Redistributing the Gains From Trade

PRELIMINARY AND WORK IN PROGRESS.

Spencer G. Lyon
New York University

Michael E. Waugh
New York University and NBER

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ABSTRACT

This paper studies the optimal degree of tax progressivity as an economy opens to trade. We answer this question within a standard incomplete markets model with frictional labor markets and Ricardian trade. Labor market frictions lead to losses in labor income and reductions in labor force participation for import-competition-exposed workers. In an incomplete markets setting, adverse shocks to comparative advantage are imperfectly insured and import-competition-exposed workers experience welfare losses. A progressive tax system provides a mechanism to transfer resources to the losers from trade and to substitute for imperfect insurance against comparative advantage risk. However, a progressive tax system reduces incentives to work and for labor to reallocate from comparative disadvantaged locations to locations with a comparative advantage. We calibrate the model to match the observed labor market response to trade exposure and solve for the optimal degree of progressivity of the tax system. Preliminary results find that the optimal tax system should be more progressive with exposure to trade.

Email: spencer.lyon@stern.nyu.edu, mwaugh@stern.nyu.edu.

There are many concerns about the forces of globalization—that the losses from trade are quite large; that there are insufficient mechanisms to insure against these losses; that globalization simply propagates existing inequality. The standard answer to these concerns is helpful in theory: that there is exist a Pareto improving transfer scheme that can compensate the losers from trade, yet still preserve the gains for the winners. In practice, this answer is less helpful given the limited mechanisms and incentive problems policy makers face in implementing any kind of transfer scheme. One conceivable way to implement a Pareto improving transfer scheme is via the tax system—that is use a progressive tax system to transfer resources from the winners from trade to the losers. This paper takes evaluates this possibility by measuring the optimal degree of tax progressivity as an economy becomes exposed to trade.

The basic idea is to start with a open-economy, standard incomplete markets model in which households face uninsurable income shocks (some of which are trade related), and yet have several margins to mitigate labor income risk. Specifically, households can (imperfectly) self-insure, opt-out of the labor force, and/or move when local labor market conditions are not favorable. These mechanisms lead to a tension on the optimal degree of tax progressivity. On the one hand, a progressive tax system provides a mechanism to substitute for imperfect insurance against comparative advantage risk and to transfer resources to the losers from trade. However, a progressive tax system reduces incentives to work and for labor to migrate. We then use the model and data to evaluate and measure how the optimal degree of progressivity of the tax system should vary as the economy is exposed to trade.

Our quantitative framework builds on our own parallel work in Lyon and Waugh (2017). In Lyon and Waugh (2017), we develop a dynamic Ricardo-Viner model of trade with incomplete markets. As in the model of Eaton and Kortum (2002), there is a continuum of goods with competitive producers who are heterogenous in productivity; comparative advantage determines the pattern of trade. The labor market is frictional and labor can only move across different goods producing markets (within a country) after paying some cost. The Ricardo-Viner aspect of the model delivers losses in labor income to import-competition-exposed workers very much consistent with the evidence in Autor, Dorn, and Hanson (2013) (henceforth ADH).[1]

As in standard incomplete markets models (e.g. Huggett (1993) or Aiyagari (1994)), households face incomplete markets but can partially self insure. That is households are exposed to uninsurable income shocks (some of which are trade related) but do have mechanisms to self-insure and manage loses in labor income. We view this as an important detail both empirically and theoretically. Empirically, evidence suggests that risk sharing is partial and incomplete (see,

[1] In particular, in Lyon and Waugh (2017) we show how our model delivers a structural interpretation of the regressions in ADH and a rationalization for their instrumental variable strategy. Our model structurally relates goods-market-level wages with import exposure through the share of domestic production relative to consumption of that commodity and the elasticity of substitution across commodities. Thus, an increase in import exposure leads to a decline in goods-market-level wages.

e.g., Cochrane (1991)). Theoretically, limited risk-sharing gives rise to a key motive in favor of tax progressivity: it provides social insurance against labor income uncertainty (see, e.g. Eaton and Rosen (1980)). Moreover, because opening to trade changes the nature of labor income risk, limited risk-sharing provides a motive for the government to change the progressivity of the tax scheme as an economy opens to trade.

In our model, the government uses a parametric, non-linear labor-income tax and transfer scheme to redistribute resources. In particular, we closely follow approach of Benabou (2002), Conesa and Krueger (2006), and Heathcote, Storesletten, and Violante (2014) where the progressivity of net-taxes depends upon on one parameter.[2] The optimal degree of progressivity is the measured as the progressivity parameter that maximizes social welfare.[3] The key contribution of our exercise is to measure how the optimal progressivity varies as the economy is exposed to trade.

We follow our parallel work in Lyon and Waugh (2017) to calibrate the model. In the model, there are essentially three key elasticities: how wages respond to trade shocks, how labor supply responds to changes in trade-induced wage changes, and how migration responds to changes in wages. The former elasticity essentially determines the amount of trade-induced income risk there is the model; the latter two elasticities speak to the ability of households to adjust in response to trade-induced income shocks. These three elasticities map into parameters regarding the elasticity of substitution across goods, the disutility of working, and migration costs. We then discipline these three parameters by asking the model to match the ADH facts regarding (i) decline in labor income in import-competition-exposed areas (ii) decline in labor force participation and (iii) migration facts in ADH and updated data.

Given the calibrated model, our main quantitative exercise measures the optimal progressivity of the economy as trade exposure varies. We implement this exercise in the following steps. First, we take a stand on the social welfare function: in the current version of the paper, we focus on a utilitarian planner which places equal weight on households within the domestic economy. Second, for a given level of trade costs, we solve for the progressivity parameter that maximizes social welfare. Third, we repeat this exercise for different levels of trade costs to trace out how the optimal progressivity of the economy should vary.

Related Literature. This paper is work in progress and we are currently surveying the literature to understand our place in it. This paper is closely related to the quantitative studies of Conesa and Krueger (2006), and Heathcote, Storesletten, and Violante (2014) who study the op-

[2] Heathcote, Storesletten, and Violante (2014) show that this functional form provides a good approximation of the actually tax and transfer scheme in the US data. Guner, Kaygusuz, and Ventura (2014) provide an exploration of this and alternative tax functions.

[3] This exercise is akin to Ramsey (1927) which seeks to find the optimal tax system given a restriction on the types of taxes available to the government. This is to be distinguished from Mirrlees (1971) which places no restrictions on the tax system.

timal progressivity of the US tax scheme in heterogenous agent, incomplete market models; but trade and open economy issues are not addressed in this work. Perhaps, most closely related is Antràs, De Gortari, and Itskhoki (2016). In a static, open economy Mirrlees (1971) framework, Antràs, De Gortari, and Itskhoki (2016) study the welfare consequences of trade-induced inequality its interaction with redistributive polices.

1. Model

Here we describe a model of international trade with households facing incomplete markets and frictions to move across labor markets. The first section discusses the production structure, the second section discusses the government and the tax function, the third section discusses the households, and finally an equilibrium is discussed and defined.

1.1. Production

The model has an intermediate goods sector and a final good sector which aggregates the intermediate goods. Within a country, there is a continuum of intermediate goods indexed by $\omega \in [0, 1]$. As in the Ricardian model of Dornbusch, Fischer, and Samuelson (1977) and Eaton and Kortum (2002), intermediate goods are not nationally differentiated and, thus, intermediate ω produced in one country is a perfect substitute for the same intermediate produced by another country.

