde{q}_{ij,k}(\omega)d\omega = X_{j,k}\},$$

$$\{U_{j,k}\}_k \in \text{argmax}_{\{\tilde{U}_{j,k}\}_k}\{U_j(\tilde{U}_{j,1},..,\tilde{U}_{j,K})|\sum_k P_{j,k}\tilde{U}_{j,k} = w_jL_j + T_j\}, \tag{A.4}$$

with the convention that $t^m_{ii,k} = 0$, and where total expenditure in country j and sector k is given by

$$X_{j,k} = P_{j,k}U_{j,k}, \tag{A.5}$$

and the price index in country j and sector k is given by

$$P_{j,k} = \min_{\{\tilde{q}_{ij,k}(\omega)\}_{i,\omega}}\{\sum_i \int p_{ij,k}(\omega)(1+t^m_{ij,k})\tilde{q}_{ij,k}(\omega)d\omega|U_{j,k}(\{\beta_{ij,k}(\omega)B_{ij,k}E^B_k(L_{i,k})\tilde{q}_{ij,k}(\omega)\}_{i,\omega}) = 1\}. \tag{A.6}$$

Market Clearing. For any country i, labor demand equals labor supply, leading to

$$\sum_{j,k} \int p_{ij,k}(\omega)(1+s_{i,k})(1-t^x_{ij,k})q_{ij,k}(\omega)d\omega = w_iL_i. \tag{A.7}$$

Government Budget Balance. For any country i, the government's budget is balanced,

$$T_i = \sum_{j,k} \int t^m_{ji,k}p_{ji,k}(\omega)q_{ji,k}(\omega)d\omega + \sum_{j,k} \int t^x_{ij,k}p_{ij,k}(\omega)(1+s_{i,k})q_{ij,k}(\omega)d\omega - \sum_{j,k} \int s_{i,k}p_{ij,k}(\omega)q_{ij,k}(\omega)d\omega. \tag{A.8}$$

Definition. A competitive equilibrium with production subsidies, $\{s_{j,k}\}$, import tariffs, $\{t^m_{ij,k}\}$, export taxes, $\{t^x_{ij,k}\}$, and lump-sum transfers, $\{T_j\}$, corresponds to quantities, $\{q_{ij,k}(\omega)\}$, with sector sizes, $\{L_{i,k}\}$, sector expenditures, $\{X_{i,k}\}$, good prices, $\{p_{ij,k}(\omega)\}$, sector price indices, $\{P_{i,k}\}$, and wages, $\{w_i\}$, such that equations (A.1)-(A.8) hold.

A.3 Factor Demand

In Section 2.2, we have argued that trade shares in a perfectly competitive equilibrium satisfy equation (2), with: (i) $\chi_{ij,k}$ homogeneous of degree zero, invertible, and a function of, and only of, $U_{j,k}$, $\{\alpha_{ij,k}(\omega)\}$, and $\{\beta_{ij,k}(\omega)\}$; and (ii) $E_k(L_{i,k}) = E^A_k(L_{i,k})E^B_k(L_{i,k})$. We now establish this formally.

By condition (A.1), equilibrium prices and quantities must satisfy

$$p_{ij,k}(\omega) \leq \frac{w_i}{(1+s_{i,k})(1-t^x_{ij,k})\alpha_{ij,k}(\omega)A_{ij,k}E^A_k(L_{i,k})} \text{ for all } \omega, \tag{A.9}$$

$$p_{ij,k}(\omega) = \frac{w_i}{(1+s_{i,k})(1-t^x_{ij,k})\alpha_{ij,k}(\omega)A_{ij,k}E^A_k(L_{i,k})} \text{ if } q_{ij,k}(\omega) > 0. \tag{A.10}$$

By condition (A.3), since $U_{j,k}$ is homothetic and taste shocks, $\beta_{ij,k}(\omega)B_{ij,k}E^B_k(L_{i,k})$, enter utility multiplicatively, optimal quantities consumed must satisfy

$$q_{ij,k}(\omega)\beta_{ij,k}(\omega)B_{ij,k}E^B_k(L_{i,k}) = \delta_{ij,k}(\{p_{i'j,k}(\omega')(1+t^m_{i'j,k})/(\beta_{i'j,k}(\omega')B_{i'j,k}E^B_k(L_{i',k}))\}_{i',\omega'}|\omega)X_{j,k} \tag{A.11}$$

where $\delta_{ij,k}(\cdot|\omega)$ only depends on $U_{j,k}$ and $\{p_{i'j,k}(\omega')(1+t^m_{i'j,k})/(\beta_{i'j,k}B_{i'j,k}E^B_k(L_{i',k})\}_{i',\omega'}$ represents the vector of quality-adjusted prices faced by the representative consumer in destination j and sector k.

Now consider the share of expenditure, $x_{ij,k} = \sum_\omega (1+t^m_{ij,k})p_{ij,k}(\omega)q_{ij,k}(\omega)/X_{j,k}$, in destination j on goods from sector k produced in country i. Equations (A.9) and (A.11) imply

$$x_{ij,k} = \chi_{ij,k}((1+t^m_{1j,k})c_{1j,k}, ..., (1+t^m_{Ij,k})c_{Ij,k}),$$

with

$$\begin{aligned}
\chi_{ij,k}(\tilde{c}_{1j,k}, ..., \tilde{c}_{Ij,k}) &= \int \frac{\tilde{c}_{ij,k}}{\alpha_{ij,k}(\omega)\beta_{ij,k}(\omega)}\delta_{ij,k}\left(\left\{\frac{\tilde{c}_{i'j,s}}{\alpha_{i'j,k}(\omega')\beta_{i'j,k}(\omega')}\right\}_{i',\omega'}|\omega\right)d\omega, \\
c_{ij,k} &= \frac{\eta_{ij,k}w_i}{(1+s_{i,k})(1-t^x_{ij,k})E_k(L_{i,k})}, \\
\eta_{ij,k} &= \frac{1}{A_{ij,k}B_{ij,k}}, \\
E_k(L_{i,k}) &= E^A_k(L_{i,k})E^B_k(L_{i,k}).
\end{aligned}$$

The fact that $\chi_{j,k}$ is homogeneous of degree zero derives from the fact that the Marshallian demand for goods is homogeneous of degree zero in prices and income. The fact that $\chi_{j,k}$ is invertible derives from the fact that demand for goods within a sector satisfies the connected substitutes property and standard Inada conditions hold, as in Adao et al. (2017).

A.4 Optimal Policy in a Large Economy

In the case of a large economy, the equilibrium labor services demanded by country j from different origins and sectors, $\{L_{ij,k}\}_{i,k}$, the equilibrium labor services exported by country j to different destinations, $\{L_{ji,k}\}_{i\neq j,k}$, and the sector equilibrium sizes in country j, $\{L_{j,k}\}_k$, still solve

$$\max_{\{\tilde{L}_{ij,k}\}_{i,k},\{\tilde{L}_{ji,k}\}_{i\neq j,k},\{\tilde{L}_{j,k}\}_k} V_j(\{\tilde{L}_{ij,k}\}_{i,k})$$
$$\sum_{i\neq j,k} c_{ij,k}(1+t^m_{ij,k})\tilde{L}_{ij,k} \leq \sum_{i\neq j,k} c_{ji,k}(1-t^x_{ji,k})\tilde{L}_{ji,k} + T_j,$$
$$\sum_i \eta_{ji,k}\tilde{L}_{ji,k} \leq (1+s_{j,k})E_{j,k}\tilde{L}_{j,k}, \text{ for all } k,$$
$$\sum_k \tilde{L}_{j,k} \leq L_j,$$

whereas the problem of country j's government generalizes to

$$\max_{\{\tilde{L}_{ij,k}\}_{i,k},\{\tilde{L}_{ji,k}\}_{i\neq j,k},\{\tilde{L}_{j,k}\}_k} V_j(\{\tilde{L}_{ij,k}\}_{i,k})$$
$$\sum_{i\neq j,k} c_{ij,k}(\{\tilde{L}_{ij,k'}\}_{i\neq j,k'},\{\tilde{L}_{ji,k'}\}_{i\neq j,k'})\tilde{L}_{ij,k} \leq \sum_{i\neq j,k} c_{ji,k}(\{\tilde{L}_{ij,k'}\}_{i\neq j,k'},\{\tilde{L}_{ji,k'}\}_{i\neq j,k})\tilde{L}_{ji,k},$$
$$\sum_i \eta_{ji,k}\tilde{L}_{ji,k} \leq E_k(\tilde{L}_{j,k})\tilde{L}_{j,k}, \text{ for all } k,$$
$$\sum_k \tilde{L}_{j,k} \leq L_j.$$

where both import and export prices, $c_{ij,k}(\{\tilde{L}_{ij,k'}\}_{i\neq j,k'},\{\tilde{L}_{ji,k'}\}_{i\neq j,k'})$ and $c_{ji,k}(\{\tilde{L}_{ij,k'}\}_{i\neq j,k'},\{\tilde{L}_{ji,k'}\}_{i\neq j,k'})$, are now a function of the entire vector of imports and exports. Although this complicates the characterization of the optimal trade policy, it is irrelevant for the optimal industrial policy: comparing the first-order conditions of the two problems, we still have

$$1+s_{j,k} = (1+s_j)(1+\frac{d\ln E_k}{d\ln L_{j,k}}), \text{ for all } k.$$

A.5 Nonparametric Identification

In Section 3, we have argued that if there exists a vector of instruments z that satisfies the exclusion restriction, that $E[\epsilon|z]=0$, as well as the completeness condition, that $E[g(l)|z]=0$ implies $g=0$

for any g with finite expectation, then for any k, E_k is identified, up to a normalization. We now establish this result formally.

