

# Redistributing the Gains From Trade Through Progressive Taxation

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## ABSTRACT

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Should a nation's tax system become more progressive as it opens to trade? Does opening to trade change the benefits of a progressive tax system? We answer these question within a standard incomplete markets model with frictional labor markets and Ricardian trade. Consistent with empirical evidence, adverse shocks to comparative advantage lead to labor income losses for import-competition-exposed workers; with incomplete markets, these workers are imperfectly insured and experience welfare losses. A progressive tax system is valuable, as it substitutes for imperfect insurance and redistributes the gains from trade. However, it also reduces the incentives to work and for labor to reallocate away from comparatively disadvantaged locations. We find that progressivity should increase with openness to trade and that it is an important tool for mitigating the negative consequences of globalization.

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# 1. Introduction

There are many concerns about the forces of globalization—that the losses from trade are large; that there are insufficient mechanisms to insure against these losses; that globalization simply propagates existing inequality. The standard response to these concerns is helpful in theory: that there exists a Pareto improving transfer scheme that can compensate the losers from trade, yet still preserve the gains for the winners. In practice, this response is less helpful, given the limited mechanisms and incentive problems that policy makers face in implementing any kind of transfer scheme.

Evidence suggests that these concerns about the forces of globalization are warranted. Autor, Dorn, and Hanson (2013) show that exposure to Chinese import competition has led to losses in labor income and reductions in labor force participation for import-competition-exposed workers. Krishna and Senses (2014)) show that increases in import penetration are associated with increases in labor income risk in the United States. Pavcnik (2017) surveys the growing body of evidence regarding trades' affect on earnings and employment opportunities. Given that risk sharing is often found to be incomplete (see, e.g., Cochrane (1991), Attanasio and Davis (1996)), this suggests that the labor market consequences of trade lead to welfare losses.

Policy need not be silent to these concerns. Building on the insights of Varian (1980) and Eaton and Rosen (1980), one way to mitigate and insure against these losses is via the tax system. That is, the government could use a progressive tax system to provide social insurance and to transfer resources from the winners from trade to the losers. This paper evaluates this possibility by measuring both the optimal degree of tax progressivity and the gains from progressivity as an economy opens to trade.

We implement these ideas by building off of our parallel work in Lyon and Waugh (2018). In this work, we develop an 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: households can self-insure, opt out of the labor force, and/or migrate. 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 labor income risk and to transfer resources to the losers from trade. On the other hand, a progressive tax system reduces incentives to work and for labor to migrate.

We model the government as using a log-linear labor-income tax and transfer scheme to redistribute resources. In particular, we closely follow the approach of Benabou (2002), Conesa and Krueger (2006), and Heathcote, Storesletten, and Violante (2014) who parameterize the progressivity of net-taxes directly.<sup>1</sup> As in that work, we take a stand on the social welfare function.

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<sup>1</sup>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. Guner, Kaygusuz, and Ventura (2014) provide an exploration of

We focus on a utilitarian planner that places equal weight on households within the domestic economy. We measure the optimal degree of progressivity as the progressivity parameter that maximizes social welfare.

The optimal degree of progressivity, the gains from progressivity, and how they vary with trade exposure are ultimately quantitative questions. We quantify the parameters of the model by having the model replicate key aggregate and cross-sectional moments of the US economy. Along with relatively standard parameter values for preferences and technologies, we insure that the model replicates aggregate trade exposure, internal migration rates, labor force participation rates, and the amount of indebtedness of households in the US economy.

Given the calibrated model, we ask several questions of the model.

**What trade-offs does the government face?** As in previous work, the key issue is the tension between providing social insurance and achieving economic efficiency. In our model, there are two reasons for losses in economic efficiency: reductions in labor supply and migration. The migration margin is new and works in the following way. While progressive taxation provides social insurance, it also shrinks the gains to households from moving away from low-productivity to high-productivity places. Yet achieving allocative efficiency requires the continual movement of households from low- to high-productivity places. In other words, there is a tension between social insurance versus the misallocation of households across space. Quantitatively, we find that this margin is important. Given a change in progressivity, labor supply changes relatively little; yet we find large changes in migration and losses in aggregate productivity.

**How does the optimal tax policy change with increased openness to trade?** Given the tension discussed above, there is an optimal policy that maximizes social welfare for a given level of openness to trade. Thus, we measure how the optional policy changes as the economy becomes more or less open to trade.

We find that the tax system should become more progressive as trade exposure increases. Moving from our baseline economy to an economy with an import share of GDP at twenty percent, optimal progressivity increases with large increases in tax rates for those at the top of the income distribution and decreases for those at the bottom. For example, average tax rates on those in the top 10th percentile of the income distribution increase by thirteen percentage points; for those in the bottom 10th percentile, the average tax rate becomes zero.

With that said, the welfare gains from a move to the optimal policy are modest. Only at large levels of trade exposure (at least for the US, but comparable to economies such as Canada and Mexico) do we find large welfare gains associated with a move towards optimal policy.

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this and alternative tax functions.

**How does openness change the benefits of a progressive tax system?** The previous result does not imply that a progressive tax system is not an important buffer to the consequences of increased exposure to trade. We illustrate this point by measuring the welfare gains of current tax policy relative to a flat tax system and how they change with increased openness to trade. In other words, this exercise measures the how the benefits of social insurance change with increased exposure to trade.

We find that a progressive tax system becomes systematically more beneficial as an economy opens up to trade. For example, a move to a flat tax system when the economy is very open would lead to a two and half percent decrease in welfare where as at the baseline the move to a flat tax system would lead to a half a percent decrease in welfare.

**How does a progressive tax system compare to import tariffs?** Finally, we compare the gains from a progressive tax system with those from an import tariff. This comparison is of interest for two reason. First, in the United States, policy makers are taking a second look at anti-trade commercial policy as a means to correct various imbalances and harms associated with trade. Second, it has been argued that import tariffs and a progressive tax system may provide similar social insurance roles. Eaton and Grossman (1985) show that a motive for anti-trade commercial policy (i.e., a tariff) is to provide social insurance to the losers from trade (see, e.g., Corden (1974) and Baldwin (1982), as well). More starkly, Newbery and Stiglitz (1984) provide an example, in a setting with risk and incomplete markets, of free trade being Pareto inferior to autarky.<sup>2</sup>

To answer this final question, we measure the optimal policy mix between tax progressivity and import tariffs. Unlike Eaton and Grossman (1985), we mostly find that a positive tariff is not welfare-improving. The optimal mix is a zero tariff and a more progressive tax system as the economy becomes more exposed to trade. Relative to Eaton and Grossman (1985) or Newbery and Stiglitz (1984), the key difference is in the policy instruments that they entertain and insurance opportunities provided to agents that might make a tariff or autarky look favorable.

**Related Literature.** Conceptually, the ideas in this paper are closely related Rodrik (1997, 1998) and Epifani and Gancia (2009). Rodrik (1998) establishes a robust relationship between the size of a nation's government and the extent to which it is open. An interpretation of this result is that nations use government spending to provide social insurance against the ills of globalization. There is a disconnect between our work and Rodrik's (1998) evidence. In particular, we hold government expenditures fixed and households do not value them. However, our broader message—the increasing importance of government-provided social insurance with openness to trade—is very much consistent with Rodrik's (1998) interpretation of the data and the related

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<sup>2</sup>We take the reason that insurance markets are missing as given; Dixit (1987, 1989a,b) shows how these conclusion depend upon the modeling as to why these markets are missing.

arguments in Rodrik (1997).

At a mechanical level, this paper is closely related to the quantitative studies of Conesa and Krueger (2006) and Heathcote, Storesletten, and Violante (2014), who study the optimal progressivity of the US tax scheme in heterogeneous agent, incomplete market models. As discussed above, we closely follow their and Benabou's (2002) approach to parameterizing the tax and transfer scheme and focus on the tension between social insurance and economic efficiency. There are two distinguishing features of our paper. First, we highlight a new and distinct tension between social insurance and the misallocation of households across space. Second, we focus on how optimal progressivity changes as an economy becomes more open to trade.

With regard to open economy issues, Spector (2001) and Antràs, De Gortari, and Itskhoki (2016) are closely related. Both papers focus on a static, open economy Mirrlees (1971) framework and study the welfare consequences of trade-induced inequality and its interaction with redistributive policies. In particular, Antràs, De Gortari, and Itskhoki (2016) study policies (a parameterized non-linear labor income tax) that take the same form as in our paper. The distinguishing feature of our work is that we focus on very different motives for redistributive taxation—that is, motives arising from risk and incomplete insurance. In our model, the key motive for progressive taxation is to redistribute resources from the “lucky” towards the “unlucky.” This insurance motive is distinct from inequality aversion per se, as in Antràs, De Gortari, and Itskhoki (2016). This is the sense in which our paper builds most closely on the earlier work of Varian (1980), Eaton and Rosen (1980), and Mirrlees (1974).

Our modeling framework is related, but distinct from, an exciting and growing body work on trade and labor market dynamics (see, e.g., Kambourov (2009); Artuç, Chaudhuri, and McLaren (2010); Dix-Carneiro (2014); Caliendo, Dvorkin, and Parro (2015); Coşar, Guner, and Tybout (2016)). We depart from this literature by studying an economy in which households face labor income shocks and incomplete markets. The cost of this departure is that we are unable to incorporate the geographic and sectoral detail found in this work (see, e.g., Caliendo, Dvorkin, and Parro (2015)) due to computational complexities. With that said, the benefits from this departure is important for several reasons.

First, the focus on a setting with incomplete markets opens up the door to a motive for government policy to provide social insurance and increased social insurance as the economy opens to trade. In other words, this allows us to study the normative implications of alternative policy schemes as an economy opens to trade. In contrast, the normative prescriptions are unclear (as well as unstudied) in previous work on trade and labor market dynamics.

Second, the migration motive in our model is for insurance. That is, households undertake costly moves to escape negative labor market conditions in one location and capture favorable labor market conditions in another location (see, e.g., Lagakos, Mobarak, and Waugh (2017)

and references therein for the importance of this in the context of developing countries). This motive is distinct from the moving motive in the stationary equilibrium of Artuç, Chaudhuri, and McLaren (2010) and Caliendo, Dvorkin, and Parro (2015), which arises from shocks to preferences across locations, while income across locations is constant. Allowing for insurance-motivated moves is important as it creates a new tension for policy makers to confront. That is a progressive tax system must balance the gains from social insurance versus the losses in allocative efficiency that come with less migration.

## 2. Model

Here, we describe a model of international trade with households facing incomplete markets and frictions to move across labor markets. The first subsection discusses the production structure; the second subsection discusses the government and the tax function; the third discusses the households.

Below, since we focus on the perspective of one country, country subscripts are omitted unless necessary. Similarly, because we focus on a stationary equilibrium, time subscripts are omitted unless necessary.