Intermediate goods are produced by competitive firms with linear production technologies,

$$q(\omega) = z(\omega)\ell, \tag{1}$$

where z is the productivity level of firms and ℓ is the number of efficiency units of labor. Intermediate goods productivity z evolves stochastically according to an AR(1) process in logs

$$\log z_{t+1} = \phi \log z_t + \epsilon_t \tag{2}$$

where ϵ_t is distributed normally with mean zero and standard deviation σ_ϵ. The innovation ϵ_t is independent across time, across goods, and across countries.

Firms producing variety ω will face a competitive product and labor market with households that can potentially supply labor. Competition implies that a household choosing to work in market ω earn the value of their marginal product of labor, which is the price of the good times the firm's productivity z.

Finally, transporting goods across countries is costly. Specifically, variety producing firms face iceberg trade costs $\tau \geq 1$ when exporting their product. This means that for a firm to deliver one unit of the intermediate good abroad, it must produce $\tau > 1$ units for shipment.

Intermediate goods are aggregated by a competitive final goods producer. This final goods producer has a standard CES production function:

$$Q = \left[\int_0^1 q(\omega)^\rho d\omega \right]^{\frac{1}{\rho}}, \tag{3}$$

where $q(\omega)$ is the quantity of individual intermediate goods ω demanded by the final goods firm and ρ controls the elasticity of substitution across variety, which is $\theta = \frac{1}{1-\rho}$.

1.2. Government

The government both consumes resources G and levies taxes and transfers to finance these expenditures. Define net tax revenues at labor income level w as $T(w)$. Following Benabou (2002) and Heathcote, Storesletten, and Violante (2014), we assume that net tax revenues is of the following parametric class:

$$T(w) = w - \lambda w^{1-\tau_p} \tag{4}$$

There are two parameters in (4). The λ parameter determines (in a sense) the average rate. The parameter τ_p directly controls the progressivity of the tax scheme. Heathcote, Storesletten, and Violante (2014) describe several ways to see how τ_p determines the progressivity. The most straightforward way is to note that $1 - \tau_p$ is equal to one minus the marginal tax rate relative to one minus the average tax rate. Thus, if $\tau_p > 0$, marginal rates exceed average rates and the tax system is progressive. If $\tau_p = 0$, the marginal rates equal average rates and the tax system is a flat tax with rate $1 - \lambda$. Finally, if $\tau_p < 0$, the marginal tax rate is lower than the average tax rate and the system is regressive. Heathcote, Storesletten, and Violante (2014) show that this functional form provides a good approximation of the actual tax and transfer scheme in the US data.

1.3. Households

In country i there is continuum of infinitesimally small households of mass L_i. Each household is infinitely lived and seeks to maximize expected discounted utility

$$E \sum_{t=0}^{\infty} \beta^t \left\{ \frac{c_t^{1-\sigma}}{1-\sigma} - \bar{h} B \right\} \tag{5}$$

where E is the expectation operator, β is the subjective discount factor, and σ controls the intertemporal elasticity of substitution. Period utility depends on both consumption of the final good and a disutility of labor $\bar{h}B$ where $\bar{h}$ is hours worked.

Households live and work along the same dimension as the intermediate goods. That is a households location is given by ω, the intermediate goods sector it can work in. Given their current location, households can chose if to work, to move and work someplace else in the future, and accumulate a non-state contingent asset. Below, we describe each of these choices in detail.

Working is a discrete choice between zero hours and $\bar{h}$. Thus, the labor supply is purely on the extensive margin. If a household works, it receives wage per efficiency unit from employment in the intermediate goods sector that the household resides. If a household does not work, if receives some (un-taxed) home production w_n.

The wage per efficiency unit that a household receives depends on the value of the marginal product of labor in that market. This depends directly on a country's productivity level in that market and indirectly through all countries productivity level in the production of that same good through trade. Thus, the relevant state variable determining the wage per efficiency unit are all countries' productivities. Thus, the wage per efficiency unit a household earns is $w(\mathbf{z})$ where $\mathbf{z}$ denotes the vector of productivity levels across countries.[4] Given the tax function in 4, the posttax earnings of the household is

$$\tilde{w}(\mathbf{z}) = \lambda w(\mathbf{z})^{1-\tau_p}. \tag{6}$$

Households can move to alternative intermediate goods sector ω' at some cost. Paying $m > 0$ in units of the final good to allows the household to change where they can work in next period. The value of the new location can take several forms. One is the best labor market as in Lucas and Prescott (1974); an alternative is a random labor market. We explore both specifications.

Per the discussion above, households residing in a intermediate goods location face idiosyncratic labor income risk associated with fluctuations in productivity and (as discussed below) fluctuations in world prices. We do not allow for any insurance markets against this risk, but let households accumulate a non-state contingent asset a that pays gross return R. For now, we treat R as exogenous and not solved for in equilibrium. An interpretation is that in the economy is a large supply of assets at this rate. Households face a lower bound on asset holding $-\phi$, so agents can acquire debt up to the value ϕ.

Given the description of the environment, the household's period t budget constraint is

$$a_{t+1} + P_h c_t + \iota_{m,t} m_t \leq R a_t + \iota_{n,t} \tilde{w}(\mathbf{z}) \bar{h} + (1 - \iota_{n,t}) w_n \tag{7}$$

[4]While standard, it is worth discussing how the location ω is not a relevant state variable—because intermediate goods enter the final goods production function symmetrically, outcomes in an intermediate goods only depend upon productivity; not any ω specific variable.

where R is the gross interest rate on assets, c_t is consumption, m_t is the moving cost a household faces multiplied by ι_t which is an indicator function equalling one if a household moves in period t and zero otherwise. And $\bar{h}$ are hours of work supplied by the household. Finally, $\iota_{n,t}$ is an indicator function equalling one if a household works.

The individual state variable of a household is its asset holdings a. The sector level state variable relevant to the household is the wage $w(\mathbf{z})$ where the household resides. This depends on domestic productivity and wold prices which are summarized in the vector $\mathbf{z}$. Thus, we denote the state variable of a household as $(a, \mathbf{z})$.

Given these states, the recursive formulation of the household's problem is a discrete choice between four options: the value of staying and working, the value of staying and not working, the value of moving and working, the value of moving and not working. The value function of the household is the max over these four options. The value of staying and working is

$$V^{s,w}(a,\ \mathbf{z}) = \max_{a' \geq -\phi} \left[u(Ra + \tilde{w}(\mathbf{z})\bar{h} - a') - \bar{h}B + \beta EV(a', \mathbf{z'}) \right]. \tag{8}$$

where $u(\bullet) = \frac{c^{1-\sigma}}{1-\sigma}$. The value of staying and not working is

$$V^{s,nw}(a,\ \mathbf{z}) = \max_{a' \geq -\phi} \left[u(Ra + w_n - a') + \beta EV(a', \mathbf{z'}) \right] \tag{9}$$

The value of moving and working is

$$V^{m,w}(a,\ \mathbf{z}) = \max_{a' \geq -\phi} \left[u(Ra + \tilde{w}(\mathbf{z})\bar{h} - a' - m) - \bar{h}B + \beta V^{m}(a') \right]. \tag{10}$$

where there are two key distinctions relative to (8). First, the moving cost, m is paid. Second, the continuation value is $V^m(a')$. As discussed above, the value of moving can take several forms: the best labor market, a random labor market, etc. Finally, the value of moving and not working is

$$V^{m,nw}(a,\ \mathbf{z}) = \max_{a' \geq -\phi} \left[u(Ra + w_n - a' - m) + \beta EV^{m}(a') \right] \tag{11}$$

Putting these together describes the value function of a household with asset level a and labor market states of $\mathbf{z}$

$$V(a,\ \mathbf{z}) = \max \left[V^{s,w},\ V^{s,nw},\ V^{m,w},\ V^{m,nw} \right]. \tag{12}$$

2. Equilibrium

In this section, we close the model by focusing on a small open economy equilibrium. Specifically, we solve for a home country equilibrium given world prices. The small open economy assumption is that there is no feed back from home country actions into world prices. Relative to the literature, this is similar to the second specification solved in Artuç, Chaudhuri, and McLaren (2010). Moreover, it has the advantage (say relative to Caliendo, Dvorkin, and Parro (2015)) to be relatively simple, yet allows us to specific about the interaction between trade flows and capital flows. And, thus, we are able to talk meaningfully about the role of trade imbalances.