Fix i_1, i_2, k_1, k_2, and j. Starting from equation (5), the exclusion restriction implies

$$E[\ln \frac{\chi^{-1}_{i_1 j,k_1}(x_{1j,k_1},...,x_{Ij,k_1})}{\chi^{-1}_{i_2 j,k_1}(x_{1j,k_1},...,x_{Ij,k_1})} - \ln \frac{\chi^{-1}_{i_1 j,k_2}(x_{1j,k_2},...,x_{Ij,k_2})}{\chi^{-1}_{i_2 j,s_2}(x_{1j,s_2},...,x_{Ij,k_2})}|z] = -E[\ln \frac{E_{k_1}(L_{i_2,k_1})}{E_{k_1}(L_{i_1,k_1})} - \ln \frac{E_{k_2}(L_{i_2,k_2})}{E_{k_2}(L_{i_1,k_2})}|z].$$

Now suppose that there are two solutions (E_{k_1}, E_{k_2}) and $(\tilde{E}_{k_1}, \tilde{E}_{k_2})$ that solve the previous equation. Then we must have

$$E[\ln \frac{E_{k_1}(L_{i_2,k_1})}{E_{k_1}(L_{i_1,k_1})} - \ln \frac{E_{k_2}(L_{i_2,k_2})}{E_{k_2}(L_{i_1,k_2})} - \ln \frac{\tilde{E}_{k_1}(L_{i_2,k_1})}{\tilde{E}_{k_1}(L_{i_1,k_1})} + \ln \frac{\tilde{E}_{k_2}(L_{i_2,k_2})}{\tilde{E}_{k_2}(L_{i_1,k_2})}|z] = 0$$

By the completeness condition, we therefore have

$$\ln \frac{E_{k_1}(L_{i_2,k_1})}{E_{k_1}(L_{i_1,k_1})} - \ln \frac{E_{k_2}(L_{i_2,k_2})}{E_{k_2}(L_{i_1,k_2})} = \ln \frac{\tilde{E}_{k_1}(L_{i_2,k_1})}{\tilde{E}_{k_1}(L_{i_1,k_1})} - \ln \frac{\tilde{E}_{k_2}(L_{i_2,k_2})}{\tilde{E}_{k_2}(L_{i_1,k_2})},$$

which can be rearranged as

$$\ln \frac{\tilde{E}_{k_1}(L_{i_1,k_1})}{E_{k_1}(L_{i_1,k_1})} = \ln \frac{\tilde{E}_{k_1}(L_{i_2,k_1})}{E_{k_1}(L_{i_2,k_1})} + \ln \frac{E_{k_2}(L_{i_2,k_2})}{E_{k_2}(L_{i_1,k_2})} - \ln \frac{\tilde{E}_{k_2}(L_{i_2,k_2})}{\tilde{E}_{k_2}(L_{i_1,k_2})}.$$

Since the right-hand side does not depend on L_{i_1,k_1}, the left-hand side cannot depend on L_{i_1,k_1} either. This implies that $\ln(\tilde{E}_{k_1}(L_{i_1,k_1})/E_{k_1}(L_{i_1,k_1}))$ is a constant, i.e., that E_{k_1} is identified up to a normalization. The same argument implies that $E_{k_2}$is identified up to a normalization as well.

A.6 Imperfect Competition

In the main text, we have discussed the case of an economy with an imperfectly competitive retail sector that buys goods at marginal costs and sells them at a profit. In this alternative environment, we have argued that we can still express trade shares as a function of factor prices, $\chi_{j,k}(c_{1j,k},...,c_{Ij,k})$. We now establish this result formally.

From our analysis in Appendix A.3, we know that the price at which the retailer from sector k in destination j can buy goods is given by

$$p_{ij,k}(\omega) = \frac{(1+t^m_{ij,k})w_i}{\alpha_{ij,k}(\omega)A_{ij,k}E^A_k(L_{i,k})}.$$

Let $p^r_{ij,k}(\omega)$ denote the price at which the same retailer sells to consumers. From our analysis in Appendix A.3, we also know that the demand of the consumer in destination j for goods from

sector k can be expressed as

$$q_{ij,k}(\omega)\beta_{ij,k}(\omega)B_{ij,k}E_k^B(L_{i,k}) = \delta_{ij,k}(\{p^r_{i'j,k}(\omega')/(\beta_{i'j,k}(\omega')B_{i'j,k}E_k^B(L_{i',k}))\}_{i',\omega'}|\omega)X_{j,k}.$$

Accordingly, we can express the profit maximization problem of the retailer as

$$\max_{\{\tilde{p}^r_{ij,k}(\omega)\}} \sum_{\omega,i} \left[\tilde{p}^r_{ij,k}(\omega) - \frac{(1+t^m_{ij,k})w_i}{\alpha_{ij,k}(\omega)A_{ij,k}E_k^A(L_{i,k})}\right] \left[\frac{\delta_{ij,k}(\{\tilde{p}^r_{i'j,k}(\omega')/(\beta_{i'j,k}(\omega')B_{i'j,k}E_k^B(L_{i',k}))\}_{i',\omega'}|\omega)X_{j,k}}{\beta_{ij,k}(\omega)B_{ij,k}E_k^B(L_{i,k})}\right]$$

or, in terms of quality-adjusted prices, $p^{ra}_{ij,k}(\omega) \equiv p^r_{ij,k}(\omega)/(\beta_{ij,k}(\omega)B_{ij,k}E_k^B(L_{i,k}))$,

$$\max_{\{\tilde{p}^{ra}_{ij,k}(\omega)\}} \sum_i \int \left(\tilde{p}^{ra}_{ij,k}(\omega) - \frac{(1+t^m_{ij,k})\eta_{ij,k}w_i}{\alpha_{ij,k}(\omega)\beta_{ij,k}(\omega)E_k(L_{i,k})}\right) \delta_{ij,k}(\{\tilde{p}^{ra}_{i'j,k}(\omega')\}_{i',\omega'}|\omega)d\omega X_{j,k}.$$

The solution to the previous problem must take the form

$$p^{ra}_{ij,k}(\omega) = \mu_{ij,k}\left(\frac{\eta_{1j,k}(1+t^m_{1j,k})w_1}{E_k(L_{1,k})}, ..., \frac{\eta_{Ij,k}(1+t^m_{Ij,k})w_I}{E_k(L_{I,k})}|\omega\right) \frac{(1+t^m_{ij,k})\eta_{ij,k}w_i}{\alpha_{ij,k}(\omega)\beta_{ij,k}(\omega)E_k(L_{i,k})},$$

with $\mu_{ij,k}(\cdot|\omega)$ the markup on good ω as a function of the vector of cost shifters. Together with the observation that,

$$x_{ij,k} = \int p^{ra}_{ij,k}(\omega)\delta_{ij,k}(\{p^{ra}_{i'j,k}(\omega')\}_{i',\omega'}|\omega)d\omega,$$

this implies that

$$x_{ij,k} = \chi_{ij,k}((1+t^m_{1j,k})c_{1j,k}, ..., (1+t^m_{Ij,k})c_{Ij,k}),$$

with

$$\chi_{ij,k}(\tilde{c}_{1j,k}, ..., \tilde{c}_{Ij,k}) =$$

$$\int \mu_{ij,k}(\tilde{c}_{1j,k}, ..., \tilde{c}_{Ij,k}|\omega)\frac{\tilde{c}_{ij,k}}{\alpha_{ij,k}(\omega)\beta_{ij,k}(\omega)}\delta_{ij,k}\left(\left\{\mu_{ij,k}(\tilde{c}_{1j,k}, ..., \tilde{c}_{Ij,k}|\omega')\frac{\tilde{c}_{i'j,k}}{\alpha_{i'j,k}(\omega')\beta_{i'j,k}(\omega')}\right\}_{i',\omega'}|\omega\right)d\omega,$$

as argued in the main text.

A.7 Counterfactuals

We first describe the system of non-linear equations that characterizes any competitive equilibrium. We then show how to go from this system to the one that characterizes the changes between an observed initial equilibrium with no taxes or subsidies and a counterfactual equilibrium with taxes and subsidies. We conclude by noting how the small open economy assumption simplifies the previous computations.