### 2.1. Production

The model has an intermediate-goods sector and a final good sector that 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. Thus, intermediate  $\omega$  produced in one country is a perfect substitute for the same intermediate  $\omega$  produced by another country.

Competitive firms produce intermediate goods with linear production technologies,

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

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

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

where  $\epsilon_{t+1}$  is distributed normally with mean zero and standard deviation  $\sigma_\epsilon$ . The innovation  $\epsilon_{t+1}$  is independent across time, goods, and countries.

Firms producing variety  $\omega$  face competitive product and labor markets with households that supply labor elastically. Competition implies that a household choosing to work in market  $\omega$



earns the value of its marginal product of labor, which is the price of the good times the firm's productivity  $z$ .

Transporting intermediate goods across countries is costly. Specifically, firms face iceberg trade costs  $\tau \geq 1$  when exporting their products. Abstracting from tariffs (which are discussed below), this means that for a firm to deliver one unit of the intermediate good abroad, it must produce  $\tau$  units for shipment.

Intermediate goods are aggregated by a competitive final-goods producer who has a standard CES production function:

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

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

## 2.2. Government

The government consumes resources  $G$ , levies a labor income tax and transfer scheme, and taxes imports via tariffs.

**Government Consumption.** We model government consumption of resources  $G$  as pure waste. That is, there is no service flow to households from the government's consumption. Motivating this modeling choice is the difficulty in disciplining the utility value of public goods (see, e.g., the discussion in Heathcote, Storesletten, and Violante (2014)). Thus, this choice reduces the number of free parameters we must take a stand on. The cost of this choice is that we abstract from a policy instrument—public goods provision—that also provides social insurance. And we lose the ability to speak to the evidence in Rodrik (1998).

**Labor Income Tax and Transfer Scheme.** As in Benabou (2002) and Heathcote, Storesletten, and Violante (2014), we assume that net tax revenues are of the following parametric class:

$$T(w) = w - \delta w^{1-\tau_p}, \quad (4)$$

where net tax revenues are  $T(w)$  and  $w$  is labor income. There are two parameters in (4). The  $\delta$  parameter determines the average rate and is chosen by the government such that its budget is balanced. The parameter  $\tau_p$  directly controls the progressivity of the tax scheme. This is the policy parameter of interest.

Heathcote, Storesletten, and Violante (2014) describe several ways to see how  $\tau_p$  determines the progressivity. The most straightforward way is to note that  $1 - \tau_p$  equals one minus the

marginal tax rate relative to one minus the average tax rate:

$$1 - \tau_p = \frac{1 - T'(w)}{1 - T(w)/w}. \quad (5)$$

Thus, when  $\tau_p$  equals zero, marginal rates equal average rates—i.e., the tax system is neither regressive nor progressive and is deemed “flat.” In contrast, when  $\tau_p$  is greater than zero, marginal rates  $T'(w)$  exceed average rates,  $T(w)/w$  and the tax system is deemed “progressive.”

In reality, the tax system is far more complex. We follow previous work by thinking about (4) vis-à-vis the data and the model as a scheme which encompass both the myriad of taxes and the transfers. That is take-home pay in the model reflects pregovernment income minus taxes plus transfers. Heathcote, Storesletten, and Violante (2014); Guner, Kaygusuz, and Ventura (2014); Antràs, De Gortari, and Itskhoki (2016), (all using different data sources) find that this functional form provides a good approximation of the actual tax and transfer scheme in the US data. In particular, Heathcote, Storesletten, and Violante (2014) and Antràs, De Gortari, and Itskhoki (2016) find very similar estimates of the  $\tau_p$  parameter.

For our purpose, the key issue that (4) abstracts from are direct forms of compensation that depend upon the circumstances for income loss, such as trade adjustment and assistance programs. For example, the reduction in net taxes for households that experience an income reduction does not depend on whether or not if the loss in income is trade related. It does not provide direct insurance to trade-imposed losses. This is an abstraction in the sense that there are (i) some forms of direct compensation for trade-induced losses through TAAP and (ii) it does not allow us to explore the gains from more direct forms of compensation.<sup>3</sup>

**Tariffs.** The government imposes a tariff on imported intermediates,  $\tau_f$ . Mechanically, this value inflates the effective trade costs discussed above. Specifically, the total cost for importing a good will be:

$$\hat{\tau} = \tau(1 + \tau_f). \quad (6)$$

This means that to purchase one unit of the good,  $\hat{\tau} > 1$  of the good must be shipped and  $(1 + \tau_f)$  of the good must be delivered to the “dock.” Out of the units delivered to the dock,  $\tau_f$  units are paid to the government and one unit is delivered to the consumer.

While tariffs (in the US context) are generally small, entertaining this policy instrument allows us to contrast the optimal labor income tax scheme versus a more “isolationist” approach of restricting trade to deal with the ill effects of globalization. Moreover, this is interesting since the optimal tariff is not about manipulating the terms-of-trade, but about providing insurance

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<sup>3</sup>The TAAP program appears to be quantitatively ineffective relative to traditional social insurance such as social security and disability insurance (see, e.g. Autor, Dorn, and Hanson (2013))



to those exposed to trade.

### 2.3. Households

Within a country, there is a continuum of infinitesimally small households of mass  $L$ . Each household is infinitely lived and maximizes expected discounted utility

$$E \sum_{t=0}^{\infty} \beta^t \left\{ \log(c_t) - B \frac{h_t^{1-\gamma}}{1-\gamma} \right\}, \quad (7)$$

where  $E$  is the expectation operator and  $\beta$  is the subjective discount factor. Period utility depends on both consumption of the final good and the disutility of labor. As we discuss below, we model labor supply as being only on the extensive margin; thus, the parameter  $\gamma$  is irrelevant and only  $B$  matters.

Households live and work along the same dimension as the intermediate goods. That is, a household's location is given by  $\omega$ —the intermediate goods sector in which it can work.

Given their current location, households can choose to work, to move and work someplace else in the future, and to 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 income from employment in the intermediate-goods sector in which the household resides. If a household does not work, it receives some (untaxed) home production  $w_n$ . As in Shimer (2005) and Hagedorn and Manovskii (2008), home production plays an important role in determining the outside value of being in the labor force and, hence, the elasticity of labor supply on the extensive margin.

Households can move to an alternative intermediate-goods sector  $\omega'$  at some cost. Paying  $m > 0$  in units of the final good allows the household to change where it can work in next period. If a household chooses to move in a given period, it remains in its current location in that period and can choose to supply labor in the original intermediate-goods sector. The household begins working in sector  $\omega'$  starting in the period after it move. 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 focus on the latter specification.

Households residing in a intermediate-goods location face labor income risk associated with fluctuations in local productivity and 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  $R$ . We treat  $R$  as exogenous and not solved for in equilibrium. An interpretation is that this country faces a large supply of assets at this rate. Households face a

lower bound on asset holding  $-\bar{a}$ , so agents can acquire debt up to the value  $\bar{a}$ .

**State Variables.** The individual state variable of a household are its location and asset holdings  $a$ . The island-level state variable is the domestic productivity state and world price state. The aggregate state is a distribution over island-level state variables and asset holdings.

Let us expand on this a bit more. The wage per efficiency unit that a household receives is a important island-level object impacting individual decisions. The wage per efficiency unit depends on the value of the marginal product of labor on that island. The marginal product depends on a country's productivity level. The "value" part depends on (i) the world price and (ii) the labor supply decisions of households residing on the island. Given our preference specification in (7), households' labor supply decisions depend on the distribution of asset holdings within the island. Thus, this is where the aggregate state matters for island-level outcomes.

We focus on a stationary equilibrium. That is, the aggregate state—the distribution over island level states and assets holdings—is constant.<sup>4</sup> Thus, to conserve on notation, we only carry around the households specific state variables: its own asset holdings and island-level state variables associated with its location. In particular, let  $\mathbf{s}$  denote the domestic productivity and world price combination associated with that island. The wage per efficiency unit a household earns is  $w(\mathbf{s})$ .

**Budget Constraints.** Given the description of the environment, the post-tax earnings of the household are

$$\tilde{w}(\mathbf{s}) = \delta (w(\mathbf{s})\bar{h})^{1-\tau_p} . \quad (8)$$

The household's period  $t$  budget constraint (all denominated in units of the final good) is

$$a_{t+1} + c_t + \iota_{m,t}m \leq Ra_t + \iota_{n,t}\tilde{w}_t(\mathbf{s}) + (1 - \iota_{n,t})w_n, \quad (9)$$

where the left-hand side are expenditures on new assets, consumption, and possibly moving costs with  $\iota_{m,t}$  being an indicator function equaling one if a household moves and zero otherwise. The right-hand side are income payments from asset returns, post-tax income, and home production with  $\iota_{n,t}$  being an indicator function equaling one if a household works.

**Recursive Formulation.** The recursive formulation of the household's problem is a discrete choice among 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

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<sup>4</sup>Given an island with state  $\mathbf{s}$ , denote the measure of agents with asset holdings  $a$  as  $\lambda(\mathbf{s}, a)$ . Stationarity implies that this value is constant.

is

$$V^{s,w}(a, \mathbf{s}) = \max_{a' \geq -\bar{a}} [u(Ra + \tilde{w}(\mathbf{s}) - a') - \bar{h}B + \beta EV(a', \mathbf{s}')] , \quad (10)$$

where  $u$  is the utility value over consumption. The value of staying and not working is

$$V^{s,nw}(a, \mathbf{s}) = \max_{a' \geq -\bar{a}} [u(Ra + w_n - a') + \beta EV(a', \mathbf{s}')] . \quad (11)$$

The value of moving and working is

$$V^{m,w}(a, \mathbf{s}) = \max_{a' \geq -\bar{a}} [u(Ra + \tilde{w}(\mathbf{s}) - a' - m) - \bar{h}B + \beta V^m(a')] , \quad (12)$$

where there are two key distinctions relative to (10). First, the moving cost,  $m$  is paid. Second, the continuation value is  $V^m(a')$  or the value associated with a move. Finally, the value of moving and not working is

$$V^{m,nw}(a, \mathbf{s}) = \max_{a' \geq -\bar{a}} [u(Ra + w_n - a' - m) + \beta V^m(a')] . \quad (13)$$

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

$$V(a, \mathbf{s}) = \max [V^{s,w}, V^{s,nw}, V^{m,w}, V^{m,nw}] . \quad (14)$$

### 3. Equilibrium

We close the model by focusing on a small open economy equilibrium. The small open economy assumption is that there is no feedback from home country actions into world prices.<sup>5</sup>

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

$$\log p_w(\omega)_{t+1} = \phi \log p_w(\omega)_t + \epsilon_{w,t+1}, \quad (15)$$

where  $\epsilon_{w,t}$  is distributed normally with mean zero and standard deviation  $\sigma_w$  and is independent of the innovation to the home country's productivity  $\epsilon_t$ .