World Prices. World prices for commodity ω evolve according to an independent AR(1) process in logs as well:

$$\log p_w(\omega)_{t+1} = \phi \log p_w(\omega) + \epsilon_{w,t} \tag{13}$$

where $\epsilon_{w,t}$ is distributed normally with mean zero and standard deviation σ_w and independent of the innovation to the home countries productivity ϵ_t. We express these prices in units of the numeraire, which we take to be the final good in the home country. Hanson, Lind, and Muendler (2015) may provide a foundation for this process.

As we discuss below, domestic prices will depend both on domestic productivity and the world price. Thus, we carry around the the vector $\mathbf{z} = \{ z_h, p_w \}$ and the relevant state variable determining the price $p(\mathbf{z})$.[5]

Finally, a notional note. We denote $\pi(\mathbf{z})$ as the stationary distribution of productivity states and world prices induced by (2) and (13). And denote $\pi(\mathbf{z'}, \mathbf{z})$ as the probability of transiting from state $\mathbf{z}$ to $\mathbf{z'}$.

2.1. Production Side of the Economy

Below we describe the equilibrium conditions associated with the production side of the economy. These take as given the choices of the household. In particular, define $\mu_h(\mathbf{z})$ as the mass of households supplying labor in market of type $\mathbf{z}$.

Final Goods Production. Final goods producer's problem is:

$$\max_{q(\mathbf{z})} P_h Q_h - \int_0^1 p_h(\mathbf{z}) q(\mathbf{z}) \pi(\mathbf{z}) dz \tag{14}$$

[5] While standard, it is worth discussing how the location ω is not a relevant state variable—because intermediate goods enter the final goods production function symmetrically, outcomes in an intermediate goods only depend upon productivity and world prices; not any ω specific variable.

which gives rise to the following the demand curve for an individual variety

$$q_h(\mathbf{z}) = \left(\frac{p_h(\mathbf{z})}{P_h}\right)^{-\theta} Q_h. \tag{15}$$

where Q_h is aggregate demand of the final good; P_h is the price associated with the final good.

Intermediate Goods Production. The intermediate goods producers problem is

$$\max_{q(\mathbf{z})} p_h(\mathbf{z})q(\mathbf{z}) - P_h w(\mathbf{z})\frac{q(\mathbf{z})}{z_h}, \tag{16}$$

or to chose the quantity produced to maximize profits. Competition implies that the wage per efficiency unit (in units of the final good) the firm hires labor at is:

$$w_h(\mathbf{z}) = \frac{p_h(\mathbf{z})z_h}{P_h}, \tag{17}$$

or the value of the marginal product of labor. Only at the wage in (17) are intermediate goods producers willing to produce.

Intermediate Goods, International Trade, and Market Clearing. To formulate the pattern of trade, we denote the set of prevailing prices that the final goods producer in the home country faces as $p_h(\mathbf{z})$, τp_w. The final goods producer in each country purchases intermediate goods from the low cost supplier. This decision gives rise to three cases with three different market clearing conditions.[6] Specifically, if the good is non-traded, if the good is imported, if the good is exported.

Below, we describe demand and production in each of these cases .

- **Non-traded.** If the good is non-traded, then the domestic price for the home country must satisfy the following inequality: $\frac{p_w}{\tau} < p_h(\mathbf{z}) < \tau p_w$. That is from home country's perspective it is optimal to source the good domestically and it is not optimal for the home country to export the product.

  In this case, the market clearing condition (for the home country) is:

  $$\pi(\mathbf{z}) \left(\frac{p_h(\mathbf{z})}{P_h}\right)^{-\theta} Q_h = z_h \mu_h(\mathbf{z}) \bar{h}, \tag{18}$$

  or that domestic demand equals production. The left-hand-side part is the measure of intermediate goods markets multiplied by the demand in those markets which must equal

[6] This is more nuanced than the standard formulation in Eaton and Kortum (2002) due to the frictional labor market. That is there are situations in which an intermediate good is both imported and produced domestically, which is not the case in the Eaton and Kortum (2002) model.

supply or the productivity of domestic suppliers multiplied by the supply of labor units in that market.

- **Imported.** If the good is imported, then the domestic price for the home country must be $p_h(\mathbf{z}) = \tau p_w$. Why? The home price can not be any larger as arbitrage implies that the domestic price must equal the price of the same imported good from the world. And if the price was lower, then it would not be imported. In this situation with frictional labor markets, we need to take into account that there may be some domestic production. So the quantity of imports is

$$\underbrace{\pi(\mathbf{z})\left(\left(\frac{\tau p_w}{P_h}\right)^{-\theta} Q_h\right) - z_h \mu_h(\mathbf{z})\bar{h}}_{\text{imports}} \;>\; 0 \tag{19}$$

  The key distinction here relative to the two country model is that we are not specifying world production of the commodity. That is at the given world price p_w, home demand is able to be met. All of this must be larger than zero. Below, it will be useful to define domestic demand as

$$\pi(\mathbf{z})\left(\left(\frac{\tau p_w}{P_h}\right)^{-\theta} Q_h\right) \;=\; z_h \mu_h(\mathbf{z})\bar{h} \;+\; \text{imports}(\mathbf{z}), \tag{20}$$

  or domestic consumption must equal domestic production plus imports of that commodity.

- **Exported.** If the good is exported, then it must be that $p_h(\mathbf{z})\tau = p_w$. Why? If the home price was larger, then it would not be purchased on the world market. And the price can not be lower as arbitrage implies that the price of the exported good sold in the world market must equal the prevailing price in that market. At this price, the quantity of exports is

$$\underbrace{\pi(\mathbf{z})\left(\frac{p_w/\tau}{P_h}\right)^{-\theta} Q_h - z_h \mu_h(\mathbf{z})\bar{h}}_{-\text{exports}} \;<\; 0 \tag{21}$$

  The left-hand-side part is the measure of intermediate goods markets multiplied by domestic demand net of production. All of this should be negative implying that the country is an exporter. Below, it will be useful to define this in the following way

$$\pi(\mathbf{z})\left(\frac{p_w/\tau}{P_h}\right)^{-\theta} Q_h \;=\; z_h \mu_h(\mathbf{z})\bar{h} \;-\; \text{exports}(\mathbf{z}) \tag{22}$$

The discussion above completely summarizes the demand and supply conditions that must be met in all intermediate goods markets.