Competitive Equilibrium with Taxes and Subsidies. Starting from equations (A.1)-(A.8), we can describe a competitive equilibrium with production subsidies, $\{s_{j,k}\}$, import tariffs, $\{t^m_{ij,k}\}$, export taxes, $\{t^x_{ij,k}\}$, and lump-sum transfers, $\{T_j\}$, as a set of sector sizes, $\{L_{i,k}\}$, within-sector expenditure shares, $\{x_{ij,k}\}$, between-sector expenditure shares, $\{x_{j,k}\}$, sector price indices, $\{P_{j,k}\}$, and wages, $\{w_j\}$, such that

$$\frac{w_i L_{i,k}}{1+s_{i,k}} = \sum_j \left(1 - t^x_{ij,k}\right) \frac{x_{ij,k}}{1+t^m_{ij,k}} x_{j,k} \left(w_j L_j + T_j + D_j\right),$$

$$T_j = \sum_{i,k} \frac{t^m_{ij,k} x_{ij,k}}{1+t^m_{ij,k}} x_{j,k} \left(w_j L_j + T_j + D_j\right) + \sum_{i,k} \left[t^x_{ji,k}\left(1+s_{j,k}\right) - s_{j,k}\right] \frac{x_{ji,k}}{1+t^m_{ji,k}} x_{i,k} \left(w_i L_i + T_i + D_i\right),$$

$$\sum_k L_{i,k} = L_i,$$

with

$$x_{ij,k} = \frac{((1+t^m_{ij,k})c_{ij,k})^{-\theta_k}}{\sum_{i'}((1+t^m_{i'j,k})c_{i'j,k})^{-\theta_k}},$$

$$P_{j,k} = \left(\sum_i ((1+t^m_{ij,k})c_{ij,k})^{-\theta_k}\right)^{-1/\theta_k},$$

$$c_{ij,k} = \frac{\eta_{ij,k} w_i}{(1-t^x_{ij,k})(1+s_{i,k})E_k(L_{i,k})},$$

$$x_{j,k} = \frac{\exp(\varepsilon_{j,k})\left(P_{j,k}\right)^{1-\rho}}{\sum_{k'}\exp(\varepsilon_{j,k'})\left(P_{j,k'}\right)^{1-\rho}},$$

where D_j denotes the trade deficit of country j, with $\sum_j D_j = 0$.

Counterfactual Changes. Suppose that the initial equilibrium has no taxes or subsidies. We are interested in a counterfactual equilibrium with taxes and subsidies:

$$t^x_{ij,k}, t^m_{ij,k}, s_{i,k}, T_j \neq 0 \text{ for some } i, j, k.$$

For any endogenous variable with value x in the initial equilibrium and x' in the counterfactual equilibrium, we let $\hat{x} = x'/x$ denote the change in this variable. We assume that D_j are fixed and do not change as we move to the counterfactual equilibrium. After simplifications, counterfactual changes in prices and quantities the initial and counterfactual equilibria are given by the solution to

$$\frac{\hat{w}_i \hat{L}_{i,k}}{1+s_{i,k}} Y_{i,k} = \sum_j \left(1 - t^x_{ij,k}\right) \frac{\hat{x}_{ij,k}}{1+t^m_{ij,k}} \hat{x}_{j,k} \left(\frac{\hat{w}_j Y_j + T'_j + D_j}{Y_j + D_j}\right) X_{ij,k}, \tag{A.12}$$

$$T_j' = \sum_{i,k} \frac{t^m_{ij,k}\hat{x}_{ij,k}\hat{x}_{j,k}}{1+t^m_{ij,k}} \left(\frac{\hat{w}_j Y_j + T_j' + D_j}{Y_j + D_j} \right) X_{ij,k}$$
$$+ \sum_{i,k} \left[t^x_{ji,k}\left(1+s_{j,k}\right) - s_{j,k} \right] \frac{\hat{x}_{ji,k}\hat{x}_{i,k}}{1+t^m_{ji,k}} \left(\frac{\hat{w}_i Y_i + T_i' + D_i}{Y_i + D_i} \right) X_{ji,k}, \tag{A.13}$$

$$\sum_k \hat{L}_{i,k} Y_{i,k} = Y_i, \tag{A.14}$$

with

$$\hat{x}_{ij,k} = \frac{\left(\left(1+t^m_{ij,k}\right)\hat{c}_{ij,k}\right)^{-\theta_k}}{\sum_{i'}\left(\left(1+t^m_{i'j,k}\right)\hat{c}_{i'j,k}\right)^{-\theta_k} x_{i'j,k}}, \tag{A.15}$$

$$\hat{c}_{ij,k} = \frac{\hat{w}_i}{(1-t^x_{ij,k})(1+s_{i,k})\hat{L}^{\gamma_k}_{i,k}}, \tag{A.16}$$

$$\hat{x}_{j,k} = \frac{\left(\hat{P}_{j,k}\right)^{1-\rho}}{\sum_{k'}\left(\hat{P}_{j,k'}\right)^{1-\rho} x_{j,k'}}, \tag{A.17}$$

$$\hat{P}_{j,k} = \left(\sum_i \left(\left(1+t^m_{ij,k}\right)\hat{c}_{ij,k}\right)^{-\theta_k} x_{ij,k} \right)^{-1/\theta_k}, \tag{A.18}$$

and where bilateral trade flows $X_{ij,k}$, sectoral value added $Y_{i,k} = \sum_j X_{ij,k}$, and total value added $Y_i = \sum_{j,k} X_{ij,k}$ are all observed in the initial equilibrium. Once changes in the previous variables have been computed using (A.12)-(A.18), welfare changes are given by

$$\hat{U}_j = \frac{\hat{w}_j w_j + T_j'/L_j + D_j/L_j}{\hat{P}_j P_j} \frac{P_j}{w_j + D_j/L_j} = \frac{\hat{w}_j Y_j + T_j' + D_j}{\hat{P}_j} \frac{1}{Y_j + D_j},$$

where

$$\hat{P}_j = \left(\sum_k \hat{P}^{1-\rho}_{j,k} x_{j,k} \right)^{1/(1-\rho)}.$$

Under the assumption that country i_0 is a small open economy and that only country i_0 imposes trade taxes and production subsidies, the system is as described above for country i_0; that is, equations (A.12)-(A.18) continue to hold if either i or j is equal to i_0. For all other countries, we set $\hat{w}_i = \hat{P}_{i,k} = \hat{L}_{i,k} = 1$ for all k and drop equations (A.12)-(A.18).

A.8 Beyond Ricardian Economies

A.8.1 Environment with Physical Capital and Input-Output Linkages

To produce and deliver a good ω from an origin country i to a destination country j in sector k, we now assume that firms require a composite input, $z_{ij}^{k}(\omega)$, such that

$$q_{ij,k}(\omega) = A_{ij,k}(\omega) z_{ij,k}(\omega).$$

We assume that the composite input is produced using labor, $l_{ij,k}(\omega)$, physical capital, $k_{ij,k}(\omega)$, and intermediate goods from different sectors, $\{q_{ij,sk}^{M}(\omega)\}_s$, according to

$$z_{ij,k}(\omega) = f_{i,k}(l_{ij,k}(\omega), k_{ij,k}(\omega), \{q_{ij,sk}^{M}(\omega)\}_s),$$

where $f_{i,k}$ is a constant returns-to-scale production function. Within each destination country j and sector k, total gross output is produced by combining all goods from all origins,

$$Q_{j,k} = U_{j,k}(\{B_{ij,k}(\omega) q_{ij,k}(\omega)\}_{i,\omega}).$$

Gross output can be used either for final consumption, $Q_{j,k}^{F}$, or as intermediates for production, $\{Q_{j,ks}^{M}\}_s$,

$$Q_{j,k}^{F} + \sum_s Q_{j,ks}^{M} = Q_{j,k}.$$

Total demand for intermediate goods from sector k by firms from sector s in country j satisfies

$$\sum_i \int q_{ji,ks}^{M}(\omega) d\omega = Q_{j,ks}^{M}.$$

As before, we allow productivity and quality to be a function of sector size, such that

$$A_{ij,k}(\omega) = \alpha_{ij,k}(\omega) A_{ij,k} E_k^A(Z_{i,k}),$$
$$B_{ij,k}(\omega) = \beta_{ij,k}(\omega) B_{ij,k} E_k^B(Z_{i,k}),$$

where sector size is now measured by the total amount of the composite input, $Z_{i,k}$, used by country i in sector k. Finally, in line with our earlier analysis, we assume that upper-level preferences are CES ,

$$U_j(Q_{j,1}^{F}, .., Q_{j,K}^{F}) = [\sum_k (\exp(\varepsilon_{j,k}))^{\frac{1}{\rho}} (Q_{j,k}^{F})^{\frac{\rho-1}{\rho}}]^{\frac{\rho}{\rho-1}},$$

with ρ the elasticity of substitution between different sectors.

