Quantifying the Losses from International Trade

PRELIMINARY AND WORK IN PROGRESS.

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ABSTRACT

Evidence suggests that trade with China harmed the US economy in the 2000s—a rapid rise in import penetration, expanding trade deficits, and local-labor-market evidence on the negative impact of trade on wages and employment are all pieces of evidence pointing in this direction. We provide an interpretation of this evidence by developing a dynamic, standard incomplete market model with Ricardian trade and frictional labor markets. We discipline our model by calibrating it to match aggregate and local-labor-market evidence then study the transition dynamics of the economy in response to a “China Shock.” Consistent with \( \), our model predicts import-competition-exposed workers experience (relative) wage losses and reductions in labor force participation. In aggregate, however, the China shock leads to a large increase in consumption and employment. So how much did the losers from trade lose? Preliminary analysis finds that those most exposed to trade suffer welfare losses of one percent in consumption equivalents.

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Trade generates winners and losers, but that the winners win more than the losers lose. This phrase is said often, but does little to assuage the concerns of people and policy makers 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. This paper takes one step toward evaluating these concerns by answering the question: How much do the losers lose from trade?

A popular narrative hints that the losses from trade were large. Stating in early 2000s and continuing into the beginning of 2008, US imports as a fraction of GDP increased by seventy percent—Chinese imports accounted for all of this growth. At the same time, the US trade deficit as a fraction of GDP expanded by two percentage points. These facts suggest that the growth in Chinese import penetration did not arrive with equivalent export and employment opportunities for those displaced from trade. Autor, Dorn, and Hanson (2013) provides evidence to support this idea. Using evidence from differential changes across local labor markets, they find that increased exposure of a labor market to Chinese trade resulted in reductions in labor income and labor force participation.

In this paper, we provide an evaluation of this evidence by developing a dynamic, standard incomplete markets model with Ricardian trade and frictional labor markets. A quantitative, structural evaluation of this evidence is important for several reasons. First, there are well known issues about the aggregation of evidence that exploits differential changes in local labor markets (as in Autor, Dorn, and Hanson (2013)). Our model provides a structural interpretation of the evidence in Autor, Dorn, and Hanson (2013) and, hence, a mapping into aggregate conclusions and welfare statements.

A second issue is that the evidence in Autor, Dorn, and Hanson (2013) suggests that households are acting to mitigate the negative labor market impacts. For example, an interpretation of the decrease in labor force participation is that wages are too low relative to the value of leisure and, hence, trade-exposed households substitute into leisure. A key feature of our analysis is that we study a model in which households have multiple mechanisms to mitigate income shocks (some of which are trade related). In particular, households can self-insure, opt-out of the labor force, and/or migrate. These mechanisms lead to a tension between the negative labor market consequences from trade and the ability of households to mute these shocks.

A final issue relates to the trade deficit. The evidence of Autor, Dorn, and Hanson (2013) is particularly compelling given that the deteriorating trade deficit during the 2000s suggests employment opportunities for those displaced from trade did not come from increases in export opportunities. While in line with traditional trade theory, this perspective ignores the fact that a rising trade deficit corresponds with a welfare improving situation where households are increasing their consumption above and beyond their savings. In other words, the of China
came with an expansion of both intra- and inter-temporal trading opportunities. This later point is closely related to the “global savings glut” hypothesis put forth by Bernanke (2005). The explicit modeling of consumption-savings decisions of households allows us to entertain alternative perspectives on the trade imbalance.

Our model builds on existing neoclassical trade theory and then departs from it in important ways. As in the model of Eaton and Kortum (2002), there is a continuum of goods with competitive producers who are heterogenous in productivity; comparative advantage determines the pattern of trade. As in Lucas and Prescott (1974) the labor market is frictional and labor can only move across different goods producing markets (within a country) after paying some cost. Dynamics at the micro-level arise as good-level productivity stochastically evolves and labor and the pattern of trade adjust in response.

Labor market frictions delivers losses in labor income to import-competition-exposed workers very much consistent with the evidence in Autor, Dorn, and Hanson (2013). We show how our model delivers a structural interpretation of the regressions in ADH and a rationalization for their instrumental variable strategy. In particular, our model structurally relates goods-market-level wages with import exposure through the share of domestic production relative to consumption of that commodity and the elasticity of substitution across commodities. Thus, an increase in import exposure leads to a decline in goods-market-level wages.