The Final Good and Market Clearing. The final good's producer sells the final good to consumers. Thus, we have the following market clearing condition

$$Q_h = C_h + G = \int_z \int_a c(\mathbf{z}, a)\lambda(\mathbf{z}, a) + G, \tag{23}$$

where $c(\mathbf{z}, a)$ is the consumption policy function which satisfies the households problem and $\lambda(\mathbf{z}, a)$ is the mass of consumers with state $\mathbf{z}$ and asset holding a (defined below in (24)) . This relationship says household-level consumption—aggregated across all households— plus government consumption must equal the aggregate production of the final good Q_h.

Market clearing conditions for the intermediate goods in (18),(20), (22), and the aggregate final good in (23) summarize the equilibrium relationship on the production side of the economy.

2.2. Household Side of the Economy

The household's in the economy make choices about where to reside, how much to work, and how much to consume. Here we describe the equilibrium conditions associated with these choices. In the discussion below, we define the following functions $\{ \iota_m(\mathbf{z}, a), \iota_n(\mathbf{z}, a), g_a(\mathbf{z}, a) \}$ as the move, work, and asset policy functions that satisfy the households problem in (12).

Population and Labor Supply. We define the probability distribution of households, across assets and states, as $\lambda_h(\mathbf{z}, a)$. Furthermore, define the probability distribution of households in the next period as $\lambda_h'(\mathbf{z}, a)$. The distribution of households evolves across time according to the following law of motion

$$\lambda_h'(\mathbf{z'}, a') = \int_{a:a'=g_a(\mathbf{z},a)} \lambda_h(\mathbf{z}, a)(1 - \iota_m(\mathbf{z}, a))\pi(\mathbf{z'}, \mathbf{z}) + \lambda_h(\mathbf{z}, a)\iota_m(\mathbf{z}, a)\bar{\pi}(\mathbf{z'}). \tag{24}$$

Equation (24) says the following. Next period, the mass of households with asset holding a' in state $\mathbf{z'}$ equals

- The mass of household that do not move multiplied by the transition probability that $\mathbf{z}$ transits to $\mathbf{z'}$. This is the first term in equation (24). Plus...
- The mass of households that do move multiplied by the probability that they end up in state $\mathbf{z'}$. This is the second term in equation (24). The probability, $\bar{\pi}(\mathbf{z'})$, is given by the moving protocol.
- All of this is conditional on those households who choose assets holdings equal to a'. This

denoted by the conditionality under the integral sign.

Given a distribution of households, the supply of labor to intermediate good producers with productivity state $\mathbf{z}$ is,

$$\int_a \iota_n(\mathbf{z}, a)\lambda_h(\mathbf{z}, a) = \mu_h(\mathbf{z}), \tag{25}$$

which is population residing in that market multiplied by the labor supply policy function and integrated over all asset states. This then connects the supply of labor with production in (18)-(22).

Asset Holdings and Consumption. The distribution of asset holdings and consumption take the following form. Next period, aggregate net-asset holdings are

$$\mathcal{A}' = \int_a \int_z g_a(\mathbf{z}, a)\lambda_h(\mathbf{z}, a). \tag{26}$$

A couple of points about this. First, this is in aggregate. However, recall that some households in the home country may have positive holdings; others may have negative holdings. Second, net asset holdings must always be claims on foreign assets since there is no domestic asset in positive supply (such as capital).

Using the definition in (26) and the focus on a stationary equilibrium (so $\mathcal{A}' = \mathcal{A}$) we can work from the consumers budget constraint and derive aggregate consumption:

$$C_h = -\mathcal{A}' + R\mathcal{A} + \int_a \int_z \left\{ \bar{h}\tilde{w}(\mathbf{z})\iota_n(\mathbf{z}, a) + w_n(1 - \iota_n(\mathbf{z}, a)) - m\iota_m(\mathbf{z}, a) \right\} \lambda_h(\mathbf{z}, a). \tag{27}$$

In words, aggregate consumption equals net asset purchases (the first two terms) plus wage income and home production net of moving costs.[7]

2.3. Government

We currently assume that the government runs a balanced budget. Thus, government spending must equal total tax revenues collected or

$$G = \int_a \int_z T(w(\mathbf{z}))\iota_n(\mathbf{z}, a)\lambda_h(\mathbf{z}, a), \tag{28}$$

[7] To understand this a bit better, note the connection with (27) and the closed, endowment economy in Huggett (1993); aggregate asset holdings are in zero net supply, thus the first term on the right-hand-side is zero, there is no moving, and there is no labor supply choice. Thus, aggregate consumption must equal aggregate labor income in Huggett's (1993) economy.

which says that government spending must equal the tax revenues conditional on working and then integrates over all markets and asset states.

What does the government do in our economy? Exogenously given are spending levels G and the tax progressivity τ_p parameter. The government then picks the average tax rate, λ, such that (28) holds. In the quantitative analysis below, we focus on the case of $G = 0$, thus the government is only playing the role of redistributing income given the progressivity parameter τ_p.

2.4. A Stationary Small Open Economy (SSOE) Equilibrium

Given the equilibrium conditions from the production and household side of the economy, we define a "Stationary Small Open Economy (SSOE) Equilibrium" equilibrium.

A Stationary Small Open Economy (SSOE) Equilibrium. Given world prices $\{p_w, R\}$ and government policy $\{G, \tau_p\}$, a stationary Small Open Economy Equilibrium is domestic prices $\{p_h(\mathbf{z}), P_h\}$, tax rate λ, policy functions $\{\ g_a(\mathbf{z}, a), \iota_n(\mathbf{z}, a), \iota_m(\mathbf{z}, a)\ \}$, a probability distribution $\lambda_h(\mathbf{z}, a)$ such that

i Firms maximize profits, (14) and (16) ;

ii The policy functions solves the household's optimization problem in (12);

iii Demand for the final and intermediate goods equals production, (18)-(21) and (23);

iv The government budget is balanced (28);

v The probability distribution $\lambda_h(\mathbf{z}, a)$ is a stationary distribution associated with $\{\ g_a(\mathbf{z}, a), \iota_m(\mathbf{z}, a), \pi(\mathbf{z'}, \mathbf{z})\ \}$. That is it satisfies

$$\lambda_h(\mathbf{z'}, a') = \int_{a:a'=g_a(\mathbf{z},a)} \lambda_h(\mathbf{z}, a)(1 - \iota_m(\mathbf{z}, a))\pi(\mathbf{z'}, \mathbf{z}) + \lambda_h(\mathbf{z}, a)\iota_m(\mathbf{z}, a)\bar{\pi}(\mathbf{z'}). \tag{29}$$

The idea behind the equilibrium definition is the following. The first bullet point (**i**) gives rise to the equilibrium conditions for the demand of intermediate goods in (15) and wages (17) at which firms are willing to produce. The second bullet point (**ii**) says that households are optimizing.

At a superficial level, bullet (**iii**) simply says that demand must equal supply. It is, however, deeper. The choices of the household matter for both the demand and the supply side. Specifically, it requires that prices (and hence wages) must *induce* a pattern of (i) consumption and (ii) labor supply such that demand for goods equals the production of goods.

Bullet point (**v**) requires stationarity. Specifically, the distribution of households across productivity and asset states is not changing. Mathematically, this means that distribution $\lambda_h(\mathbf{z}, a)$ must be such that when plugged into the law of motion in (24), the same distribution is returned.