In this environment, the counterpart of trade in labor services, $L_{ij,k}$, between country i and j in

sector k is trade in input services, $Z_{ij,k}$, with price

$$c_{ij,k} \equiv \frac{\eta_{ij,k} c_{i,k}(w_i, r_i, \{P_{i,s}\}_s)}{(1+s_{i,k})(1-t^x_{ij,k})E_k(Z_{i,k})},$$

where $\eta_{ji,k} \equiv 1/(A_{ij,k}B_{ij,k})$ still captures systematic productivity and quality differences; w_i, r_i, and $\{P_{i,s}\}_s$ are the prices of labor, capital, and the sector-level composite goods in country i; and $c_{i,k}(w, r, \{P_s\}_s) \equiv \min_{l,k,q^M_s}\{wl + rk + \sum_s P_s q^M_s | f_{i,k}(l, k, \{q^M_s\}) \geq 1\}$ is the unit cost function for producing the composite input in country i and sector k. Like in Section 2.2, the share of expenditure in destination j on input services from country i in sector k, $z_{ij,k} \equiv [(1+t^m_{ij,k})c_{ij,k}Z_{ij,k}]/(\sum_{i'}[(1+t^m_{i'j,k})c_{i'j,k}Z_{i'j,k}])$, can be expressed as

$$z_{ij,k} = \chi_{ij,k}((1+t^m_{1j,k})c_{1j,k}, ..., (1+t^m_{Ij,k})c_{Ij,k}),$$

where $\chi_{j,k} \equiv (\chi_{1j,k}, ..., \chi_{Ij,k})$ is again homogeneous of degree zero, invertible, and a function of, and only of, $U_{j,k}$, $\{\alpha_{i,k}(\omega)\}$ and $\{\beta_{ij,k}(\omega)\}$.

A.8.2 Optimal Policy

We follow the same steps as in Sections 2.2 and 2.3. For a given vector of input services, $\{Z_{ij,k}\}_i$, used in a destination country j and sector k, let $Q_{j,k}(\{Z_{ij,k}\}_i)$ denote the maximum amount of gross output that can be produced,

$$\begin{aligned} Q_{j,k}(\{Z_{ij,k}\}_i) &\equiv \max_{\{q_{ij,k}(\omega), z_{ij,k}(\omega)\}_{i,\omega}} U_{j,k}(\{\beta_{ij,k}(\omega) q_{ij,k}(\omega)\}_{i,\omega})) \\ q_{ij,k}(\omega) &\leq \alpha_{ij,k}(\omega) z_{ij,k}(\omega) \text{ for all } \omega \text{ and} i, \\ \int z_{ij,k}(\omega) d\omega &\leq Z_{ij,k} \text{ for all } i. \end{aligned}$$

In a competitive equilibrium, the input services demanded by country j from different origins and sectors, $\{Z_{ij,k}\}_{i,k}$, the input services exported by country j towards different destinations, $\{Z_{ji,k}\}_{i \neq j,k}$, the sector-level amounts of employment and capital used in country j, $\{L_{j,k}\}_k$ and $\{K_{j,k}\}_k$, and the sector-level amounts of gross output used for consumption and production in

country j, $\{Q^F_{j,k}\}$ and $\{Q^M_{j,ks}\}_{k,s}$, must solve

$$\max_{\{\tilde{Z}_{ij,k}\}_{i,k},\{\tilde{Z}_{ji,k}\}_{i\neq j,k},\{\tilde{L}_{j,k},\tilde{K}_{j,k},\tilde{Z}_{j,k}\}_k,\{\tilde{Q}^M_{j,ks}\}_{k,s},\{\tilde{Q}^F_{j,k}\}_k} U_j(\{\tilde{Q}^F_{j,k}\}_k) \tag{A.19a}$$

$$\sum_{i\neq j,k} c_{ij,k}(1+t^m_{ij,k})\tilde{Z}_{ij,k} \leq \sum_{i\neq j,k} c_{ji,k}(1-t^x_{ji,k})\tilde{Z}_{ji,k} + T_j,$$

$$\sum_i \eta_{ji,k}\tilde{Z}_{ji,k} \leq (1+s_{j,k})E_{j,k}\tilde{Z}_{j,k} \text{ for all } k,$$

$$\tilde{Z}_{j,k} \leq f_{j,k}(\tilde{L}_{j,k},\tilde{K}_{j,k},\{\tilde{Q}^M_{j,sk}\}_s) \text{ for all } k, \tag{A.19b}$$

$$\tilde{Q}^F_{j,s} + \sum_k \tilde{Q}^M_{j,sk} \leq Q_{j,s}(\{\tilde{Z}_{lj,s}\}_l) \text{ for all } s,$$

$$\sum_k \tilde{L}_{j,k} \leq L_j, \tag{A.19c}$$

$$\sum_k \tilde{K}_{j,k} \leq K_j. \tag{A.19d}$$

Let $c_{ji,k}(Z_{ji,k})$ denote the equilibrium price of country j's input in sector k as a function of its own exports, $Z_{ji,k}$. It is implicitly given by the solution to

$$\chi_{ji,k}((1+t^m_{1i,k})c_{1i,k},...,(1+t^m_{Ii,k})c_{Ii,k}) = \frac{(1+t^m_{ji,k})c_{ji,k}Z_{ji,k}}{\sum_{i'\neq j}(1+t^m_{i'i,k})c_{i'i,k}Z_{i'i,k} + (1+t^m_{ji,k})c_{ji,k}Z_{ji,k}},$$

with the equilibrium costs of other exporters, $\{c_{i'i,k}\}_{i'\neq j}$, as well as their exports of input services, $\{Z_{i'i,k}\}_{i'\neq j}$, taken as given. The problem of country j's government is then given by

$$\max_{\{\tilde{Z}_{ij,k}\}_{i,k},\{\tilde{Z}_{ji,k}\}_{i\neq j,k},\{\tilde{L}_{j,k},\tilde{K}_{j,k},\tilde{Z}_{j,k}\}_k,\{\tilde{Q}^M_{j,ks}\}_{k,s},\{\tilde{Q}^F_{j,k}\}_k} U_j(\{\tilde{Q}^F_{j,k}\}_k) \tag{A.20a}$$

$$\sum_{i\neq j,k} c_{ij,k}\tilde{Z}_{ij,k} \leq \sum_{i\neq j,k} c_{ji,k}(\tilde{Z}_{ji,k})\tilde{Z}_{ji,k},$$

$$\sum_i \eta_{ji,k}\tilde{Z}_{ji,k} \leq E_k(\tilde{Z}_{j,k})\tilde{Z}_{j,k} \text{ for all } k,$$

$$\tilde{Z}_{j,k} \leq f_{j,k}(\tilde{L}_{j,k},\tilde{K}_{j,k},\{\tilde{Q}^M_{j,sk}\}_s) \text{ for all } k, \tag{A.20b}$$

$$\tilde{Q}^F_{j,s} + \sum_k \tilde{Q}^M_{j,sk} \leq Q_{j,s}(\{\tilde{Z}_{lj,s}\}_l), \text{ for all } s,$$

$$\sum_k \tilde{L}_{j,k} \leq L_j, \tag{A.20c}$$

$$\sum_k \tilde{K}_{j,k} \leq K_j. \tag{A.20d}$$

Comparing the first-order conditions associated with (A.19) and (A.20), we again obtain

$$1 + s_{j,k} = (1 + s_j)(1 + \frac{d \ln E_k}{d \ln Z_{j,k}}), \text{ for all } k,$$
$$1 - t^x_{ji,k} = (1 + t_j)(1 + \frac{d \ln c_{ji,k}}{d \ln Z_{ji,k}}), \text{ for all } i \text{ and } k,$$
$$1 + t^m_{ij,k} = 1 + t_j, \text{ for all } i \text{ and } k.$$

A.8.3 Counterfactuals

We now describe how counterfactual changes can be computed in an environment with multiple factors of production and input-output linkages. We assume that in each country i and sector k the production functions f_k are Cobb-Douglas,

$$f_k(l, k, \{q^M_s\}_s) = \left(l^{v_k} k^{1-v_k}\right)^{b_k} \prod_s (q^M_s)^{b_{sk}}, \tag{A.21}$$

with $b_k + \sum_s b_{sk} = 1$ and $v_k \in [0, 1]$.

Competitive Equilibrium with Taxes and Subsidies. The equilibrium system is given by

$$w_i L_{i,k} = v_k b_k \left(1 + s_{i,k}\right) \sum_j \frac{1 - t^x_{ij,k}}{1 + t^m_{ij,k}} x_{ij,k} X_{j,k},$$

$$r_i K_{i,k} = \left(1 - v_k\right) b_k \left(1 + s_{i,k}\right) \sum_j \frac{1 - t^x_{ij,k}}{1 + t^m_{ij,k}} x_{ij,k} X_{j,k},$$

$$T_j = \sum_k \left[\sum_i \frac{t^m_{ij,k}}{1 + t^m_{ij,k}} x_{ij,k} X_{j,k} + \sum_i \left(\frac{t^x_{ji,k}\left(1 + s_{j,k}\right) - s_{j,k}}{1 + t^m_{ji,k}} \right) x_{ji,k} X_{i,k} \right],$$

$$\sum_k L_{i,k} = L_i,$$

$$\sum_k K_{i,k} = K_i,$$

$$X_{j,k} = x^F_{j,k} \left(w_j L_j + r_j K_j + T_j + D_j\right) + \sum_{i,s} b_{ks} \left(1 + s_{j,s}\right) \frac{1 - t^x_{ji,s}}{1 + t^m_{ji,s}} x_{ji,s} X_{i,s},$$

$$x_{ij,k} = \frac{\left(\left(1 + t^m_{ij,k}\right) c_{ij,k}\right)^{-\theta_k}}{\sum_{i'} \left(\left(1 + t^m_{i'j,k}\right) c_{i'j,k}\right)^{-\theta_k}},$$

$$c_{ij,k} = \frac{\eta_{ij,k} \left[v_k^{-v_k b_k} \left(1 - v_k\right)^{-(1-v_k) b_k} \prod_s b_{sk}^{-b_{sk}}\right] \left(w_i^{v_k} r_i^{1-v_k}\right)^{b_k} \prod_s P_{i,s}^{b_{sk}}}{\left(1 + s_{i,k}\right) \left(1 - t^x_{ij,k}\right) Z_{i,k}^{\gamma_k}},$$

$$Z_{i,k} = \left(L_{i,k}^{v_k} K_{i,k}^{1-v_k}\right)^{b_k} \prod_s Q_{i,sk}^{b_{sk}},$$

$$Q_{i,sk} = \frac{b_{sk} w_i L_{i,k}}{\nu_k b_k P_{i,s}},$$

$$x_{j,k}^F = \frac{\exp(\varepsilon_{j,k}) \left(P_{j,k}\right)^{1-\rho}}{\sum_{k'} \exp(\varepsilon_{j,k'}) \left(P_{j,k'}\right)^{1-\rho}},$$

$$P_{j,k} = \left(\sum_i \left(\left(1 + t_{ij,k}^m\right) c_{ij,k}\right)^{-\theta_k}\right)^{-1/\theta_k}.$$