We depart from recent quantitative trade theory by positing an environment where insurance markets are incomplete. As in the standard incomplete markets model (Huggett (1993), Aiyagari (1994)) households can self-insure by accumulating a non-state contingent asset. In contrast to essentially all models of trade and labor market dynamics, this aspect of the model allows for the partial—but not complete—pass through of income shocks into consumption. Given that risk sharing is often found to be incomplete (see, e.g., Cochrane (1991), Attanasio and Davis (1996)), this formulation provides a middle ground between a complete markets benchmark where the losses from trade are shared equally and where all households are hand-to-mouth with no opportunities to smooth out shocks.

In addition, we endow households with two additional margins to mitigate shocks. First, we allow households to migrate and move to alternative labor markets. This margin has been an important dimension in models of trade and labor market dynamics (see, e.g., Kambourov (2009), Artuç, Chaudhuri, and McLaren (2010), Dix-Carneiro (2014), Caliendo, Dvorkin, and Parro (2015)). Second, households can exit the labor force and substitute into leisure. Our formulation of labor supply follows the work of Rogerson (1988) and more closely Chang and

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1 The quantitative nature of our analysis distinguishes this paper from earlier discussions about risk, incomplete markets, and the gains from trade, e.g., see Newbery and Stiglitz (1984) and Eaton and Grossman (1985). Furthermore the standard incomplete markets setting take the reason that insurance markets are missing as given; Dixit (1987, 1989a,b) shows how certain conclusion depend upon the modeling as to why these markets are missing.
Kim (2007). This formulation of labor supply allows our model to speak directly to the evidence on labor force participation in Autor, Dorn, and Hanson (2013). Moreover, this formulation is consistent with the evidence discussed in Keane (2011)—our model has a small micro-labor supply elasticity, but can deliver a large aggregate labor supply elasticity due to movements along the extensive margin.

We discipline our model by calibrating it to match aggregate and cross-sectional evidence for the US and then study the transition dynamics of the economy in response to a “China Shock.” We focus on two types of shocks. First, we study a change in the ability to import goods. We think about this change as correspond with China’s accession to the World Trade Organization and the the policy changes and reduction in uncertainty surrounding it (see, e.g., Pierce and Schott (2016)). Second, we study a reduction in the world real interest rate. We think of this shock as reflecting a global savings glut shock echoing the arguments of Bernanke (2005). The idea is that an expansion of global savings from developing countries (including China) lead to a world wide decrease in real interest rates.

An important feature of our analysis is that we focus on transition paths. That is we change parameter values in an unanticipated fashion and compute the transition path from the initial stationary equilibrium to the new stationary equilibrium. Thus, our welfare gains/losses include the costs of adjustment in response to the shock.

In our baseline specification with a reduction in trade costs and a reduction in the world interest rate— trade expands and there is a widening trade imbalance. In our quantitative exercise, the trade imbalance is not target and declines by 0.75 percentage points. This is nearly half of the actual change in trade deficit seen in the subsequent years after China’s accession to the WTO and large expansion of trade with the US. This sequence of events gives rise to a boom in output, consumption, and labor supply.

We then compare evaluate the micro-level implications of our model to the evidence of Autor, Dorn, and Hanson (2013). We do this by constructing model generated data in a fashion consistent with the empirical analogs. And then we implement the same IV strategy they employ on our model generated data. Despite the boom occurring in the aggregate economy, we find trade exposure resulting in large wage losses, reductions in labor supply. The magnitudes are in the ball park, but different than those of Autor, Dorn, and Hanson (2013) and we discuss possible reasons for this.

We then compute welfare. First, average welfare gains from the China Shock are our 0.60 percent in lifetime consumption equivalents. There is, however, large dispersion around this number. On average, initially import exposed regions in our economy experience losses of 0.80 percent (with some losing substantially more).

Finally, a key issue that comes out of this analysis is the trade imbalance. In our baseline
specification, the China shock is composed of two effects, a reduction to the cost of importing goods and a reduction in the world interest rate. Consistent with the data, this gave rise to a deteriorating trade imbalance. In contrast, only the cost of importing goods is changed, the model tells a different story. The trade imbalance improves, consumption declines, labor supply declines. And, surprisingly, the welfare gains from trade are on average smaller and the losers from trade lose more than when the trade imbalance behave more like the data.

**Related Literature.** 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 the geographic and sectoral detail found in this work (see, e.g., Caliendo, Dvorkin, and Parro (2015)) due to computational complexities.

We view this as an important departure for several reasons. First, it because it breaks the link between labor market outcomes and welfare. And it breaks the link in non-obvious ways. For example, if households are sufficiently wealthy, they can smooth out the trade induced losses to labor income and, thus, the losses from trade are small. This is an example where households do have a mechanism to mitigate the losses from trade through self-insurance. However, if workers in import-competing sectors are already wealth poor, then the welfare losses from trade could be quite large. This is an example where the previously poor bear the burden of globalization and inequality is amplified.