Finally, note that there is no requirement that the assets market clear, i.e., that (26) equals zero. This is an aspect of the small open economy assumption. At the given world interest rate R, the assets need not be in zero net supply (which is in contrast, to say Huggett's (1993)). As we discuss below, this implies that trade need not balance as the trade imbalance will reflect asset income on foreign assets and the acquisition of assets.

Computationally, finding a solution to this economy is straightforward: guess a set of prices, solve the household problem and construct the stationary distribution, then check that the market clearing conditions are satisfied. The open-economy aspect of this economy (that domestic demand and supply may not be equal, but that prices must respect specified bounds) mean that the market clearing conditions can be represented as a mixed complementarity problem (see, e.g., Miranda and Fackler (2004)).

2.5. Connection with National Accounts

This section connects these equilibrium relationships to national income and product accounts (NIPA). This will help facilitate an understanding of the connection between trade imbalances and household's consumption-savings decisions.

The Income Side of NIPA. It is first useful to start from an income side measure of production (or GDP) in our economy. Given competition, the value of aggregate production of the final good must equal aggregate payments for intermediate goods plus. The latter equals aggregate payments to labor in the production of all intermediate goods.

$$P_h Y_h = \int_{\mathbf{z}} P_h w_h(\mathbf{z}) \mu_h(\mathbf{z}) \tag{30}$$

Examining (27) and (30) allows us to connect aggregate income with consumption

$$P_h Y_h = P_h C_h + P_h G - P_h R \mathcal{A} + P_h \mathcal{A}' - P_h \int_a \int_z w_n (1 - \iota_n(\mathbf{z}, a)) \lambda_h(\mathbf{z}, a) + P_h \int_a \int_z m \iota_m(\mathbf{z}, a) \lambda_h(\mathbf{z}, a) \tag{31}$$

so aggregate income equals consumption (private and public) minus (i) returns on assets (ii) new purchases of assets (iii) home production and (iv) plus moving costs. This basically says that income/production must equal consumption net of income not associated with production (i.e. returns on assets and home production) plus "investment" in assets and moving costs. For

example, if consumption is larger than income one reason is that (in aggregate) households (on net) are borrowing from abroad ($\mathcal{A}' < 0$).

Production Side of NIPA. The the value of aggregate production of the final good must equal the value of intermediate goods production

$$P_h Y = \int_{\mathbf{z}} p_h(\mathbf{z}) z \mu_h(\mathbf{z}) \tag{32}$$

which we can then connect with the expenditure side of GDP through the market clearing conditions for intermediate goods and final goods. Specifically, by connecting the production side with the demand side for non-traded goods in (18), imports in (20) and exports in (22) and the equating final demand with consumption we have

$$P_h Y = P_h C_h + P_h G + \int_z \text{exports}(\mathbf{z}) - \int_z \text{imports}(\mathbf{z}). \tag{33}$$

Or GDP equals consumption (private and public) plus exports minus imports.

Savings, Trade Imbalances, and Capital Flows. Finally, we can connect the income side and the production side the national accounts to arrive at a relationship between asset holdings and trade imbalances. By working with both (31) and (33) we get the following relationship

$$P_h Y - P_h C_h - P_h G = \int_z \text{exports}(\mathbf{z}) - \int_z \text{imports}(\mathbf{z}), \tag{34}$$

$$= - P_h r \mathcal{A} + P_h(\mathcal{A}' - \mathcal{A}) - P_h \int_a \int_z w_n (1 - \iota_n(\mathbf{z}, a)) \lambda_h(\mathbf{z}, a) + P_h \int_a \int_z m \iota_m(\mathbf{z}, a) \lambda_h(\mathbf{z}, a),$$

where r is the net real interest rate. This relationship says the following: aggregate savings equals the trade imbalance. And this, in turn, we can connect the trade balance with the savings decisions of the households. That is the trade balance equals payments on net asset holdings plus net change in asset holdings (adjusted for home production and moving costs).[8] That last statement is essentially a statement about international capital flows. To see this, consider the special case where moving costs are zero and no home production. Then we have the relationship

$$P_h Y - P_h C_h - P_h G = \int_z \text{exports}(\mathbf{z}) - \int_z \text{imports}(\mathbf{z}) = -P_h r \mathcal{A} + P_h(\mathcal{A}' - \mathcal{A}). \tag{35}$$

Here if exports are greater than imports, then this implies that the households in the home coun-

[8] To map this into Balance of Payments language: the trade imbalance plus foreign income payments is the current account; the capital account is the net change in foreign asset holdings; then (we suspect) home production and moving costs would show up as the "balancing item."

try are doing several things. The trade surplus may reflect that households (on net) are making debt payments ($r\mathcal{A}$ is negative). Second, the trade surplus may reflect that the households (on net) are acquiring foreign assets ($\mathcal{A}' - \mathcal{A}$ is positive). Finally, note that in a stationary equilibrium, the trade imbalance only reflects payments from foreign asset holdings. This implies that the current account and capital account are always zero in a stationary equilibrium.

3. Model Properties

This section describes some qualitative properties of the model. It borrows from our own parallel work in Lyon and Waugh (2017) that focuses in detail on the workings of the model. Below we focus on two issues (i) the pattern of trade and (ii) how trade changes the distribution of wages.

3.1. Trade and Wages Inequality

This section illustrates some further properties of our model. We compute a station equilibrium in a preliminary calibration of the model. And we some of the mechanics of the model below.

Trade. To illustrate the pattern of trade, first define the following statistic:

$$\omega(\mathbf{z}) := \frac{p_h(\mathbf{z}) z_h \mu_h(\mathbf{z})}{p_h(\mathbf{z}) z_h \mu_h(\mathbf{z}) \bar{h} \;+\; p_h(\mathbf{z})\text{imports}(\mathbf{z}) - p_h(\mathbf{z})\text{exports}(\mathbf{z})}, \tag{36}$$

What does equation (36) represent? The denominator is the value of consumption (everything domestically produced plus imported net of what I shipped out via exports). Then the numerator is production. So the interpretation is how much of domestic consumption is the home country producing. This is essentially the micro-level "home share" summary statistic emphasized in Arkolakis, Costinot, and Rodríguez-Clare (2012). This statistic is interesting because we show in Lyon and Waugh (2017) how to structurally connect the home share in (36) with market-level wages. The Appendix discuss this in more detail.

Figure 1 plots the home share (raised to the power of inverse θ) by world price and home productivity. There are three regions to take note of: where goods are imported, exported, and non-traded. First, in the region where world prices are low or home productivity is low, the country is an importer of commodities with these characteristics. And for the lowest regions, the country does not produce any of these commodities. Second, the region where world prices are high or home productivity is very high is the opposite. This is where the country is an exporter of the commodities with these characteristics.