Counterfactual Changes. The counterfactual changes associated with moving from zero taxes and subsidies to export taxes $t_{ij,k}^x$, import taxes $t_{ij,k}^m$, and production subsidies $s_{i,k}$, are

$$\hat{w}_i \hat{L}_{i,k} Y_{i,k} = b_k \left(1 + s_{i,k}\right) \sum_j \frac{1 - t_{ij,k}^x}{1 + t_{ij,k}^m} \hat{x}_{ij,k} x_{ij,k} X'_{j,k},$$

$$\hat{r}_i \hat{K}_{i,k} Y_{i,k} = b_k \left(1 + s_{i,k}\right) \sum_j \frac{1 - t_{ij,k}^x}{1 + t_{ij,k}^m} \hat{x}_{ij,k} x_{ij,k} X'_{j,k},$$

$$T'_j = \sum_k \left[\sum_i \frac{t_{ij,k}^m \hat{x}_{ij,k} x_{ij,k}}{1 + t_{ij,k}^m} X'_{j,k} + \sum_i \left(\frac{t_{ji,k}^x \left(1 + s_{j,k}\right) - s_{j,k}}{1 + t_{ji,k}^m}\right) \hat{x}_{ji,k} x_{ji,k} X'_{i,k}\right],$$

$$\sum_k \hat{L}_{i,k} v_k Y_{i,k} = \bar{v}_i Y_i,$$

$$\sum_k \hat{K}_{i,k} \left(1 - v_k\right) Y_{i,k} = \left(1 - \bar{v}_i\right) Y_i,$$

$$X'_{j,k} = \hat{x}_{j,k}^F x_{j,k}^F \left(\hat{w}_j \bar{v}_j Y_j + \hat{r}_j \left(1 - \bar{v}_j\right) Y_j + T'_j + D_j\right) + \sum_{i,s} b_{ks} \left(1 + s_{j,s}\right) \frac{1 - t_{ji,s}^x}{1 + t_{ji,s}^m} \hat{x}_{ji,s} x_{ji,s} X'_{i,k},$$

$$\hat{x}_{ij,k} = \frac{\left(\left(1 + t_{ij,k}^m\right) \hat{c}_{ij,k}\right)^{-\theta_k}}{\sum_{i'} \left(\left(1 + t_{i'j,k}^m\right) \hat{c}_{i'j,k}\right)^{-\theta_k} x_{i'j,k}},$$

$$\hat{c}_{ij,k} = \frac{\left(\hat{w}_i^{v_k} \hat{r}_i^{1-v_k}\right)^{b_k} \prod_s \hat{P}_{i,s}^{b_{sk}}}{\left(1 + s_{i,k}\right) \left(1 - t_{ij,k}^x\right) \hat{Z}_{i,k}^{\gamma_k}},$$

$$\hat{Z}_{i,k} = \left(\hat{L}_{i,k}^{v_k} \hat{K}_{i,k}^{1-v_k}\right)^{b_k} \prod_s \left(\frac{\hat{w}_i \hat{L}_{i,k}}{\hat{P}_{i,s}}\right)^{b_{sk}},$$

$$\hat{x}_{j,k}^F = \frac{\left(\hat{P}_{j,k}\right)^{1-\rho}}{\sum_{k'} \left(\hat{P}_{j,k'}\right)^{1-\rho} x_{j,k'}^F},$$

$$\hat{P}_{j,k} = \left(\sum_i \left(\left(1 + t^m_{ij,k}\right) \hat{c}_{ij,k} \right)^{-\theta_k} x_{ij,k} \right)^{-1/\theta_k}.$$

where the observed value added in sector k is now given by $Y_{i,k} = b_k \sum_j X_{ij,k}$, total value added is $Y_i = \sum_k Y_{i,k}$, and country i's labor share is $\bar{v}_i = \sum_k v_k (Y_{i,k}/Y_i)$. We solve this system of equations using trade data as in the baseline analysis, augmented with data on factor and inputs shares from the OECD ICIO and WIOD datasets, as described in Appendix B.3.4, for 2010.[33]

Once changes in the previous variables have been computed, counterfactual welfare changes are given by

$$\hat{U}_j = \frac{\hat{w}_j \bar{v}_j + \hat{r}_j \left(1 - \bar{v}_j\right) + \left(T'_j + D_j\right)/Y_j}{\hat{P}_j} \frac{1}{1 + D_j/Y_j},$$

with

$$\hat{P}_j = \left(\sum_k \hat{P}^{1-\rho}_{j,k} x^F_{j,k} \right)^{1/(1-\rho)}.$$

Under the assumption that country i_0 is a small open economy and that only country i_0 imposes trade taxes and production subsidies, we follow the same procedure as in Appendix A.7 and impose $\hat{w}_i = \hat{r}_i = \hat{P}_{i,k} = \hat{L}_{i,k} = \hat{K}_{i,k} = 1$ for all k and $i \neq i_0$.

[33] In practice, with factor and input shares set to their global levels, a small number of country-sectors have implied domestic consumption that is negative. In such cases we increase domestic consumption entries to zero and recalculate the resulting global factor and input shares.

B Online Empirical Appendix

B.1 Elasticity of Substitution Between Sectors

Specification. The CES preferences in equation (8) imply the following sector-level expenditures,

$$\ln x_{j,k}^t = (1-\rho)\ln P_{j,k}^t + \delta_j^t + \delta_k^t + \varepsilon_{j,k}^t, \tag{B.1}$$

where δ_j^t is a country-year fixed effect that controls for the upper-tier manufacturing price index. Estimates of the price indices $P_{j,k}^t$ can be obtained from the estimated importer-sector-year fixed effect $\delta_{j,k}^t$ in a relaxed version of our main estimating equation (10),

$$\frac{1}{\theta_k}\ln x_{ij,k}^t = \delta_{i,k}^t + \delta_{ij}^t + \delta_{j,k}^t + \xi_{ij,k.}^t \tag{B.2}$$

With such estimates in hand, which we denote by $\widehat{P}_{j,k}^t = \exp\hat{\delta}_{j,k}^t$, we estimate ρ in the demand equation (B.1), for which an instrumental variables (IV) procedure is necessary to circumvent simultaneity bias.[34]

We construct instruments from the interaction of $\overline{L}_j^t$ and a set of sector indicators. The first stage of our 2SLS upper-tier demand elasticity estimation procedure is

$$\ln \widehat{P}_{j,k}^t = \sum_s \beta_s \mathbf{1}_{s=k}\cdot \ln \overline{L}_j^t + \widetilde{\delta}_j^t + \widetilde{\delta}_k^t + \widetilde{\varepsilon}_{j,k}^t \tag{B.3}$$

where $\mathbf{1}_{s=k}$ denotes an indicator variable for the event that $s=k$, and $\widetilde{\delta}_j^t$ and $\widetilde{\delta}_k^t$ represent country-year and sector-year fixed effects, respectively. The exclusion restriction requires that countries with large populations do not have systematically greater demand, relative to smaller countries, in some sectors than others.

Estimates. Table B.1 reports the first-stage coefficients β_k from estimating equation (B.3). Estimates of the parameter ρ itself are reported in Table B.2. The OLS estimate, in column (1), implies that $\widehat{\rho} = 3.35$, whereas our preferred 2SLS estimate in column (2) reveals that $\widehat{\rho} = 1.47$.

[34] Equation (B.2) recovers estimates of $\ln \widehat{P}_{j,k}^t$ up to a sector-year-specific and an importer-year-specific scale factor only, but this has no bearing on our subsequent use of $\ln \widehat{P}_{j,k}^t$ in equation (B.1) because of the inclusion of δ_j^t and δ_k^t.