**A Note on Notation.** We denote  $\pi(\mathbf{s})$  as the stationary distribution of productivity states and

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<sup>5</sup>Relative to the trade and labor market dynamics 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)) of being relatively simple, yet allows us to be specific about the interaction between trade flows and capital flows.

world prices induced by (2) and (15). And denote  $\mu(\mathbf{s})$  as the measure of households working on an island with state  $\mathbf{s}$ .

### 3.1. 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.

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

$$\max_{q(\mathbf{s})} P_h Q - \int p(\mathbf{s}) q(\mathbf{s}) \pi(\mathbf{s}) dz \quad (16)$$

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

$$q(\mathbf{s}) = \left( \frac{p(\mathbf{s})}{P_h} \right)^{-\theta} Q. \quad (17)$$

where  $Q$  is aggregate demand of the final good;  $P_h$  is the price associated with the final good. As discussed above, this is carried around briefly but is normalized to the value one.

**Intermediate Goods Production.** The intermediate goods producer's problem is

$$\max_{q(\mathbf{s})} p(\mathbf{s}) q(\mathbf{s}) - P_h w(\mathbf{s}) \frac{q(\mathbf{s})}{z_h}, \quad (18)$$

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:

$$w_h(\mathbf{s}) = \frac{p(\mathbf{s}) z_h}{P_h}, \quad (19)$$

or the value of the marginal product of labor. Only at the wage in (19) 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  $p(\mathbf{s})$ ,  $\hat{\tau} p_w$ . 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.<sup>6</sup> Specifically, if the good is non-traded, if the good is imported, and if the good is exported.

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<sup>6</sup>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.

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:  $\frac{p_w}{\tau} < p(\mathbf{s}) < \hat{\tau}p_w$ . 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:

$$\pi(\mathbf{s}) \left( \frac{p(\mathbf{s})}{P_h} \right)^{-\theta} Q = z_h \mu(\mathbf{s}) \bar{h}, \quad (20)$$

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 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  $p(\mathbf{s}) = \hat{\tau}p_w$ . Why? If the price was lower, then it would not be imported. If the price was higher, it would be imported but at world price plus the trade cost. 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

$$\underbrace{\pi(\mathbf{s}) \left( \left( \frac{\hat{\tau}p_w}{P_h} \right)^{-\theta} Q \right)}_{(1-\tau_f) \text{ imports}} - z_h \mu(\mathbf{s}) \bar{h} > 0 \quad (21)$$

That is at the given world price  $p_w$ , home demand met by imports of the commodity, net of tariffs. Below, it will be useful to define domestic demand as

$$\pi(\mathbf{s}) \left( \left( \frac{\hat{\tau}p_w}{P_h} \right)^{-\theta} Q \right) = z_h \mu(\mathbf{s}) \bar{h} + (1 - \tau_f) \text{ imports}(\mathbf{s}). \quad (22)$$

That is domestic consumption equals domestic production plus imports net of tariffs.

- **Exported.** If the good is exported, then it must be that  $p(\mathbf{s})\tau = p_w$ . 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. Finally, note that only the trade

cost matters here, not the tariff. At this price, the quantity of exports is

$$\underbrace{\pi(\mathbf{s}) \left( \frac{p_w/\tau}{P_h} \right)^{-\theta} Q - z_h \mu(\mathbf{s}) \bar{h}}_{- \text{ exports}} < 0 \quad (23)$$

The left-hand-side 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

$$\pi(\mathbf{s}) \left( \frac{p_w/\tau}{P_h} \right)^{-\theta} Q = z_h \mu(\mathbf{s}) \bar{h} - \text{ exports}(\mathbf{s}) \quad (24)$$

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

$$Q = C + G = \int_{\mathbf{s}} \int_a c(\mathbf{s}, a) \lambda(\mathbf{s}, a) + \tilde{G}, \quad (25)$$

where  $c(\mathbf{s}, a)$  is the consumption policy function which satisfies the households problem and  $\lambda(\mathbf{s}, a)$  is the mass of consumers with state  $\mathbf{s}$  and asset holding  $a$  (defined below in (26)). This relationship says household-level consumption—aggregated across all households— plus government consumption (excluding tariff revenue) must equal the aggregate production of the final good  $Q$ .

Market clearing conditions for the intermediate goods in (20),(22), (24), and the aggregate final good in (25) summarize the equilibrium relationship on the production side of the economy.

### 3.2. Household Side of the Economy

The households 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  $\{ \iota_m(\mathbf{s}, a), \iota_n(\mathbf{s}, a), g_a(\mathbf{s}, a) \}$  as the move, work, and asset policy functions that satisfy the households problem in (14).

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



following law of motion

$$\lambda'(\mathbf{s}', a') = \int_{a:a'=g_a(\mathbf{s},a)} \lambda(\mathbf{s}, a)(1 - \iota_m(\mathbf{s}, a))\pi(\mathbf{s}', \mathbf{s}) + \lambda(\mathbf{s}, a)\iota_m(\mathbf{s}, a)\bar{\pi}(\mathbf{s}'). \quad (26)$$

Equation (26) says the following: next period, the mass of households with asset holding  $a'$  in state  $\mathbf{s}'$  equals

- The mass of household that do not move multiplied by the transition probability that  $\mathbf{s}$  transits to  $\mathbf{s}'$ . This is the first term in equation (26). Plus...
- The mass of households that do move multiplied by the probability that they end up in state  $\mathbf{s}'$ . This is the second term in equation (26). The probability,  $\bar{\pi}(\mathbf{s}')$ , is given by the moving protocol, i.e., random assignment across islands according to the invariant distribution associated with  $\pi(\mathbf{s}', \mathbf{s})$ .
- 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  $\mathbf{s}$  is,

$$\int_a \iota_n(\mathbf{s}, a)\lambda(\mathbf{s}, a) = \mu(\mathbf{s}), \quad (27)$$

which is the size of the 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 (20)-(24).

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

$$\mathcal{A}' = \int_a \int_{\mathbf{s}} g_a(\mathbf{s}, a)\lambda(\mathbf{s}, a). \quad (28)$$

A couple of points to be made about this. First, this is in aggregate—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 (28) and the focus on a stationary equilibrium (so  $\mathcal{A}' = \mathcal{A}$ ) we can work

from the consumers budget constraint and derive aggregate consumption:

$$C = -\mathcal{A}' + R\mathcal{A} + \int_a \int_{\mathbf{s}} \left\{ \tilde{w}(\mathbf{s})\iota_n(\mathbf{s}, a) + w_n(1 - \iota_n(\mathbf{s}, a)) - m\iota_m(\mathbf{s}, a) \right\} \lambda(\mathbf{s}, a). \quad (29)$$

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

### 3.3. Government

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

$$G = \int_a \int_{\mathbf{s}} T(w(\mathbf{s}))\iota_n(\mathbf{s}, a)\lambda(\mathbf{s}, a) + \tau_f \int_{\mathbf{s}} p(\mathbf{s})\text{imports}(\mathbf{s}), \quad (30)$$

which says the following: Government spending must equal (i) labor income tax revenues conditional on working and then integrates over all markets and asset states plus (ii) tariff revenue which imports (in units of the final good) multiplied by the tariff rate.

What does the government do in our economy? The spending level  $G$ , the tax progressivity  $\tau_p$  parameter, and the tariff rate are exogenously given. The government then picks the average tax rate,  $\delta$ , such that (30) holds.

### 3.4. 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  $\{G, \tau_p, \tau_f\}$ , a stationary Small Open Economy Equilibrium is domestic prices  $\{p(\mathbf{s})\}$ , tax rate  $\delta$ , policy functions  $\{g_a(\mathbf{s}, a), \iota_n(\mathbf{s}, a), \iota_m(\mathbf{s}, a)\}$ , a probability distribution  $\lambda(\mathbf{s}, a)$  such that

- i Firms maximize profits, (16) and (18) ;
- ii The policy functions solves the household’s optimization problem in (14);
- iii Demand for the final and intermediate goods equals production, (20)-(23) and (25);
- iv The government budget is balanced (30);

---

<sup>7</sup>To understand this a bit better, note the connection with (29) 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.

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

$$\lambda(\mathbf{s}', a') = \int_{a: a' = g_a(\mathbf{s}, a)} \lambda(\mathbf{s}, a) (1 - \iota_m(\mathbf{s}, a)) \pi(\mathbf{s}', \mathbf{s}) + \lambda(\mathbf{s}, a) \iota_m(\mathbf{s}, a) \bar{\pi}(\mathbf{s}'). \quad (31)$$

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 (17) and wages (19) 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  $\lambda_h(\mathbf{s}, a)$  must be such that when plugged into the law of motion in (26), the same distribution is returned.

Finally, note that there is no requirement that the assets market clear, i.e., that (28) 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. 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.

**Computation.** Computing a stationary equilibrium for this economy deserves some discussion. First, this economy is unlike standard incomplete markets models where only one or two prices (e.g., one wage per efficiency unit and/ or the real interest rate) must be solved for. In contrast, we must solve for an equilibrium *function*  $p(\mathbf{s})$  (see, e.g., Krusell, Mukoyama, and Şahin (2010) who face a similar problem.). Thus, the iterative procedure is to (i) guess a price function, (ii) solve the household's dynamic optimization problem, (iii) construct the stationary distribution  $\lambda(\mathbf{s}, a)$ , and (iv) check if markets clear, (v) update the price function.

An important observation is that the open-economy aspect of this economy means that problem to finding an equilibrium has more structure than simply finding a solution to a non-linear system of equations. The key observation is that when domestic demand and supply are not equal, the price in those markets must respect bounds on international arbitrage. This implies that problem to finding a price function that is consistent with a stationary equilibrium can be represented as a mixed complementarity problem (see, e.g., Miranda and Fackler (2004)).

## 4. Model Properties

This section describes some qualitative properties of the model. It borrows from our own parallel work in Lyon and Waugh (2018) that focuses in detail on the workings of the model. Below we focus on two issues (i) the pattern of trade across labor markets and (ii) how trade exposure affects wages.

### 4.1. Trade

To illustrate the pattern of trade across islands, first define the following statistic:

$$\omega(\mathbf{s}) := \frac{p(\mathbf{s})z_h\mu(\mathbf{s})\bar{h}}{p(\mathbf{s})z_h\mu(\mathbf{s})\bar{h} + p(\mathbf{s})\text{imports}(\mathbf{s}) - p(\mathbf{s})\text{exports}(\mathbf{s})}. \quad (32)$$

What does equation (32) represent? The denominator is the value of domestic consumption (everything domestically produced plus imports minus exports). The numerator is production. The interpretation of (32) is how much of domestic consumption (at the island level) is the home country producing. This is essentially the micro-level “home share” summary statistic emphasized in Arkolakis, Costinot, and Rodríguez-Clare (2012). As we discuss below, this statistic provides (i) a clean interpretation of a labor markets exposure to trade and (ii) is tightly connected with local labor market wages.