Finally, there is the "table top" region in the middle where the home share equals one for moderate world prices and home productivity. This is the region where the goods are non-traded (home demand equals home supply). Exactly like the inner, non-traded region in the Ricardian

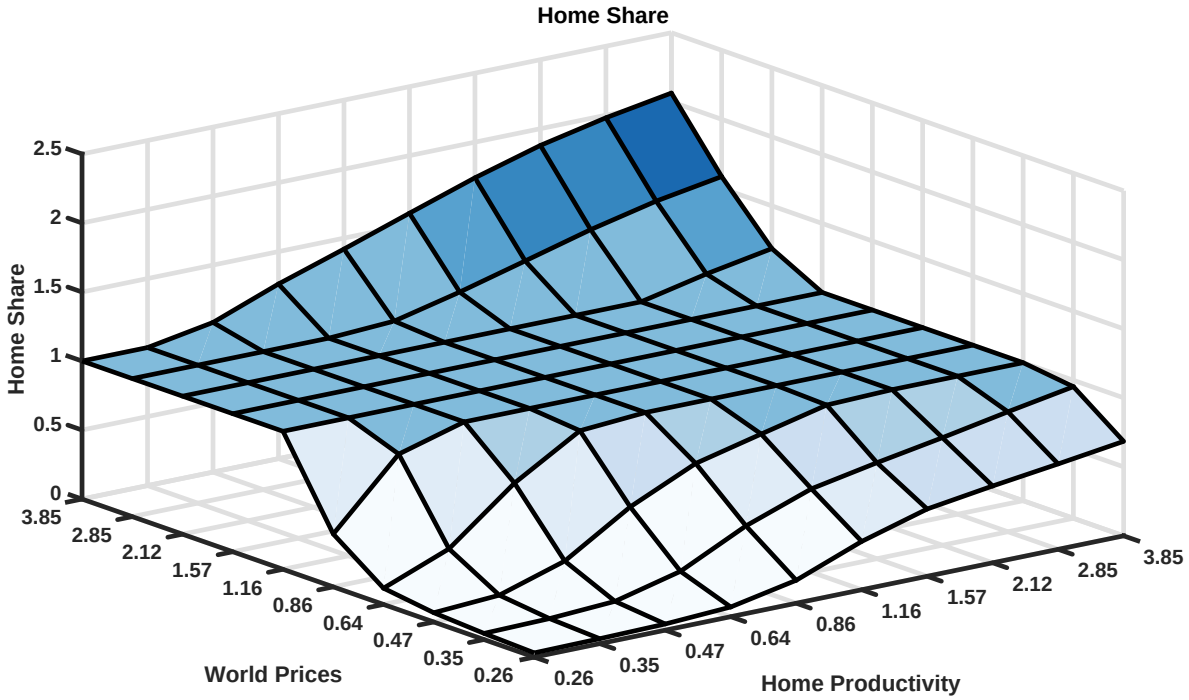


Figure 1: Trade: Home Share, $\omega(\mathbf{z})^{\frac{1}{\theta}}$

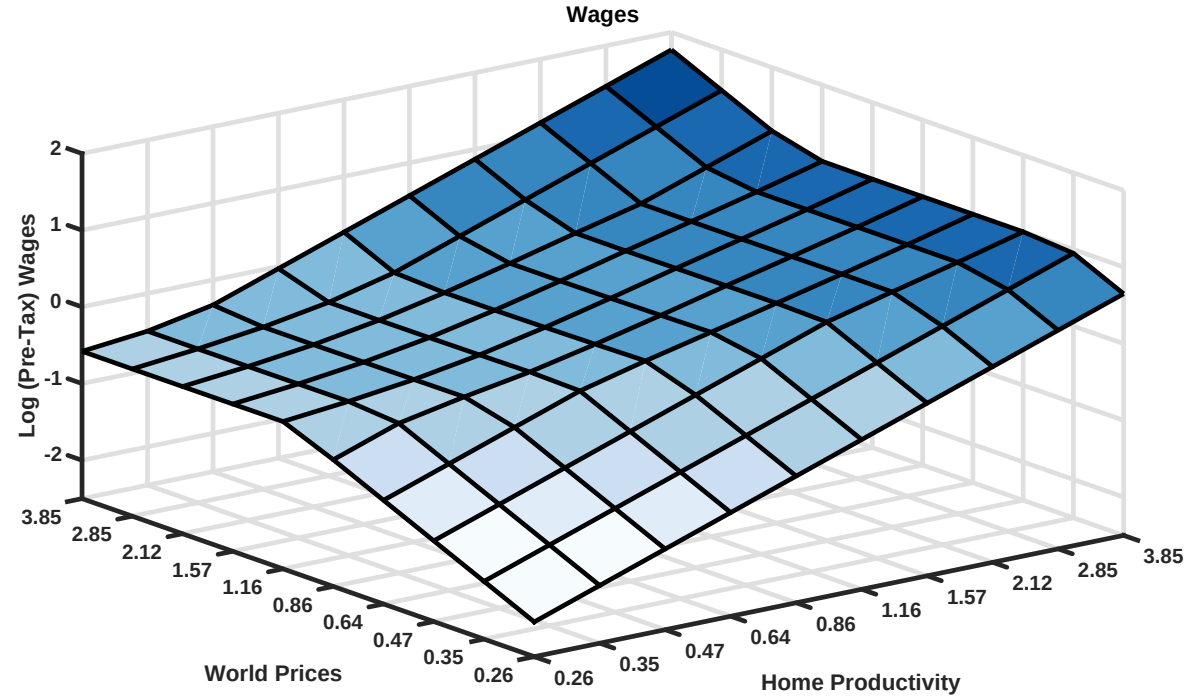


Figure 2: Wages (Pre-tax): Open Economy

model of Dornbusch, Fischer, and Samuelson (1977), the reasons is because of trade costs. In this region, the home country finds that it is best to source the goods from home and not export.

Wages. Figure 2 plots the logarithm of wages by world price and home productivity. Like in Figure 1, there are three regions to take note of. The first one is where import competition is prevalent (low world prices or low home productivity), wages are low.

A simply way to understand this result is the following: wages reflect the value of the marginal product of labor. In import competing sectors, trade results in lower prices and, hence, lower wages. The exporting region (high world prices or high home productivity) is the opposite. Exporting regions are able to capture high world prices and, thus, wages are high in these sectors. The center region is where commodities are non-traded. Here the gradient of wages very much mimics the the increase in domestic productivity. In contrast, where goods are imported or exported, the wage gradient mimics the the change in world prices.

Finally, note the close correspondence between wages and the home share in Figure 1. As discussed in Proposition 1 of Lyon and Waugh (2017) (and presented in the Appendix A) the change in the home share statistic is a sufficient statistic for how labor income in a labor market will change with trade exposure. Qualitatively, this comparison is broadly consistent with the facts of ADH that; import exposure leads to lower labor income.

4. Quantitative Analysis

We first describe the calibration (or how we are currently doing it). We then describe our main quantitative exercise: measures the optimal progressivity of the economy as trade exposure varies. We then discuss some preliminary results.

4.1. Calibration

This is currently in progress. We plan on using the calibration results from our parallel work in Lyon and Waugh (2017). In the results below, we simply use existing parameter values from various literatures and/or guesstimates. Below is the discussion that summarizes our approach from Lyon and Waugh (2017) to calibrate the model.

In the model, there are essentially three key elasticities: how wages respond to trade shocks, how labor supply responds to changes in trade-induced wage changes, and then how migration responds to changes in wages. The former elasticity essentially determines the amount of trade-induced income risk there is the model; the latter two elasticities speak to the ability of households to adjust in response to trade-induced income shocks. These three elasticities map into parameters regarding the elasticity of substitution across goods, the disutility of working, and migration costs. We then discipline these three parameters by asking the model to match

the ADH facts regarding (i) decline in labor income in import-competition-exposed areas (ii) decline in labor force participation and (iii) migration facts in ADH and updated data.