Table B.1: First-Stage Estimates from Between-Sector Elasticity ($1-\rho$) Estimation

Sector	Coeff.	Sector	Coeff.
Food, Beverages and Tobacco	-0.05	Basic Metals	-0.00
	(0.01)		(0.01)
Textiles	-0.03	Fabricated Metals	-0.01
	(0.01)		(0.01)
Wood Products	-0.01	Machinery and Equipment	-0.01
	(0.01)		(0.01)
Paper Products	-0.01	Computers and Electronics	-0.00
	(0.01)		(0.01)
Coke/Petroleum Products	0.00	Electrical Machinery, NEC	-0.00
	(0.00)		(0.01)
Chemicals	-0.02	Motor Vehicles	-0.04
	(0.01)		(0.01)
Rubber and Plastics	-0.08	Other Transport Equipment	-0.02
	(0.01)		(0.01)
Mineral Products	-0.02		
	(0.01)		
Within R^2		0.16	
Observations		3,660	

Notes: This table reports the first-stage coefficients corrresponding to the 2SLS estimate of the upper tier elasticity of substitution ($1-\rho$). These are obtained from an OLS regression of log prices on log population interacted with sector dummies, while controlling for sector-time and country-time fixed effects. The Coke and Petroleum sector is the omitted category. Standard errors clustered at the country-sector level.

Table B.2: Estimate of Elasticity of Substitution Between Sectors ($1-\rho$)

	log (sectoral expenditure share)	log (sectoral expenditure share)
	OLS	2SLS
	(1)	(2)
log (sectoral price index)	-2.35	-0.47
	(0.21)	(0.47)
Within R^2	0.13	0.05
Observations	3,660	3,660
First-stage F-statistic		8.606

Notes: This table reports OLS and 2SLS estimates of the upper-tier elasticity of substitution ($1-\rho$) from equation (B.1). The instruments are the natural log of country population interacted with sector dummies. All regressions include sector-time and country-time fixed effects. Table B.1 reports the corresonding first-stage coefficients from the specification in column (2). Standard errors in parentheses are clustered at the country-sector level.

B.2 Trade Elasticities

Table B.3: Trade Elasticity (θ_k) Estimates from Prior Studies

Sector	Shapiro (1)	BSY (2)	CP (3)	GYY (4)	Median (5)
Food, Beverages and Tobacco	5.3	10.7	2.6	3.6	4.4
Textiles	18.6	7.3	8.1	4.4	7.7
Wood Products	5.9	12.0	11.5	4.2	8.7
Paper Products	5.8	9.9	16.5	3.0	7.8
Coke/Petroleum Products	9.0	13.9	64.9	3.8	11.4
Chemicals	1.6	7.7	3.1	3.8	3.4
Rubber and Plastics	1.6	9.5	1.7	4.1	2.9
Mineral Products	12.9	8.6	2.4	5.1	6.8
Basic Metals	12.9	6.9	3.3	8.9	7.9
Fabricated Metals	12.9	5.8	7.0	5.1	6.4
Machinery and Equipment	10.8	9.0	1.5	3.3	6.2
Computers and Electronics	10.8	8.0	13.0	3.3	9.4
Electrical Machinery, NEC	10.8	9.4	12.9	3.3	10.1
Motor Vehicles	6.9	7.5	1.8	4.5	5.7
Other Transport Equipment	6.9	6.4	0.4	4.5	5.4

Notes: This table reports estimates of the trade elasticity θ_k from prior studies, matched as closely as possible to our sector classification. Column (1) refers to Table 4, column 2 in Shapiro (2016); column (2) to Table 2 in Bagwell et al. (2018); column (3) to Table 1, column 4 in Caliendo and Parro (2015); column (4) to Table 4 in Giri et al. (2018); and column 5 reports the median of columns (1)-(4).

B.3 Scale Elasticities

B.3.1 First-Stage

Table B.4: Summary of First-Stage Regressions, Sector-Level Scale Elasticities (γ_k)

Sector	Diagonal Coeff. (1)	Max. (Abs) Off-Diagonal Coeff. (2)	F-Stat (3)	SW F-Stat (4)
Food, Beverages and Tobacco	1.05	-0.01	77.00	388.8
	(0.04)	(0.01)		
Textiles	1.09	0.01	71.60	352.5
	(0.03)	(0.01)		
Wood Products	0.94	-0.04	18.50	217.0
	(0.07)	(0.02)		
Paper Products	1.03	-0.04	72.60	689.4
	(0.03)	(0.01)		
Coke/Petroleum Products	1.30	-0.07	14.40	299.9
	(0.09)	(0.03)		
Chemicals	1.10	-0.04	38.20	341.9
	(0.06)	(0.01)		
Rubber and Plastics	1.09	-0.04	54.70	464.4
	(0.04)	(0.01)		
Mineral Products	1.02	-0.06	58.20	436.8
	(0.04)	(0.01)		
Basic Metals	1.00	-0.11	15.70	255.4
	(0.07)	(0.03)		
Fabricated Metals	1.04	-0.03	75.90	441.0
	(0.04)	(0.01)		
Machinery and Equipment	1.08	-0.01	69.90	405.3
	(0.04)	(0.01)		
Computers and Electronics	1.14	0.02	20.00	296.3
	(0.07)	(0.02)		
Electrical Machinery, NEC	0.99	-0.03	50.30	423.2
	(0.04)	(0.01)		
Motor Vehicles	1.40	-0.01	40.00	391.1
	(0.06)	(0.01)		
Other Transport Equipment	1.02	-0.07	23.20	375.6
	(0.06)	(0.02)		

Notes: This table summarizes the first-stage regressions corresponding to the 2SLS estimates of equation (10) reported in Table 1. With 15 endogenous variables in equation (10) and 15 instruments, there are 15 first-stage regressions, each a regression of $\ln L^t_{i,k}$ on the 15 demand-shifter instruments (for sector k itself, and also for the other 14 sectors). We refer to the coefficient on the demand shifter for sector k as the "diagonal" coefficient, and to all others as the "off-diagonal" coefficients. Column (1) reports the diagonal coefficient, and column (2) the maximum (in absolute value) among the 14 off-diagonal coefficients, for each of the first-stage regressions. All regressions control for importer-sector-year fixed-effects and (asymmetric) trading pair-year effects. Standard errors in parentheses are clustered at the exporter-sector level. Column (3) reports the corresponding conventional F-statistic, and column (4) the Sanderson-Windmeijer F-statistic, from each first-stage.

B.3.2 Single Cross-Section

Table B.5: Estimates of Sector-Level Scale Elasticities (γ_k), Single Cross-Sections

Sector	2SLS 1995 (1)	2SLS 2000 (2)	2SLS 2005 (3)	2SLS 2010 (4)
Food, Beverages and Tobacco	0.14	0.15	0.18	0.17
	(0.02)	(0.02)	(0.02)	(0.02)
Textiles	0.11	0.11	0.13	0.11
	(0.02)	(0.02)	(0.02)	(0.01)
Wood Products	0.10	0.11	0.13	0.10
	(0.02)	(0.02)	(0.02)	(0.02)
Paper Products	0.10	0.10	0.13	0.11
	(0.02)	(0.02)	(0.02)	(0.02)
Coke/Petroleum Products	0.06	0.06	0.08	0.07
	(0.02)	(0.02)	(0.01)	(0.01)
Chemicals	0.19	0.19	0.22	0.21
	(0.02)	(0.02)	(0.02)	(0.02)
Rubber and Plastics	0.26	0.24	0.28	0.24
	(0.03)	(0.03)	(0.03)	(0.03)
Mineral Products	0.12	0.13	0.16	0.13
	(0.02)	(0.02)	(0.02)	(0.02)
Basic Metals	0.10	0.11	0.13	0.11
	(0.02)	(0.02)	(0.02)	(0.01)
Fabricated Metals	0.13	0.12	0.15	0.13
	(0.02)	(0.02)	(0.02)	(0.02)
Machinery and Equipment	0.12	0.11	0.14	0.13
	(0.02)	(0.02)	(0.02)	(0.01)
Computers and Electronics	0.08	0.08	0.11	0.09
	(0.02)	(0.02)	(0.02)	(0.01)
Electrical Machinery, NEC	0.08	0.08	0.10	0.09
	(0.02)	(0.02)	(0.02)	(0.01)
Motor Vehicles	0.15	0.14	0.16	0.15
	(0.02)	(0.01)	(0.01)	(0.01)
Other Transport Equipment	0.14	0.15	0.17	0.16
	(0.02)	(0.02)	(0.02)	(0.02)
Observations	50,291	51,785	52,541	52,925

Notes: Columns (1)-(4) report the IV estimates of equation (10) when the sample is restricted to a single cross-section of countries and sectors from the indicated year. The instruments are the log of (country population $\times$ sectoral demand shifter), interacted with sector dummies. All regressions control for importer-sector fixed-effects and (asymmetric) trading pair effects. Standard errors in parentheses are clustered at the exporter-sector level.