Figure 1 plots the home share (raised to the power of inverse  $\theta$ ) 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 regions where the home share lies below one, demand is greater than supply and, hence, goods are being imported. This region naturally corresponds with situation where world prices are low or home productivity is low, i.e. the economy has a comparative disadvantage at producing these commodities. And for most extreme points, the economy literally does not produce any of these commodities and everything is imported.

Second, in the regions where the home share lies above one, supply is greater than demand and, hence, goods are being exported. This region corresponds world prices are high or home productivity is very high. In other words, this is where the country has a comparative advantage and is an exporter of the commodities.

Third, there is the “table top” region in the middle where the home share equals one and demand equals supply. Hence, this is the region where the goods are non-traded. Exactly like the inner, non-traded region in the Ricardian model of Dornbusch, Fischer, and Samuelson (1977), the reasons is because of trade costs. In this region, world prices and domestic productivity is not high enough to be an exporter of these commodities given trade costs. Furthermore, world prices and domestic productivity are not low enough to merit importing these commodities either. Thus, these goods are non-traded.

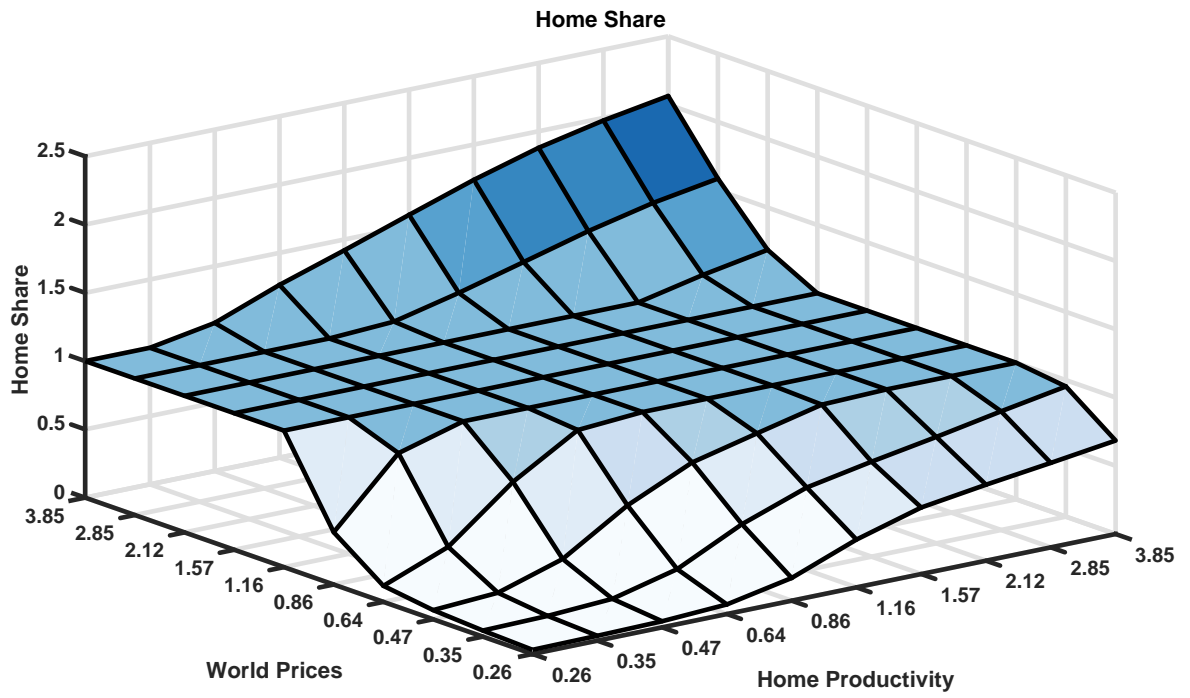


Figure 1: Trade: Home Share,  $\omega(s)^{\frac{1}{\theta}}$

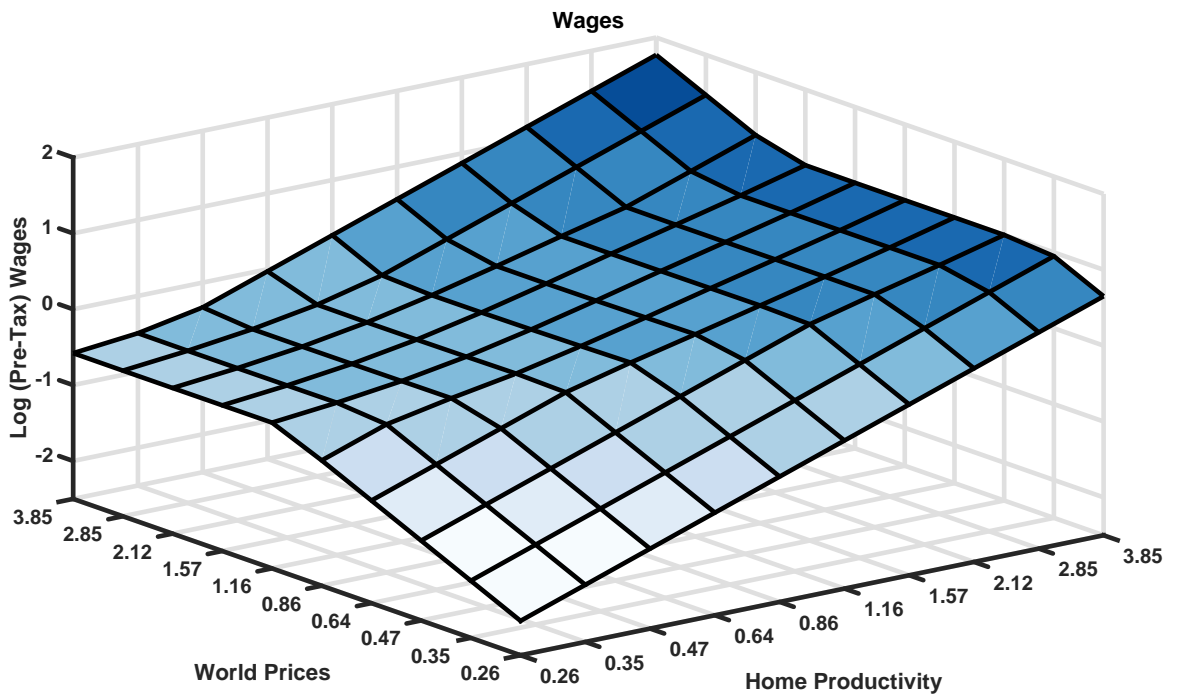


Figure 2: Wages (Pre-tax): Open Economy

It is important to reflect on the stochastic nature of this economy. While the stationary equilibrium of the economy leads to stationary pattern of trade seen in Figure 1, individual islands are transiting between different states (world prices and domestic productivity). For example, an island may be an exporter, but given a sequence of bad productivity shocks, the island will stop exporting and maybe even become an importer of a commodity it once exported.

## 4.2. Trade and Wages

One can connect the pattern of trade across islands/labor markets in Figure (1) with the structure of wages in the economy. More specifically, as we show in the Appendix and in Lyon and Waugh (2018), (pre-tax) real wages in a market with state variable  $\mathbf{s}$  equal

$$w(\mathbf{s}) = \omega(\mathbf{s})^{\frac{1}{\theta}} \hat{\mu}(\mathbf{s})^{\frac{-1}{\theta}} z_h^{\frac{\theta-1}{\theta}} C^{\frac{1}{\theta}}. \quad (33)$$

Here  $\omega(\mathbf{s})$  is the home share defined in (32);  $\hat{\mu}(\mathbf{s}) = \frac{\mu_h(\mathbf{s})\bar{h}}{\pi(\mathbf{s})}$  is the number of labor units per island of type  $\mathbf{s}$ ;  $z_h$  is domestic productivity;  $C$  is aggregate consumption.

The key observation is how equation (33) connects the trade exposure measure in (32) with island level wages. A **smaller** home share implies that wages are **lower** with elasticity  $\frac{1}{\theta}$ . This means that, if imports (relative to domestic production) are **larger**, then **wages in that labor market are lower**. Similarly, a larger home share (which could be above one if an exporter), are wages are larger. This is the exact opposite of the aggregate result of Arkolakis, Costinot, and Rodríguez-Clare (2012).

Figure 2 illustrates these observations by plotting the logarithm of (pre-tax) wages by world price and home productivity (so it exactly matches up with Figure 1) . As equation (33) makes clear, note the close correspondence between wages and the home share in Figure 1. Like in Figure 1, there are three regions to take note of.

The first region 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 second region is where exporting is prevalent. Exporting regions are able to capture high world prices and, thus, wages are high in these sectors. Finally, 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.

Again, it is important to reflect on the stochastic nature of this economy. While the stationary equilibrium of the economy leads to stationary distribution of wages seen in Figure 2, individual islands (and households living on those islands) are transiting between different states



(world prices and domestic productivity). For example, an island may be an exporter with households receiving high wages, but given a sequence of bad productivity shocks, the island will stop exporting and household wages fall.

Outcomes of this nature—a sequence of uninsurable, bad shocks—motivate the desire for social insurance. International trade changes the labor market consequences of various shocks and, in turn, change the demand for social insurance. This is what we now quantitatively explore.

## 5. Calibration

This section outlines our calibration approach. Our current approach uses existing parameter values from various literatures and then picks several parameter values so that the model replicates certain cross-sectional moments in US data.

### 5.1. Calibration

**Time Period and Geography.** The time period is set to a year. Geographically, in our model there is an abstract notion of a island, households living on that island, and working within its local labor market. Empirically, we will think about the empirical counterpart to an island as a Commuting Zone (see Tolbert and Sizer (1996)) and as used in Autor, Dorn, and Hanson (2013)).

Alternatives would be to think of an island as some cross between physical geography (like a commute zone) and an occupation/industry. The benefit of our choice is that it provides a direct connection to Autor, Dorn, and Hanson’s (2013) evidence on trade’s affects at the commute zone level. Given the above discussion about equation (33), this is consistent with their finding that commute zones with increases in import exposure experience relative wage losses. The cost of this choice is that alternative perspectives on geography in our model may affect how much income smoothing households can achieve through changing, say, occupations. And, in turn, this would affect the desirability of social insurance.

**Preferences.** Given our specification in (7) and the restriction on labor supply, there are only two parameters to calibrate:  $B$  which controls the disutility of working and the the discount factor  $\beta$ . We pick the disutility term  $B$  to match aggregate labor force participation rates. We follow the strategy of Chang and Kim (2007) (who have essentially the same specification) and target a employment to population ratio of sixty percent.

The discount factor is set equal to 0.95.

**Endowments and Financial Constraints:** There are two parameters controlling households endowments: a time endowment and home production. And one parameter controlling the borrowing limit on the household  $\bar{a}$ .

The time endowment is simply a normalization. We set it equal to one.