In addition to these facts, we also ask cross-validate the model by focusing on the facts about how household debt and consumption responded. On the household debt side, we compare our model's predictions to Barrot, Loualiche, Plosser, and Sauvagnat (2016) who find a large increase in household debt in areas exposed to import competition. This evidence is suggestive that households facing losses in labor income, accumulated debt in an attempt to smooth out the labor income shocks from import exposure. On the consumption side, we contribute to this discussion by adding new evidence on the consumption response import competition from China. We construct a measure of consumption at the local labor market level in the US built from the Kilts-Nielsen Retail Scanner Dataset (KNRS). The use of KNRS data set is similar to measure the response of consumption to various shocks is similar to the strategy of Kaplan, Mitman, and Violante (2016) in their replication of Mian, Rao, and Sufi (2013). Similar to the strategy of ADH and Barrot, Loualiche, Plosser, and Sauvagnat (2016), we exploit regional variation in exposure to imports from China in the 2000s to study the response of consumption to trade shocks.

The calibration approach of Lyon and Waugh (2017) is to simulating the transition path associated with a reduction in trade costs that mimics both aggregate and micro level data. One the aggregate dimension, we ask the model to replicate the aggregate import share and trade imbalance attributed to China. On the micro-level dimension, we ask the model to replicate the facts described about: labor income response, participation response, debt response, and the consumption response seen across differentially trade exposed areas.

4.2. Social Welfare Function

Our social welfare function we focus on a utilitarian planner which places equal weight on households within the domestic economy. That is

$$W(\tau_p,\ \tau) = \int_z \int_a V(a,\ \mathbf{z}) \lambda_h(\mathbf{z}, a). \tag{37}$$

or the value function of an agent integrated over markets and asset states with respect to the stationary distribution of households across those states $\lambda_h(\mathbf{z}, a)$ (thus no weight is given to foreign agents). Here we explicitly index social welfare by the tax progressivity parameter and by the trade cost. Thus, given the social welfare function in (37), the optimal degree of progressivity is

$$\tau_p^*(\tau) = \arg\max \ \ W(\tau_p,\ \tau). \tag{38}$$

That is, the tax progressivity parameter that maximizes social welfare. Here we make explicit that the tax progressivity parameter depends upon the trade cost or the extent to which the economy is open or closed. Our main quantitative exercise traces out how $\tau_p^*(\tau)$ varies with τ.

4.3. How Optimal Progressivity Varies with Openness

Figure 3 plots how $\tau_p^*(\tau)$ varies with τ. The key observation to note is that as the economy is more exposed to trade (low trade cost, τ), then the optimal tax progressivity parameter increases. For example, when the trade cost is low (the economy is relatively open), then we find that the optimal scheme has a τ_p which is a bit above zero. That is the tax system is slightly progressive. In contrast, when trade cost is high (the economy is relatively closed), the tax system becomes significantly more regressive. Thus, what Figure 3 shows is tax system should become more progressive as the economy opens up.

Figure 4 illustrates this same point. For two different levels of trade costs, it plots welfare as a function of the tax progressivity parameter (fix τ and trace out τ_p). Here welfare is reported as the in percent relative to the optimum (for a given trade cost). In Figure 4, you can see the impact of two tensions: On the one hand, a progressive tax system provides a mechanism to substitute for imperfect insurance. However, a progressive tax system reduces incentives to work and for labor to migrate. This tension gives rise to the arch-shaped welfare function as progressivity is changed.

The red, dotted arch in Figure 4 is with relatively large trade costs, i.e. it is a relatively closed economy. In the relatively closed economy, the optimal tax scheme is **regressive** with an optimal τ_p parameter of about -0.15.

In contrast, the blue solid arch in Figure 4 is with relatively small trade costs, i.e. it is a relatively open economy. In the relatively open economy, the optimal tax scheme is **progressive** and with an optimal τ_p parameter of about 0.03. Moreover, relative to the high trade cost economy, the low trade cost economy's optimal tax scheme is significantly more progressive. That is the optimal tax system should be more progressive with exposure to trade.

5. Conclusion

Still work in progress.