B.3.3 Ricardian Controls

Table B.6: Estimates of Sector-Level Scale Elasticities (γ_k) with Ricardian Controls

Sector	(1)	(2)	(3)
Food, Beverages and Tobacco	0.16	0.15	0.15
	(0.02)	(0.03)	(0.03)
Textiles	0.12	0.10	0.09
	(0.01)	(0.02)	(0.02)
Wood Products	0.11	0.09	0.08
	(0.02)	(0.02)	(0.02)
Paper Products	0.11	0.10	0.10
	(0.02)	(0.02)	(0.02)
Coke/Petroleum Products	0.07	0.06	0.06
	(0.01)	(0.01)	(0.01)
Chemicals	0.20	0.23	0.25
	(0.02)	(0.02)	(0.02)
Rubber and Plastics	0.25	0.29	0.31
	(0.03)	(0.03)	(0.03)
Mineral Products	0.13	0.14	0.15
	(0.02)	(0.02)	(0.02)
Basic Metals	0.11	0.10	0.10
	(0.01)	(0.01)	(0.01)
Fabricated Metals	0.13	0.13	0.13
	(0.02)	(0.02)	(0.02)
Machinery and Equipment	0.12	0.12	0.12
	(0.01)	(0.01)	(0.01)
Computers and Electronics	0.09	0.07	0.07
	(0.01)	(0.01)	(0.01)
Electrical Machinery, NEC	0.09	0.07	0.07
	(0.01)	(0.02)	(0.01)
Motor Vehicles	0.15	0.16	0.16
	(0.01)	(0.01)	(0.01)
Other Transport Equipment	0.16	0.16	0.17
	(0.02)	(0.02)	(0.02)
(Contract enforcement)×(sector-year fixed-effects)		✓	✓
(Financial development)×(sector-year fixed-effects)		✓	✓
(GDP per capita)×(sector-year fixed-effects)			✓

Notes: 2SLS estimates of equation (10). All regressions control for importer-sector-year fixed-effects and (asymmetric) trading pair-year effects. Column (1) repeats column (2) from Table 1 for purposes of comparison. Standard errors in parentheses are clustered at the exporter-sector level. The number of observations for columns (2) and (3) is 169,483.

B.3.4 Beyond Ricardian Economies

Like in Appendix A.8.3, we assume that production functions are Cobb-Douglas, as described in equation (A.21). Maintaining our other parametric restrictions, as described in equations (6) and (7), this leads to the following generalization of our baseline estimating equation

$$\frac{1}{\theta_k}\ln(z^t_{ij,k}) + \ln c^t_{i,k} = \delta^t_{ij} + \nu^t_{j,k} + \gamma_k \ln Z^t_{i,k} + \epsilon^t_{ij,k}. \tag{B.4}$$

where the unit input cost bundle is given by

$$c^t_{i,k} = \kappa^t_k \left(w^t_i\right)^{v^t_k b^t_k} \left(r^t_i\right)^{(1-v^t_k)b^t_k} \prod_s (P^t_{i,s})^{b^t_{sk}},$$

and $\kappa^t_k \equiv (v^t_k)^{-v^t_k b^t_k}\left(1-v^t_k\right)^{-(1-v^t_k)b^t_k}\prod_s (b^t_{sk})^{-b^t_{sk}}$. Further, the aggregate amount of traded input services $Z^t_{i,k}$ satisfies $Z^t_{i,k} = X^t_{i,k}/c^t_{i,k}$. With measures of $c^t_{i,k}$ and $Z^t_{i,k}$ at hand, our estimation of γ_k in equation (B.4) proceeds via the same instrumental variable procedure as in our baseline of equation (10).

We draw on trade and national accounts data in order to measure $c^t_{i,k}$. We take the intermediate goods shares b^t_{sk} from the OECD's ICIO tables by using the relevant global share in each year. Unfortunately, this dataset does not report capital and labor shares of value added v^t_k, so we obtain those from the World Input Output Database (after creating an industry concordance with our dataset). We next compute wages and capital rental rates by using the formulas $w^t_i = (\sum_k v^t_k b^t_k X^t_{i,k})/\bar{L}^t_i$ and $r^t_i = (\sum_k (1-v^t_k) b^t_k X^t_{i,k})/\bar{K}^t_i$, with $\bar{L}^t_i$ and $\bar{K}^t_i$ as in the Penn World Tables 9.0 (the variables "POP" and "CK", respectively). Finally, the intermediate goods price indices $P^t_{i,k}$ have already been estimated following the procedure described in Section 4.2 and Appendix B.1.

Two complications arise from this procedure. First, trade data reveal the price indices $P^t_{i,k}$ for traded sectors but not those for non-traded sectors. However, by using the known cost functions for such non-traded sectors, which depend on wages, capital rental rates, and the price indices of traded sectors, we can recover estimates of the non-traded sector price indices up to a term composed of the productivities of non-traded sectors.[35] This

[35] Formally, the price index for any non-traded sector (dropping country and time notation for simplicity) is given by $P_k = \kappa_k \eta_k w^{v_k b_k} r^{(1-v_k)b_k}\prod_s (P_s)^{b_{sk}}$. Letting $\widetilde{y} \equiv \ln y$ for any variable y, $\widetilde{P}^N$ denote the vector $\left\{\widetilde{P}_k\right\}_{k\in N}$, $\widetilde{P}^T$ the vector $\left\{\widetilde{P}_k\right\}_{k\in T}$, K the vector $\{\widetilde{\kappa}_k\}_k$, E the vector $\{\widetilde{\eta}_k\}_k$, VB the vector $\{v_k b_k\}_k$, $(1-V)B$ the vector $\{(1-v_k)b_k\}_k$, B^{NN} the matrix $\{b_{sk}\}_{s\in N, k\in N}$, and B^{TN} the matrix $\{b_{sk}\}_{s\in T, k\in N}$, we have

$$(I - B^{NN})\widetilde{P}^N = K + E + \widetilde{w}VB + \widetilde{r}(1-V)B + B^{TN}\widetilde{P}^T.$$

We solve this equation for $\widetilde{P}^N$, up to a term that involves the unobserved productivity η_k, in every country and year (the matrix $I - B^{NN}$ is always invertible in our data).

changes the interpretation of the (supply-side) error term in equation (B.4) but does not alter the validity of our demand-side instrument.

Second, the auxiliary gravity regression described in Appendix B.1 only identifies the sectoral price indices up to unobserved destination-time and industry-time shifters. These terms then interact with the sector-time-specific factor shares used to construct the intermediate goods price indices. We therefore augment our specification in equation (B.4) to additionally control for an interaction between $(1 - b_k^t)$ and a full set of origin-time indicators.

OLS and 2SLS estimates of the scale elasticity parameters γ_k from equation (B.4) are reported in Table B.7.[36]

[36] In practice, we compute these estimates by using values of $c_{i,k}^t$ that are based on value-added shares $b_{i,k}^t$ and input use shares $b_{i,sk}^t$ that vary across countries (and hence we additionally include controls for the interaction between each input share and a time indicator to account for the unobserved industry time shifter in the price index estimation). This turns out to make very little difference to the resulting estimates of γ_k.

Table B.7: Estimates of Sector-Level Scale Elasticities (γ_k), Intermediates and Capital

Sector	OLS (1)	2SLS (2)	First-stage F-stat (3)	SW F-stat (4)
Food, Beverages and Tobacco	0.17	0.15	31.10	346.3
	(0.01)	(0.02)		
Textiles	0.06	0.06	50.60	292.7
	(0.01)	(0.02)		
Wood Products	0.06	0.06	8.70	203.6
	(0.01)	(0.02)		
Paper Products	0.10	0.09	31.20	338.9
	(0.01)	(0.02)		
Coke/Petroleum Products	0.10	0.09	17.00	301.7
	(0.01)	(0.02)		
Chemicals	0.24	0.23	24.00	261.6
	(0.01)	(0.02)		
Rubber and Plastics	0.28	0.23	19.30	287.1
	(0.02)	(0.03)		
Mineral Products	0.12	0.12	27.30	325.9
	(0.01)	(0.02)		
Basic Metals	0.09	0.10	7.90	204.5
	(0.01)	(0.01)		
Fabricated Metals	0.12	0.11	16.70	310.5
	(0.01)	(0.02)		
Machinery and Equipment	0.11	0.09	23.70	311.6
	(0.01)	(0.02)		
Computers and Electronics	0.07	0.07	20.20	243.2
	(0.01)	(0.02)		
Electrical Machinery, NEC	0.07	0.07	28.50	359.0
	(0.01)	(0.01)		
Motor Vehicles	0.14	0.12	29.10	375.0
	(0.01)	(0.01)		
Other Transport Equipment	0.14	0.13	20.60	312.8
	(0.01)	(0.02)		

Notes: Column (1) reports the OLS estimate, and column (2) the 2SLS estimate, of equation (B.5). The instruments are the log of (country population $\times$ sectoral demand shifter), interacted with sector dummies. All regressions control for importer-sector-year fixed-effects, (asymmetric) trading pair-year effects, interactions between total intermediate shares and a full set of exporter-year fixed-effects, and interactions between each intermediate input share and a set of (make)-sector-year fixed-effects. Column (3) reports the conventional F-statistic, and column (4) the Sanderson-Windmeijer F-statistic, from the first-stage regression corresponding to each row. Standard errors in parentheses are clustered at the exporter-sector level. The number of obserations is 207,542.