Home production is more complicated, but important. The reason is that value of home production affects the reservation wage of the households and, thus, controls how elastic labor supply is to various shocks (including tax changes). In the current calibration, we set the value of home production equal to zero. Thus, by setting this value to zero we are picking the most inelastic labor supply specification.

The borrowing limit parameter is calibrated to match properties of the aggregate wealth distribution. Krueger, Mitman, and Perri (2016) report from the Survey of Consumer Finances that approximately forty percent of households have zero or negative wealth. Thus, we chose the borrowing limit so that the model replicates this fact.

**Productivity and World Price Process.** The productivity process in (2) and (15) leave three parameters to be calibrated:  $\{\phi, \sigma_z, \sigma_w\}$ , the parameter controlling the persistence of the shocks and the size of the innovations.

We simplify the process more and restrict the standard deviation of innovations to productivity to be the same size as the standard deviation of innovations to world prices. A specification of this nature would make sense in a symmetric two country world.

Given this restriction, we use existing estimates of labor income processes to discipline these parameters. Specifically, we use the estimates from Kaplan (2012) which imply a value of 0.95 for  $\phi$  and a value of 0.026 for  $\sigma_z$ . Given the relationship between wages and productivity described above, much of the economy will not be import or export exposed and, thus, wages will simply mimic the productivity process  $z$  adjusted for the value of  $\theta$ . Thus, it is natural to have our model to replicate these features of the data.

With that said, a key issue in this class of models is how persistent the shocks are; and more specifically for our question, the permanence of the change in comparative advantage. This is important in that it will affect how insurable or not these shocks are and, thus, the desirability of progressive taxation and social insurance.<sup>8</sup> We speculate that the results of Krishna and Senses (2014) and Hanson, Lind, and Muendler (2015) speak to these dynamics of comparative advantage as well.

The final world price that we must calibrate is the gross real interest rate,  $R$ . We set this equal to 1.02 which corresponds with a two percent annual interest rate.

**Migration Cost and Location Choice:** We chose the migration cost to match aggregate data on

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<sup>8</sup>These parameters also play a deeper and less obvious role in determining how elastic aggregate trade flows are to a change in trade frictions. Much like in the model of Eaton and Kortum (2002), the extent of technology heterogeneity controls how elastic trade flows are to changes in trade costs. Furthermore, per the insights of Arkolakis, Costinot, and Rodríguez-Clare (2012), these parameters will control the aggregate gains from trade as well.

**Table 1: Parameter Values**

| Parameter                                 | Value | Target Moment/Notes                          |
|---|-------|--|
| Discount Factor, $\beta$                  | 0.95  | —  |
| Time Endowment, $\bar{h}$                 | 1.00  | Normalization                                |
| Home production, $h$                      | 0.00  | —  |
| Persistence of $z$ and $p_w$ process      | 0.95  | —  |
| Std. Dev. of innovations to $z$ and $p_w$ | 0.17  | —  |
| World Interest Rate, $R$                  | 1.02  | —  |
| Tax Progressivity                         | 0.18  | Heathcote, Storesletten, and Violante (2014) |
| Demand Elasticity                         | 4.00  | —  |
| Disutility of work, $B$                   | 1.74  | 60 % participation rate                      |
| Migration Cost, $m$                       | 0.81  | 3 % migration rate                           |
| Borrowing Limit, $-\bar{a}$               | 1.01  | 40 % households with $\leq 0$ net worth      |
| Tax Parameter, $\delta$                   | 0.86  | Government = 20 % of GDP                     |
| Trade Cost                                | 2.29  | Imports = 10 % of GDP                        |

migration rates across commuting zones. We use the the IRS migration data which uses the address and reported income on individual tax fillings to track how many individuals move in or out of a county. We compute that a bit over three percent of households move across a commute zone at a yearly frequency. This is slightly larger than the values reported in Molloy, Smith, and Wozniak (2011). We pick the migration cost to target this value. As we discuss below, this will result in more conservative estimates of the change in optimal progressivity and gains from progressivity with openness.

A related issue is the specification of where moving households end up. As discussed above, we use the random labor market specification. That is upon moving, a household will end up in a random labor market, with the distribution function being the invariant distribution of labor markets. Again, this is a simplification, but a more flexible specification would allow us to think about the worker-level evidence of Autor, Dorn, Hanson, and Song (2014) and the repeated expose of certain workers to trade shocks.

**Tax Function and Government Spending.** We set government spending,  $G$  to be twenty percent of GDP. This is consistent with National Accounts data for the US over the past forty years. Given that we calibrate the model to the US economy, we must take a stand on the current

progressiveness of the tax code. We use the estimates from Heathcote, Storesletten, and Violante (2014) and set  $\tau_p$  equal to 0.18. Using an alternative data set from the Congressional Budget Office, Antràs, De Gortari, and Itskhoki (2016) find a very strong fit of the tax function in (4) and similar estimate of progressivity.

**Demand Elasticity  $\theta$ .** Consistent with a wide range of estimates we set its value equal to four.

**Trade Costs and Tariffs.** We set tariffs equal to zero, which is a rough approximation of current US policy (trade weighted). We choose the iceberg trade cost to target an aggregate import to GDP ratio of ten percent. This is consistent with the aggregate level of trade in the mid 1990's, pre-China WTO accession. As we discuss below, our main exercise is to vary trade costs to target different levels of openness while keeping all other parameters held constant.

## 6. Optimal Progressivity and Openness to Trade

Given the calibrated model, we ask several questions of it: First, what is the optimal policy and what trade-offs does the policy maker face? Second, how do the gains from moving to an optimal policy change with increased openness to trade? Third, how does optimal policy change? Finally, how do these conclusions depend upon the particular calibration (e.g. labor supply and migration elasticities).

Below, we describe the social welfare function the policy maker is maximizing and then answer each of these questions.

### 6.1. Social Welfare Function

We focus on a utilitarian planner which places equal weight on households within the domestic economy. That is

$$W(\tau_p, \tau) = \int_{\mathbf{s}} \int_a V(a, \mathbf{s}) \lambda(\mathbf{s}, a). \quad (34)$$

or the value function of an agent integrated over markets and asset states with respect to the stationary distribution of households across those states  $\lambda(\mathbf{s}, a)$  (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 (34), the optimal degree of progressivity is

$$\tau_p^*(\tau) = \arg \max W(\tau_p, \tau). \quad (35)$$

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. When presenting results, we convert units into consumption equiv-

alent values. That is the permanent, percent change in consumption that must be allocated to make an agent indifferent between living in the baseline economy and an economy with an alternative progressivity parameter  $\tau_p$ .

When we compare social welfare across different levels of openness, we do not consider the transition dynamics associated with the move to a more open regime. In Lyon and Waugh (2018), we find that welfare gains and costs of a trade shock are substantially larger, more dispersed once transition dynamics are taken into account. In particular, for certain segments of the population, the initial adjustment is quite costly. Given discounting, this suggests that consideration of transition dynamics would strengthen the argument for a more progressive tax system.

## 6.2. Optimal Progressivity and the Insurance, Migration Trade-off

What is the optimal policy and what trade-offs does the planner face? We explore this question by tracing out social welfare for different levels of  $\tau_p$  or tax progressivity. All other parameters are fixed. Furthermore, we report welfare in consumption equivalent values relative to the baseline economy (thus, when  $\tau_p = 0.18$ , the welfare gain equals zero since this is the baseline economy).

Figure 3 shows that social welfare displays an inverted “U” shape as progressivity varies. In our calibration, the US economy lies to the left of the optimal policy. In particular, the optimal progressivity is found to be 0.28 versus current progressivity 0.18 as measured by Heathcote, Storesletten, and Violante (2014).

With that said, welfare gains are very small from a move to optimally progressive system. Less than one tenth of a percent. In other words, the costs of not having an optimal system are small. This observation is not generically true. As we discuss below, one key issue about increased trade exposure is that these costs start to grow.

The reason behind the inverted “U” shape in Figure 3 is the tradeoff between distorting labor supply and migration and, hence, reducing the size of the “pie” versus providing better social insurance.

To show that insurance improves with tax progressivity, Figure 4 plots the slope coefficient from the projection of household consumption on household pre-tax labor income. This coefficient is analogous to the tests of risk sharing in Cochrane (1991) and Townsend (1994). If the coefficient is zero, then interpretation is that the household is completely insured against household-level income shocks (as in the complete markets allocation). Figure 4 shows that pass-through of income to consumption systematically declines as the tax system becomes more progressive. To flip it around, “insurance” is better with a more progressive tax system. This is welfare improving.