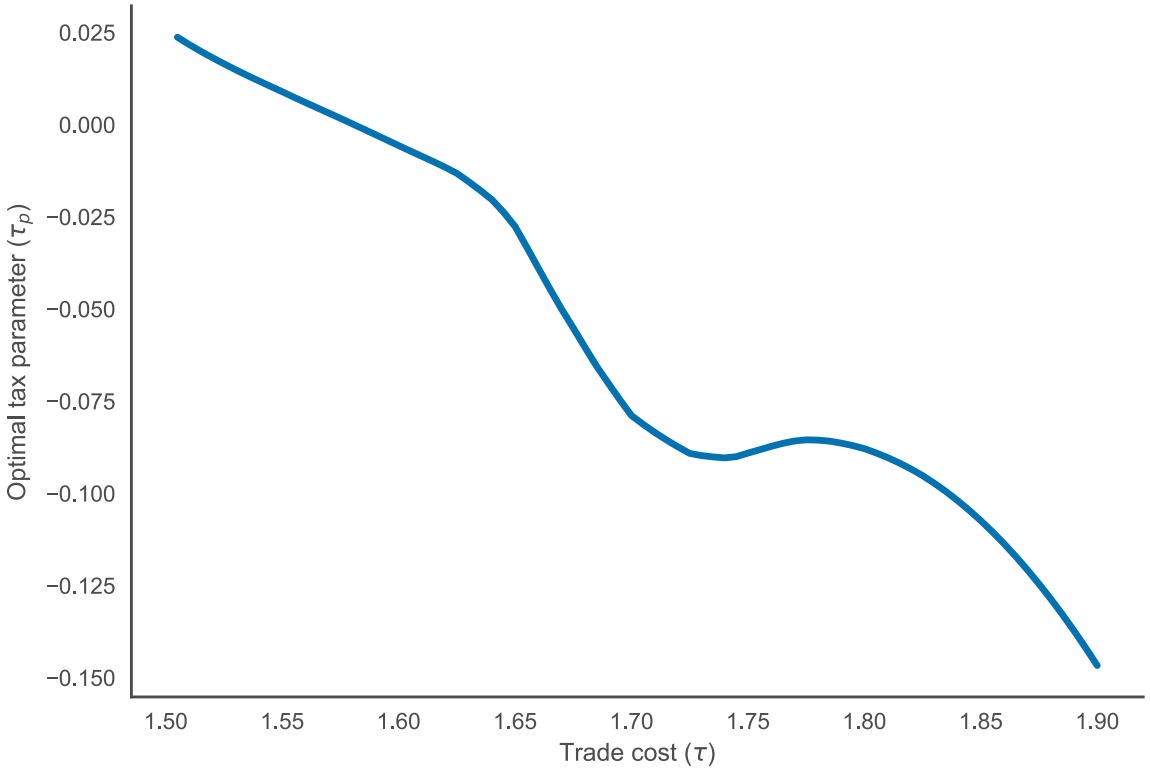


Figure 3: Trade Cost and Tax Progressivity

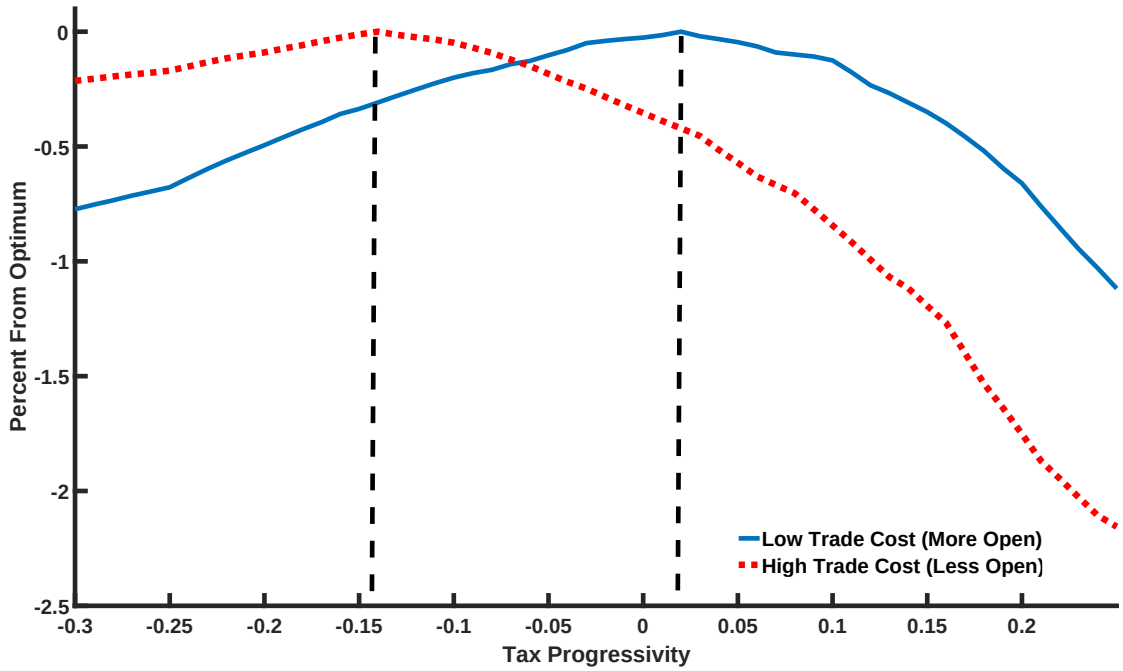


Figure 4: Welfare and Progressivity

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A. Connection with Autor, Dorn, and Hanson (2013)

This discussion is borrowed from Lyon and Waugh (2017) but presented here for convenience.

This section connects wages with trade exposure in a structural way. There are basically two insights that deliver the key result in Proposition 1. First, in a competitive environment, wages reflect the value of the marginal product of labor. This implies that any change in wages through trade exposure works through prices—the "value" part. Second, the CES production structure tightly links changes in prices and changes in quantities. Together, these two insights provide a link between wages and a quantity based measure of trade exposure much like in Autor, Dorn, and Hanson (2013).

To arrive at this conclusion, take the relationships in (18), (20), (21) and "combine" them by noting that demand must simply equal domestic production plus imports minus exports. Then manipulating the demand curve to arrive at a relationship between prices and the share of domestic production relative to consumption. Then connecting this relationship with the wage we have Proposition 1 summarized below.

Proposition 1 (Wages and Trade Exposure) *Real wages in a market with state variable* $\boldsymbol{z}$ *equal*

$$w(\boldsymbol{z}) = \omega(\boldsymbol{z})^{\frac{1}{\theta}} \hat{\mu}_h(\boldsymbol{z})^{\frac{-1}{\theta}} z_h^{\frac{\theta-1}{\theta}} C_h^{\frac{1}{\theta}}. \tag{39}$$

where

$$\omega(\boldsymbol{z}) := \frac{p_h(\boldsymbol{z}) z_h \mu_h(\boldsymbol{z})}{p_h(\boldsymbol{z}) z_h \mu_h(\boldsymbol{z}) \bar{h} \;+\; p_h(\boldsymbol{z}) \text{imports}(\boldsymbol{z}) - p_h(\boldsymbol{z}) \text{exports}(\mathbf{z})}, \tag{40}$$

which is the production of goods relative to consumption or the "home share," and $\hat{\mu}_h(\boldsymbol{z}) = \frac{\mu_h(\boldsymbol{z})\bar{h}}{\pi(\boldsymbol{z})}$ *is the number of labor units per market.*

Lets talk through Proposition 1 in the following way. First, what does equation (40) represent? The denominator is the value of consumption (everything domestically produced plus imported net of what I shipped out via exports). Then the numerator is production. So the interpretation is how much of domestic consumption is the home country producing. This is essentially the micro-level "home share" summary statistic emphasized in Arkolakis, Costinot, and Rodríguez-Clare (2012).

Equation (39) connects the home-share measure with wages. The key thing to notice is that a **smaller** home share implies that wages are **lower** with elasticity $\frac{1}{\theta}$. This means that, if imports (relative to domestic production) is large, then wages in the production of that commodity must be lower. Similarly, a larger home share—which could be above one if an exporter—, are wages are larger.

To understand this, consider the case when imports are increasing (relative to domestic production) in a market, i.e. the home share is falling. What is going on is that the increase in imports (holding all else fixed) implies that prices must be falling. Because the wage equals the value of the marginal product of labor, then the wage must be falling. The CES production structure just ties the price with the home share through the parameter θ in a very succinct manner.

Finally, notice the role that θ plays. The parameter θ is critical in determining how much productivity risk is associated with a market. For example, if $\theta = 1$ (i.e. the production technology is Cobb-Douglas), then wages become independent of productivity.

Now we can connect this with wage regression performed in ADH that linked changes in wages with changes in trade exposure. To do so, start with (39) and take log differences across time

$$\Delta \log w(\mathbf{z}) = \frac{1}{\theta}\Delta \log \left(\omega(\mathbf{z})/\hat{\mu}_h(\mathbf{z})\right) + \frac{1}{\theta}\Delta \log C_h + \Delta \log \left(z_h^{\frac{\theta-1}{\theta}}\right), \tag{41}$$

which says that the change in wages across locations is summarized by (i) trade exposure via the change in per-worker home share, (ii) the change in location-specific productivity and (iii) aggregate consumption.

Equation (41) makes clear that an instrumental variable strategy is necessary to identify the causal effect of trade exposure on wages. Generally, domestic productivity is unobserved to the econometrician, but it is correlated with home trade share. That is imports could (and hence the home share could decrease) increase because either world prices changed or domestic productivity changed. Our notation makes this clear in that ω is a function of $\mathbf{z} = \{z_h, p_w\}$.

The structure of the model suggests several instrumental variable strategies. One valid instrument would be to use the world price (if observed) directly. The world price is orthogonal to domestic productivity (the exclusion restriction), yet correlated with the home trade share. The exclusion restriction follows from our small open economy assumption and the specification the stochastic process in (13) that is assumed to be orthogonal to z_h.[9]

An alternative strategy would be to use another country's imports as an instrument. Another country's imports would be orthogonal to the home country's productivity (the exclusion restriction), but correlated with world prices. This, in fact, is quite similar to the instrument proposed in ADH. That is ADH use Chinese imports to non-US advanced economies as an instrument to identify the causal effect of Chinese imports on US wages.

There are several empirical issues in going from the specification in (41) to that used in ADH. First, they only have industry level imports at the aggregate level and a geographic region

[9]This discussion makes clear that in general equilibrium, one should be concerned that a change in domestic productivity would feed into world prices and, thus, invalidate this strategy.

has multiple industries operating within it. In other words, a commuting zone more closer to a collection of islands in our model. If one made the assumption that one industry corresponds with one region, then their ΔIPW measure would be imports per worker. So similar to $\Delta \log\left(\omega(\mathbf{z})/\hat{\mu}_h(\mathbf{z})\right)$ but operating directly with the level of imports rather than the shares. We explore this distinction in future work.