B.4 Gains from Optimal Policies, All Countries

Table B.8 (Part I): Gains from Optimal Policies, All Countries

Country	Optimal Policy (1)	Ind. Policy Only (2)	Trade Policy Only (3)	Gains from Trade Policy (4)	Gains from Ind. Policy (5)
Argentina	0.86%	0.22%	0.23%	0.64%	0.63%
Australia	0.75%	0.31%	0.33%	0.44%	0.42%
Austria	0.97%	-0.12%	0.25%	1.09%	0.72%
Belgium	1.06%	0.06%	0.34%	1.00%	0.73%
Brazil	0.65%	0.35%	0.17%	0.30%	0.48%
Brunei	1.78%	1.10%	1.18%	0.68%	0.59%
Bulgaria	1.10%	-0.05%	0.33%	1.15%	0.77%
Cambodia	1.55%	0.80%	0.76%	0.75%	0.79%
Canada	0.80%	-0.08%	0.19%	0.88%	0.61%
Chile	1.00%	0.29%	0.34%	0.71%	0.67%
China	0.66%	0.36%	0.15%	0.30%	0.51%
Colombia	0.82%	0.50%	0.31%	0.32%	0.51%
Costa Rica	1.17%	0.41%	0.49%	0.76%	0.68%
Croatia	1.14%	0.54%	0.52%	0.60%	0.62%
Cyprus	1.49%	0.80%	0.82%	0.69%	0.67%
Czech Republic	0.99%	-0.48%	0.16%	1.47%	0.82%
Denmark	1.06%	-0.06%	0.37%	1.12%	0.69%
Estonia	1.29%	0.06%	0.44%	1.23%	0.85%
Finland	0.78%	-0.13%	0.17%	0.91%	0.61%
France	0.75%	-0.03%	0.17%	0.78%	0.58%
Germany	0.91%	-0.17%	0.18%	1.08%	0.73%
Greece	0.88%	0.27%	0.36%	0.61%	0.53%
Hong Kong	1.19%	0.43%	0.64%	0.76%	0.55%
Hungary	1.09%	-0.94%	0.22%	2.03%	0.87%
Iceland	0.98%	-0.13%	0.19%	1.11%	0.78%
India	0.83%	0.41%	0.30%	0.42%	0.53%
Indonesia	0.94%	0.42%	0.34%	0.52%	0.60%
Ireland	1.56%	-1.49%	0.26%	3.05%	1.31%
Israel	0.91%	-0.14%	0.25%	1.05%	0.66%
Italy	0.72%	0.04%	0.16%	0.68%	0.57%
Japan	0.57%	0.21%	0.11%	0.36%	0.47%
Latvia	0.90%	0.13%	0.27%	0.77%	0.62%

Table B.8 (Continued): Gains from Optimal Policies, All Countries

Country	Optimal Policy (1)	Ind. Policy Only (2)	Trade Policy Only (3)	Gains from Trade Policy (4)	Gains from Ind. Policy (5)
Lithuania	1.15%	0.12%	0.39%	1.03%	0.76%
Luxembourg	2.23%	0.58%	0.87%	1.65%	1.36%
Malaysia	1.32%	0.08%	0.45%	1.24%	0.86%
Malta	1.44%	0.44%	0.73%	1.00%	0.71%
Mexico	0.90%	0.04%	0.26%	0.86%	0.64%
Netherlands	0.85%	0.11%	0.27%	0.74%	0.58%
New Zealand	0.86%	0.21%	0.28%	0.65%	0.58%
Norway	1.33%	0.53%	0.63%	0.80%	0.70%
Philippines	0.95%	0.36%	0.38%	0.59%	0.57%
Poland	0.91%	-0.16%	0.18%	1.07%	0.74%
Portugal	0.80%	-0.07%	0.19%	0.87%	0.61%
Republic of Korea	0.90%	-0.05%	0.26%	0.95%	0.64%
Romania	0.79%	0.06%	0.18%	0.73%	0.61%
Russian Federation	0.98%	0.40%	0.42%	0.58%	0.57%
Saudi Arabia	1.69%	0.20%	0.87%	1.49%	0.82%
Singapore	1.56%	0.00%	0.60%	1.56%	0.96%
Slovakia	0.94%	-0.61%	0.12%	1.55%	0.83%
Slovenia	1.10%	-0.39%	0.24%	1.49%	0.86%
South Africa	0.81%	0.18%	0.25%	0.63%	0.56%
Spain	0.87%	0.06%	0.23%	0.81%	0.64%
Sweden	0.96%	-0.21%	0.24%	1.17%	0.72%
Switzerland	1.16%	-0.83%	0.28%	1.99%	0.88%
Taiwan	1.14%	-0.19%	0.39%	1.33%	0.75%
Thailand	1.10%	-0.14%	0.28%	1.24%	0.82%
Tunisia	1.38%	0.33%	0.56%	1.05%	0.82%
Turkey	0.81%	0.36%	0.24%	0.45%	0.57%
United Kingdom	0.86%	-0.05%	0.26%	0.91%	0.61%
United States	0.55%	0.21%	0.15%	0.34%	0.40%
Vietnam	1.41%	0.44%	0.62%	0.97%	0.79%
Avg., Unweighted	**1.05%**	**0.10%**	**0.36%**	**0.95%**	**0.69%**
Avg., GDP-weighted	**0.71%**	**0.14%**	**0.20%**	**0.57%**	**0.51%**

Notes: Each column reports the gains, expressed as a share of initial real national income, that could be achieved by each type of policy. See the text for detailed descriptions of the exercises. Column (4) equals the difference between columns (1) and (2); likewise, column (5) is defined as the difference between columns (1) and (3).

Table B.9 (Part I): Gains from Constrained and Globally Efficient Industrial Policies, All Countries

Country	Baseline Industrial Policy (1)	Constrained Industrial Policy (2)	Globally Efficient Industrial Policy (3)
Argentina	0.63%	0.45%	0.12%
Australia	0.42%	0.47%	0.52%
Austria	0.72%	0.42%	-0.05%
Belgium	0.73%	0.47%	-0.06%
Brazil	0.48%	0.40%	0.40%
Brunei	0.59%	1.37%	0.79%
Bulgaria	0.77%	0.50%	0.51%
Cambodia	0.79%	1.01%	1.19%
Canada	0.61%	0.37%	0.47%
Chile	0.67%	0.53%	0.11%
China	0.51%	0.41%	0.21%
Colombia	0.51%	0.54%	0.89%
Costa Rica	0.68%	0.67%	1.02%
Croatia	0.62%	0.71%	0.92%
Cyprus	0.67%	1.03%	1.98%
Czech Republic	0.82%	0.35%	-0.22%
Denmark	0.69%	0.52%	-0.14%
Estonia	0.85%	0.64%	0.51%
Finland	0.61%	0.32%	-0.20%
France	0.58%	0.33%	0.33%
Germany	0.73%	0.36%	-0.36%
Greece	0.53%	0.49%	1.01%
Hong Kong	0.55%	0.80%	0.71%
Hungary	0.87%	0.38%	-0.37%
Iceland	0.78%	0.47%	-0.44%
India	0.53%	0.47%	0.49%
Indonesia	0.60%	0.56%	0.49%
Ireland	1.31%	0.83%	-1.81%
Israel	0.66%	0.44%	0.04%
Italy	0.57%	0.32%	0.19%
Japan	0.47%	0.34%	0.05%
Latvia	0.62%	0.44%	0.80%

Table B.9 (Continued): Gains from Constrained and Globally Efficient Industrial Policies, All Countries

Country	Baseline Industrial Policy (1)	Constrained Industrial Policy (2)	Globally Efficient Industrial Policy (3)
Lithuania	0.76%	0.57%	0.49%
Luxembourg	1.36%	1.40%	0.50%
Malaysia	0.86%	0.54%	-0.33%
Malta	0.71%	0.84%	0.86%
Mexico	0.64%	0.48%	0.75%
Netherlands	0.58%	0.39%	-0.25%
New Zealand	0.58%	0.44%	0.18%
Norway	0.70%	0.82%	0.49%
Philippines	0.57%	0.49%	0.35%
Poland	0.74%	0.38%	0.32%
Portugal	0.61%	0.37%	0.66%
Republic of Korea	0.64%	0.39%	-0.36%
Romania	0.61%	0.38%	0.62%
Russian Federation	0.57%	0.66%	0.39%
Saudi Arabia	0.82%	1.27%	0.62%
Singapore	0.96%	0.78%	-1.06%
Slovakia	0.83%	0.27%	-0.06%
Slovenia	0.86%	0.46%	0.08%
South Africa	0.56%	0.45%	0.45%
Spain	0.64%	0.41%	0.35%
Sweden	0.72%	0.40%	-0.30%
Switzerland	0.88%	0.58%	-0.31%
Taiwan	0.75%	0.46%	-0.28%
Thailand	0.82%	0.46%	-0.39%
Tunisia	0.82%	0.75%	1.07%
Turkey	0.57%	0.47%	0.72%
United Kingdom	0.61%	0.42%	0.51%
United States	0.40%	0.31%	0.42%
Vietnam	0.79%	0.80%	1.36%
Avg., Unweighted	**0.69%**	**0.56%**	**0.29%**
Avg., GDP-Weighted	**0.51%**	**0.38%**	**0.22%**

Notes: Each column reports the gains, expressed as a share of initial real national income, that could be achieved by each type of policy. See the text for detailed descriptions of the exercises.