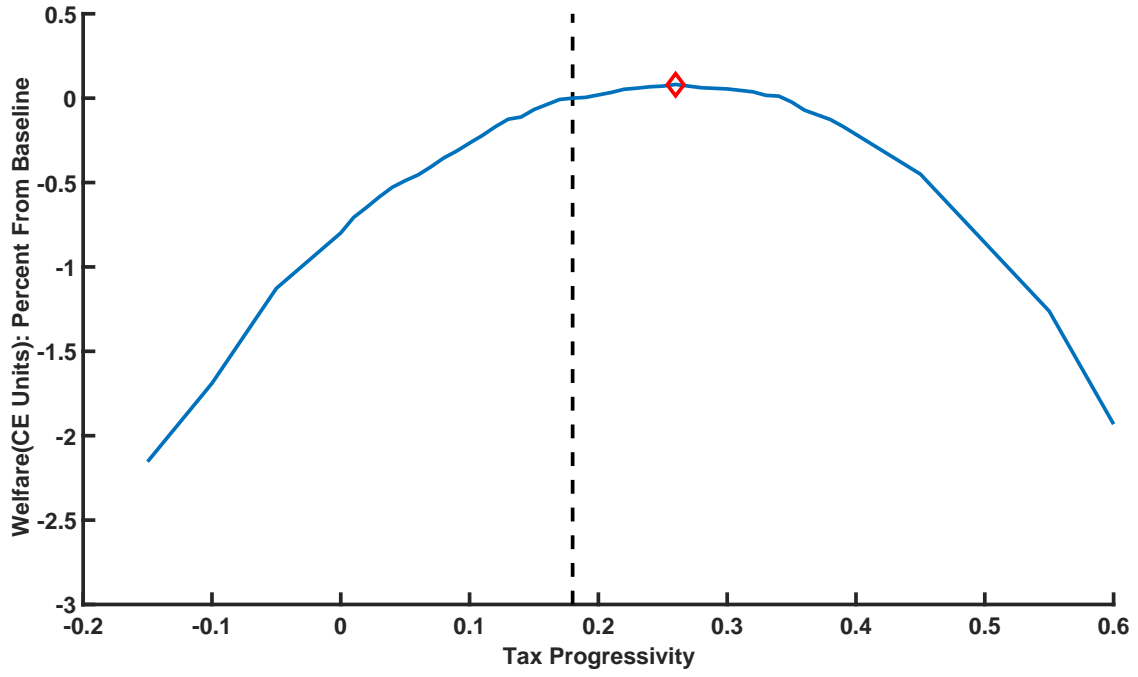


Figure 3: Social Welfare at Calibrated Model

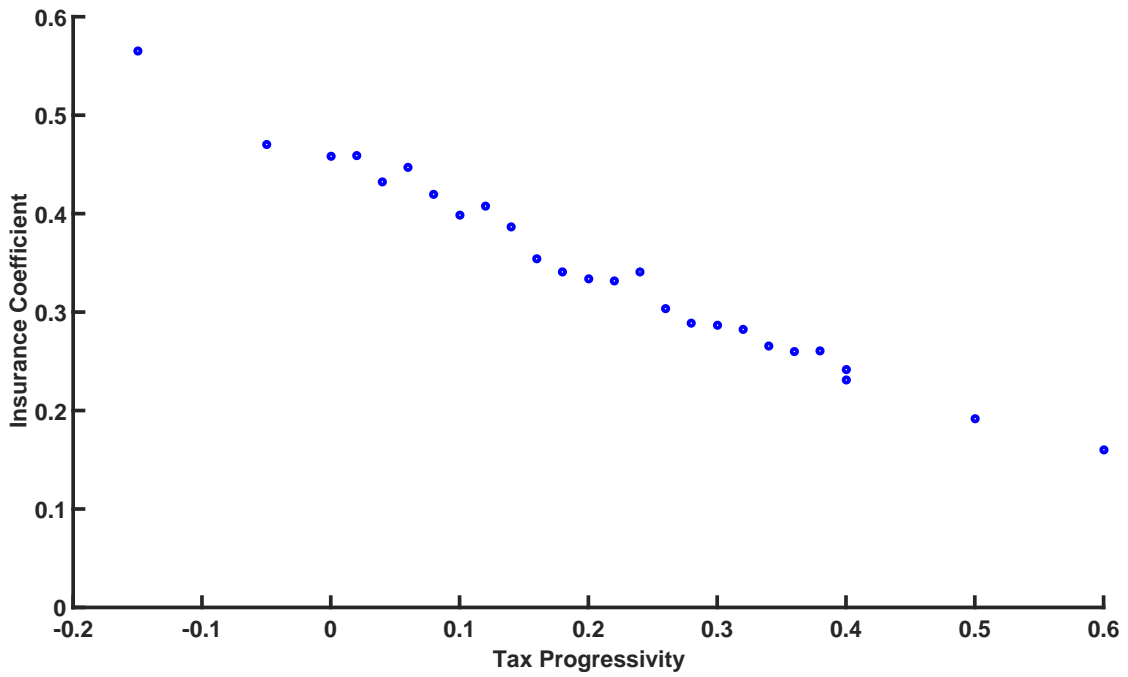


Figure 4: Insurance and Tax Progressivity



Gains from insurance are offset by losses in economic efficiency. In our model, the loss in efficiency is *not* about labor supply. Labor supply changes by less than half a percentage point over the whole span of tax progressivity parameters on the x-axis in Figure 3. This largely follows from our choice to model labor supply as being purely on the extensive margin and we set the outside option of not being in the labor force to zero. Labor supply at the micro level is inelastic given the choice set of the household level. Labor supply at the macro level is also very inelastic since the extensive margin responds very little as well.

What does reduce welfare is the reduction of migration and allocative efficiency. Figure 5 plots the percentage change in migration rates relative to the baseline economy. Here there are large declines in migration as the tax system becomes more progressive.

The reason for this result is that migration is a substitute for insurance. The motive to migrate in this model is to move in response to negative economic shocks to find a better income realization (see, e.g., Lagakos, Mobarak, and Waugh (2017) and references therein for the importance of this in developing countries context).<sup>9</sup> As the tax system becomes more progressive, this provides better households insurance and, hence, households chose alternative (and costly) forms of insurance, i.e. migration, less often.

Migration, however, is important for allocative efficiency. Absent labor market frictions, the ideal allocation would have households locate in the most productive, high comparative advantage sectors of the economy. Higher migration rates help achieve this. However, as migration rates decline, allocative efficiency starts to fall and aggregate productivity falls. Figure 6 illustrates this point showing how output per worker falls by large amounts. For example, a move from a flat tax to the baseline lowers aggregate productivity by nearly two percent. That is a year of economic growth is given up at current rates in the US.

To summarize: The key tension in our model between social insurance versus the misallocation of households across space. Figure 3 illustrates how social welfare changes with the progressivity in the current calibration of our model. As in previous analysis, this curve reflects a tradeoff between insurance and economic efficiency. What is unique about our setting is that the reduction in economic efficiency is not primarily about labor supply issues, but migration issues and allocative efficiency that arises as labor becomes less mobile as the tax system becomes more progressive.

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<sup>9</sup>This mechanism is in contrast to the motive for moves in the stationary equilibrium of Artuç, Chaudhuri, and McLaren (2010) and Caliendo, Dvorkin, and Parro (2015). While similar in spirit to this model, labor earnings across regions/sectors are constant and households dynamically because of shocks to preferences, not because of unexpected shocks to labor earnings as in our model.

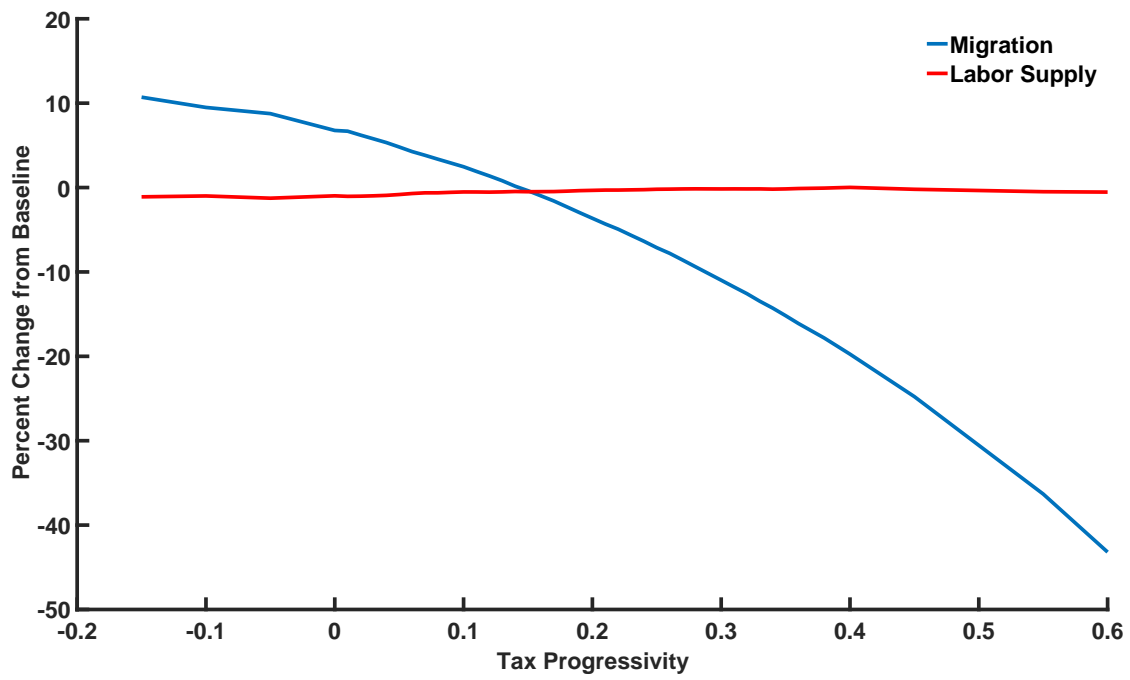


Figure 5: Migration and Labor Supply

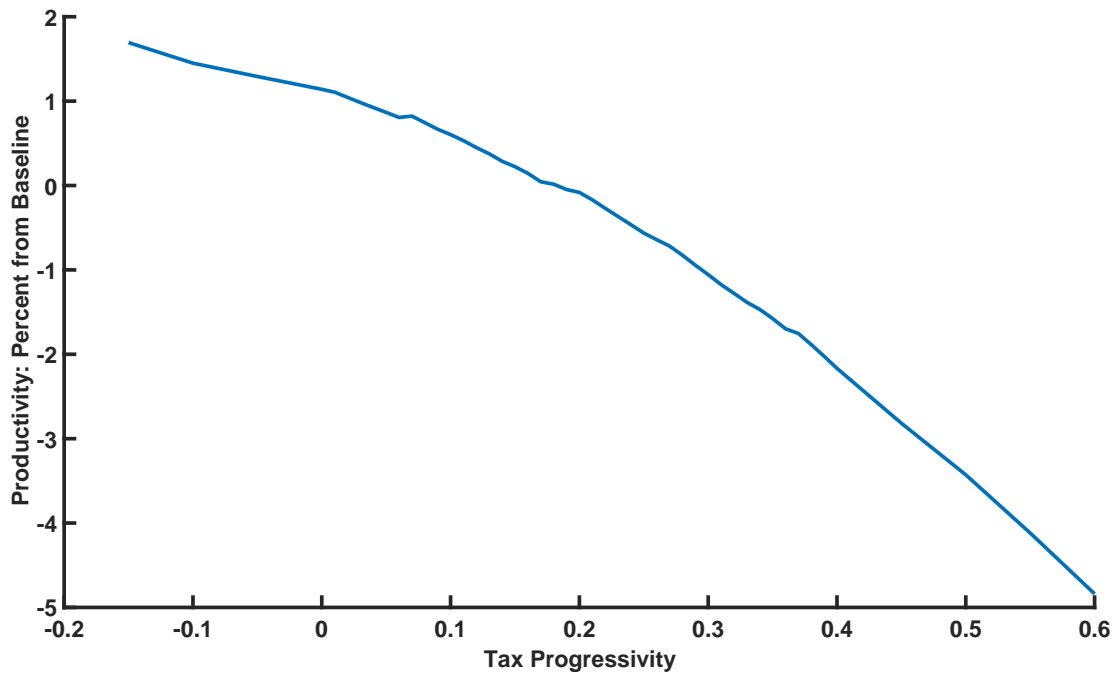


Figure 6: Aggregate Productivity

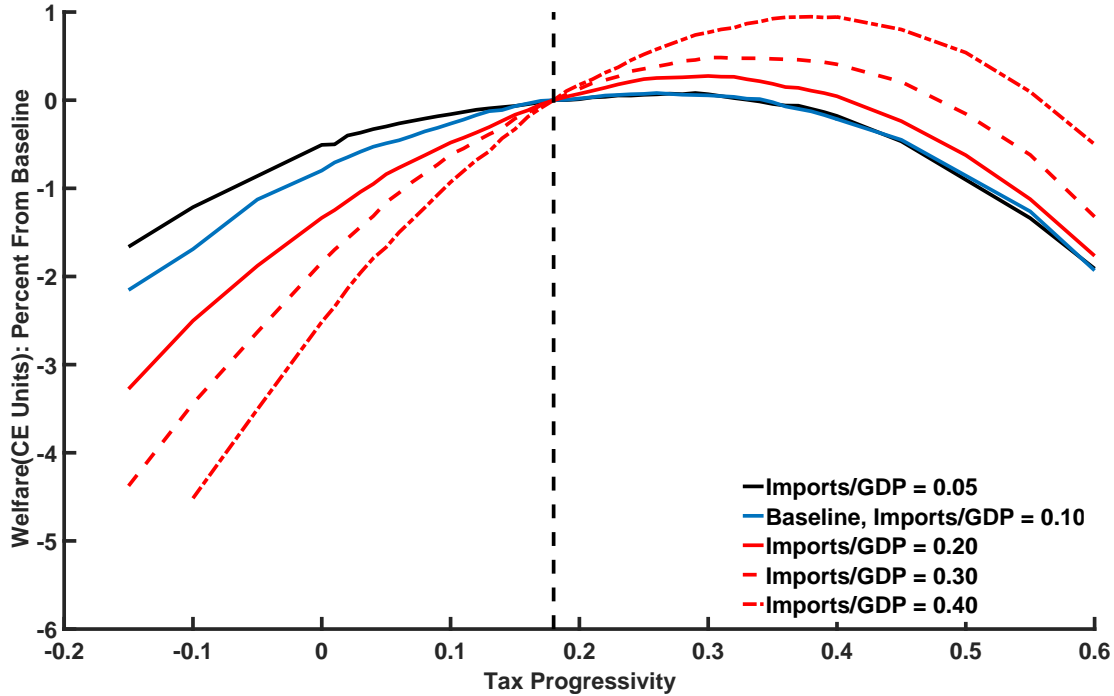


Figure 7: Welfare and Progressivity

### 6.3. How Does Optimal Policy Change with Openness to Trade?

To answer this question, we hold all calibrated values fixed, but change trade costs to target several different regimes of openness. Specifically, we find the trade costs such that the calibrated economy delivered a five, twenty, thirty, and forty percent import to GDP ratio. Then for different regimes, we both (i) trace out social welfare as a function of the tax progressivity parameter and (ii) solved directly for optimal tax progressivity for a given trade regime (iii) measure the welfare gains from a move to the optimum.

Figure 7 plots social welfare as a function of tax progressivity for several different regimes (as before we plot everything in percent difference from current policy). The second column in Table 2 reports optimal values.

We find that the tax system should generally become more progressive as the economy becomes more open relative to the current baseline. For example, Table 2 shows that optimal progressivity steadily increases when moving above recent levels of US openness (an import share of ten percent). Graphically, this is seen by noting how the peaks of the different social welfare curves in Figure 7 are systematically shifting towards the right as the economy becomes more open.

The third column in Table 2 reports the welfare gains from moving to an optimal policy. First note the gains from moving towards optimal policy are increasing with the level of openness. With that said, only at relatively large levels of openness (at least for the US, but comparable to

**Table 2: Openness and Optimal Progressivity**

| Imports/GDP | $\tau_p^*$ | Welfare               |                  | Average Tax Rate |            |
|-------------|------------|-----------------------|------------------|------------------|------------|
|             |            | Gains from $\tau_p^*$ | Losses from Flat | 90th Prct.       | 10th Prct. |
| 0.05        | 0.29       | 0.08                  | -0.50            | 45.1             | 7.11       |
| 0.10        | 0.26       | 0.08                  | -0.79            | 44.7             | 7.0        |
| 0.20        | 0.30       | 0.27                  | -1.31            | 50.0             | 1.3        |
| 0.30        | 0.33       | 0.48                  | -1.81            | 56.8             | -3.9       |
| 0.40        | 0.37       | 0.95                  | -2.45            | 62.9             | -9.0       |

**Note:** 90th Prct is the 90th percentile of the labor income distribution; 10th is the 10th percentile. Gains are consumption equivalent values between living in the baseline economy and an economy with an alternative progressivity parameter  $\tau_p^*$ .

economies such as Canada and Mexico) do we see quantitatively large, welfare gains in moving towards optimal policy.

The one deviation from this general prescription is in the case of a near closed economy (an import share of only 5 percent), while the optimum seems to be virtually the same as the baseline economy in Figure 7, we calculate that optimal progressivity rises. With that said, the welfare gains associated with a move towards the optimum is small.

These prescribed changes in progressivity map into large changes in tax rates as the economy becomes more open. The last two columns of Table 2 report the average tax rates of those in different labor income percentiles at the optimal tax system. In an economy with a ten percent Import/GDP ratio, those in the top 10th percentile of the labor income distribution have an average tax rate of 44 percent versus 7 percent for those in the bottom 10th percentile.<sup>10</sup> In the more open economy, with an import share of twenty percent, optimal policy prescribes that average tax rates of those in the top 10th percentile increase to 50 percent. Where as those in the bottom 10th percentile essentially pay nothing.

This result is worth comparing to Antràs, De Gortari, and Itskhoki (2016) who find that tax progressivity should decrease as the economy opens up. Like their model, our trade setting has a close mapping to modern, quantitative frameworks (in our case Eaton and Kortum (2002),

<sup>10</sup>These values are large relative to observed average tax rates. The issue is that the average rate here is being set to balance the governments budget. An alternative would be to allow the government to run an deficit and set  $\delta$  to its empirical value.

their's Melitz (2003)). We speculate that the key difference is that we focus on a different benefit of redistributive taxation. In our model, the motive for redistributive taxation arises from risk and incomplete insurance. Trade changes the nature of uninsurable income risk and this motivates the increased provision of social insurance. This insurance motive is absent from Antràs, De Gortari, and Itskhoki (2016). In their setting, trade benefits all agents (see, e.g., Proposition 4) but generates increases in earnings inequality; aversion to inequality is the only reason to engage in redistributive taxation.

#### **6.4. How Does Openness Change the Benefits of a Progressive Tax System?**

While the gains from moving toward optimal policy may be small, this does not imply that a progressive tax policy is not welfare enhancing. In fact, a progressive tax system does play an important role in an open economy. To illustrate this point, we ask what the costs of having a flat tax system are and how they change with level of openness. While related to the previous question, it is distinct in the sense that it is about the concavity of the social welfare curve and less about how optimal policy changes.

Figure 7 shows that the social welfare curves become more concave as the economy is more open. This means the benefits of a progressive tax system become larger as the economy become more open. Unlike the gains associated with optimal policy, the gains are quantitatively large even for current levels of openness. Table 2 reports that a move to a flat tax system at current levels of openness would lower welfare by a little less than one percent. For higher levels of openness, a move to a flat tax system would erode welfare by two and half percent.

This final point provides an interesting perspective on the historical evolution of tax policy and openness to trade. Antràs, De Gortari, and Itskhoki (2016) find that the US tax system has declined in its progressivity, i.e., the measure  $\tau_p$  to decline from 0.25 in 1980 to 0.16 in 2005. During this same time period, imports over GDP essentially doubled. Viewed through the lens of our model, as the tax system has become more regressive, the US economy has not gained what it could have and has become increasingly exposed to the negative consequences of trade.

### **7. Tariffs as Insurance?**

This section asks and answers the following question: How does a progressive tax system compare to import tariffs? This comparison is of interest for two reason. First, in the United States policy makers are taking a second look at anti-trade commercial policy as a means to correct various imbalances and harms associated with trade. Moreover, the practical application of this tool may be easier as the executive branch has broader authority over trade policy relative to changes in the tax code.

A second motive is that import tariffs may provide a similar social insurance role as a progres-

sive tax system. Early work by Corden (1974) and Baldwin (1982) speculated that one reason for tariffs is exactly to provide social insurance. Eaton and Grossman (1985) show that a motive for a positive tariff is to provide social insurance. More starkly, Newbery and Stiglitz (1984) provide an example in a setting with risk and incomplete markets that free trade is Pareto inferior to autarky. Moreover, one may speculate that a tariff may be more beneficial since it directly affects those impacted by trade.

To answer this question we perform the following quantitative exercises. Starting from our baseline economy, we compute and trace out social welfare under different mixes of tariffs and tax progressivity.

One important issue is what to do with tariff revenue. Like the tax revenue, we treat this as pure waste. Furthermore, we turn off the idea that the tariff becomes a substitute for the income tax as a revenue collection device. To avoid this issue, what we do is, for a given level of progressivity, hold constant average tax rates as we vary the tariff rate. So the way to think about the question we are answering is “given a labor income tax system, does a tariff improve or not?”

Figure 8 and 9 illustrate the results. Each panel is an economy calibrated to a different level of openness in the baseline. On the horizontal axis we have the import tariff and the tax progressivity parameter. On the vertical axis we report welfare in consumption equivalent units relative to the baseline. The surface traces out welfare as we varied tariff rates and tax progressivity. Finally, the black star and red “x” mark the baseline and the optimal policy.

The key observation from this figure is that tariffs are not welfare improving. As tariffs increase, welfare declines in all instances (the surface on both plots is always below 0). Mimicking our previous results, the optimal policy is a zero tariff with a mild increase in the progressivity of the tax system.

What are the distinguishing features between our work and say, Eaton and Grossman (1985) or Newbery and Stiglitz (1984). It’s hard to say given the very stark differences in our model relative to their work. However, we speculate that there are some important differences in terms of policy instruments and insurance opportunities that might make a tariff or autarky look favorable. For example, Eaton and Grossman (1985) allow for lump-sum redistribution of tariff revenue, state-contingent tariffs, and abstract from redistribution via labor income taxes. Newbery and Stiglitz (1984) deliberately turn off any other mechanisms for households to self-insure (either through non-state contingent assets or other margins such as migration).

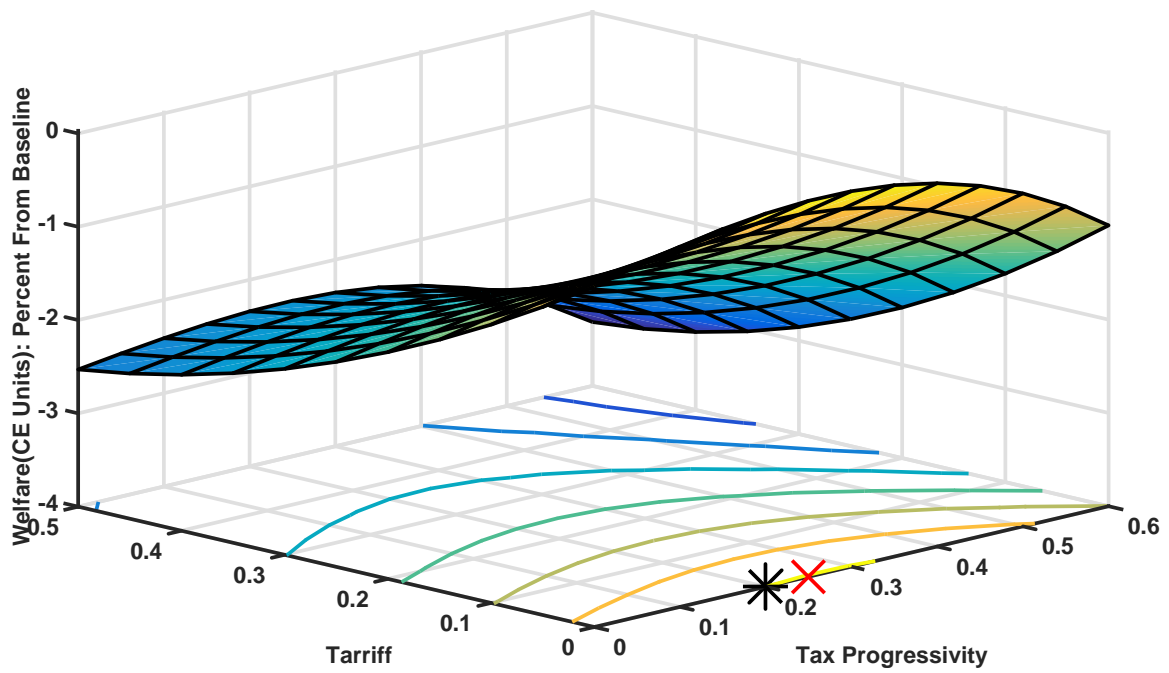


Figure 8: Relatively Closed Economy, Baseline Imports/GDP = 0.10

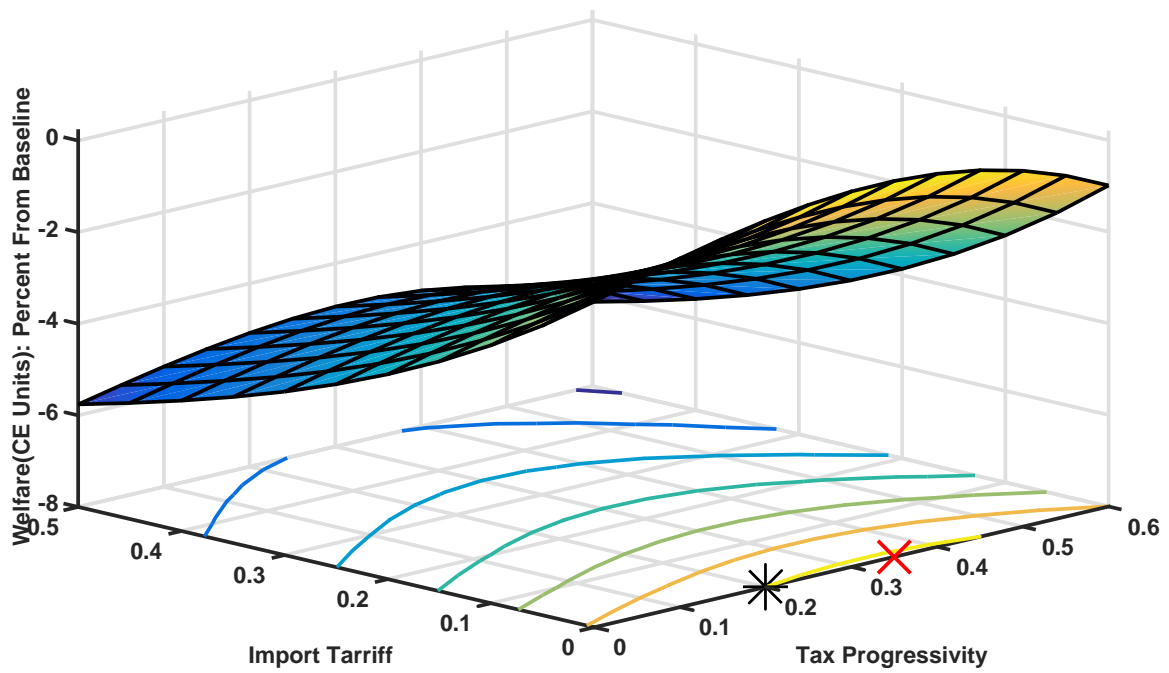


Figure 9: Relatively Open Economy, Baseline Imports/GDP = 0.20



## 8. Conclusion

We motivated this paper by discussing the concerns with regards to globalization. And we explored the idea that redistributive taxation could be used to provide social insurance and, in turn, mitigate the losses from trade that certain segments of the population have experienced.

In an incomplete markets model with frictional labor markets and Ricardian trade we studied the optimal degree of tax progressivity and the gains from progressivity as an economy opens to trade. Big picture, we found two main results:

- Optimal progressivity should increase as the economy becomes more exposed to trade, but the welfare gains associated with optimal policy are modest relative to current system.
- A progressive tax system becomes increasingly beneficial as the economy becomes open, enhancing the gains from trade.

Many open questions and directions for future research remain. Let us suggest two. First, we would prefer a tighter mapping from the evidence of Autor, Dorn, and Hanson (2013), Autor, Dorn, Hanson, and Song (2014) to how migrating workers are re-allocated across labor markets as well as normative welfare statements and policy conclusions. We are currently pursuing such a strategy in our parallel work of Lyon and Waugh (2018).

Second, our model abstracted from many things, especially non-traded factors within a local-labor market—housing is one of these. Computationally, the introduction of housing is challenging. However, the economic environment of the United States in the 2000s' were basically characterized by two events: a housing boom and bust and an unprecedented explosion in import exposure to Chinese trade. For example, the evidence of housing masking of the decline in manufacturing in Charles, Hurst, and Notowidigdo (2016) raises many questions about how these two events relate.

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## A. 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. Note that in all of this derivation, we normalize the price of the final good to one.

**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. The latter equals aggregate payments to labor in the production of all intermediate goods.

$$Y = \int_{\mathbf{s}} w(\mathbf{s})\mu(\mathbf{s}) \quad (36)$$

Examining (29) and (36) allows us to connect aggregate income with consumption. Specifically, by integrating over the consumers budget constraint, then noting how total value added must equal take home pay plus taxes/transfers from the government, one can substitute (36) into (29). Then from the definition of the governments budget constraint (which includes tax revenue and tariff revenue), we arrive at the following:

$$Y = C + G - RA + \mathcal{A}' - \int_a \int_{\mathbf{s}} w_n(1 - \iota_n(\mathbf{s}, a))\lambda(\mathbf{s}, a) + \int_a \int_{\mathbf{s}} m\iota_m(\mathbf{s}, a)\lambda(\mathbf{s}, a) - \tau_f \int_{\mathbf{s}} p(\mathbf{s})\text{imports}(\mathbf{s}) \quad (37)$$

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 (v) minus tariff revenue. The last point follows from noting that government consumption is both tax revenue and tariff revenue.

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

$$Y = \int_{\mathbf{s}} p(\mathbf{s})z\mu(\mathbf{s}) \quad (38)$$

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 (20), imports in (22) and exports in (24) and the equating final demand with consumption we have

$$Y = C + \tilde{G} + \int_{\mathbf{s}} p(\mathbf{s}) \text{exports}(\mathbf{s}) - (1 - \tau_f) \int_{\mathbf{s}} p(\mathbf{s}) \text{imports}(\mathbf{s}) \quad (39)$$

$$= C + G + \int_{\mathbf{s}} p(\mathbf{s}) \text{exports}(\mathbf{s}) - \int_{\mathbf{s}} p(\mathbf{s}) \text{imports}(\mathbf{s}). \quad (40)$$

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 (37) and (40) we get the following relationship

$$\begin{aligned} Y - C - G &= \int_{\mathbf{s}} p(\mathbf{s}) \text{exports}(\mathbf{s}) - \int_{\mathbf{s}} p(\mathbf{s}) \text{imports}(\mathbf{s}), \quad (41) \\ &= -r\mathcal{A} + (\mathcal{A}' - \mathcal{A}) - \int_a \int_{\mathbf{s}} w_n(1 - \iota_n(\mathbf{s}, a)) \lambda_h(\mathbf{s}, a) + \int_a \int_{\mathbf{s}} m \iota_m(\mathbf{s}, a) \lambda(\mathbf{s}, a) - \tau_f \int_{\mathbf{s}} p(\mathbf{s}) \text{imports}(\mathbf{s}), \end{aligned}$$

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 and tariff revenue). 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.”

To see this, consider the special case where moving costs are zero, no home production, and tariffs are zero. Then we have the relationship

$$Y - C - G = \int_{\mathbf{s}} p(\mathbf{s}) \text{exports}(\mathbf{s}) - \int_{\mathbf{s}} p(\mathbf{s}) \text{imports}(\mathbf{s}) = -r\mathcal{A} + (\mathcal{A}' - \mathcal{A}). \quad (42)$$

Here if exports are greater than imports, then this implies that the households in the home country 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, but that trade may be imbalanced.**



## B. Connection with Autor, Dorn, and Hanson (2013)

This discussion is borrowed from Lyon and Waugh (2018) 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 (20), (22), (23) 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  $s$  equal*

$$w(\mathbf{s}) = \omega(\mathbf{s})^{\frac{1}{\theta}} \hat{\mu}_h(\mathbf{s})^{\frac{-1}{\theta}} z_h^{\frac{\theta-1}{\theta}} C_h^{\frac{1}{\theta}}. \quad (43)$$

where

$$\omega(\mathbf{s}) := \frac{p_h(\mathbf{s}) z_h \mu_h(\mathbf{s})}{p_h(\mathbf{s}) z_h \mu_h(\mathbf{s}) \bar{h} + p_h(\mathbf{s}) \text{imports}(\mathbf{s}) - p_h(\mathbf{s}) \text{exports}(\mathbf{s})}, \quad (44)$$

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

Lets talk through Proposition 1 in the following way. First, what does equation (44) 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 (43) 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  $\theta$  in a very succinct manner.

Finally, notice the role that  $\theta$  plays. The parameter  $\theta$  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 (43) and take log differences across time

$$\Delta \log w(\mathbf{s}) = \frac{1}{\theta} \Delta \log (\omega(\mathbf{s}) / \hat{\mu}_h(\mathbf{s})) + \frac{1}{\theta} \Delta \log C_h + \Delta \log \left( z_h^{\frac{\theta-1}{\theta}} \right), \quad (45)$$

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 (45) 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  $\omega$  is a function of  $\mathbf{s} = \{z_h, p_w\}$ .

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 (15) that is assumed to be orthogonal to  $z_h$ .<sup>11</sup>

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 (45) to that used in ADH. First, they only have industry level imports at the aggregate level and a geographic region

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<sup>11</sup>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  $\Delta IPW$  measure would be imports per worker. So similar to  $\Delta \log (\omega(\mathbf{s})/\hat{\mu}_h(\mathbf{s}))$  but operating directly with the level of imports rather than the shares. We explore this distinction in future work.