Second, it opens the door to questions about government policy and the correct response when the economy is increasingly exposed to trade. As we show in our parallel work in Lyon and Waugh (2018b), we find that progressivity should increase with openness to trade and that progressivity is an important tool to mitigate the negative consequences of globalization.

1. **Motivating Facts**

There is a body of evidence suggesting that trade with China harmed the US economy in the 2000s. This section discusses this evidence and it provides benchmarks that we will ask our quantitative experiment to replicate.

1.1. **Macro Facts**

**Fact 1: Large rise in US Import Exposure.** Figure 1 plots US imports of goods and services divided by GDP for the time period 1990 until the beginning of 2008. The red line is US imports in total, the blue line is all but China, thus the difference reflects Chinese imports relative to GDP. US import exposure grew dramatically during this time period from approximately 10
percent of GDP to near 17 percent of GDP by the beginning of 2008.

The blue line shows that non-Chinese US import exposure was roughly constant over this time at around 10 percent. What this implies that nearly all the rise in US import exposure during this time period came from an increase in Chinese import exposure. Moreover, most of this expansion was after China’s accession to the World Trade Organization at the end of 2001.

**Fact 2: An Expansion in the US Trade Deficit.** Figure 2 plots US exports minus imports divided by GDP for the time period 1990 until the beginning of 2008. During this time period, the trade deficit grew by about five percentage points in total; three percentage points prior to the large expansion in Chinese import expansion, and then two percentage points subsequently.

From a trade perspective, these two facts suggest that the “traditional” replacement of job opportunities did not occur with the rise in Chinese trade. That is import exposure was not offset by an increase export opportunities and, thus, was a drag on the US labor market in the 2000s as the facts below suggest. An alternative perspectives on Figure 2 is the “global savings glut” hypothesis put forth by Bernanke (2005). Developments in international credit markets during the 1990s and 2000s lead to an glut of foreign savings (some of which is Chinese related) and the US borrowed these funds and led to an expansion of the trade deficit.

### 1.2. Micro Facts

The next three facts focus on labor market outcomes from Autor, Dorn, and Hanson (2013). The idea behind Autor, Dorn, and Hanson (2013) is to exploit changes in the variation in trade exposure at the commuting zone level (see Tolbert and Sizer (1996)) and correlate it with changes in labor market outcomes such as earnings and labor force participation. Their measure of trade exposure is:

\[
\Delta IPW_{uit} = \sum_j \left( \frac{L_{ijt}}{L_{it}} \right) \left( \frac{\Delta M_{ucjt}}{L_{ijt}} \right)
\]

(1)

where \(u\) stands for united states, \(c\) stands for China, \(i\) is a commute zone, \(t\) is time, and \(j\) is industry. This measure essentially takes aggregate US imports from China \(M_{ucjt}\) for industry \(j\) and essentially apportions these imports to a commute zone based on that commute zones share of national employment in that industry. It then aggregates across industries for that commute zone.

Given this measure of trade exposure, they estimate its affect on labor market outcomes with the following empirical specification:

\[
\Delta L_{it} = \gamma_t + \beta \Delta IPW_{uit} + \text{controls}_i + \epsilon_{it}.
\]

(2)
Figure 1: US Imports

Figure 2: US Trade Deficit
Table 1: ADH Evidence: Labor Market Outcomes and Trade Exposure

<table>
<thead>
<tr>
<th></th>
<th>∆ Labor Earnings</th>
<th>∆ NILF</th>
<th>∆ Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standardized ∆ IPW</td>
<td>−4.30</td>
<td>1.11</td>
<td>−0.05</td>
</tr>
<tr>
<td></td>
<td>[−6.62, −2.00]</td>
<td>[0.52, 1.72]</td>
<td>[−1.51, 1.41]</td>
</tr>
</tbody>
</table>

Note: Values in brackets report 95–5 confidence intervals. Variable definitions are as follows. ∆ Labor Earnings is average household “wage and salary” income per adult variable from the Census and ACS; the units are in decadal, percent changes. ∆ NILF corresponds to the change in the not in labor force share. ∆ Population corresponds with the log change in population. ∆ IPW is standardized by netting out the mean and dividing by the standard deviation.

A key issue is that the error term may incorporate factors that are simultaneously changing a commute zone’s trade exposure and labor market outcomes. As our model makes clear (see Section 4.3), local productivity shocks would be a key threat to identification, i.e. they would both change the pattern of trade and labor markets outcomes. To avoid this problem, Autor, Dorn, and Hanson (2013) estimate (2) using an other countries imports from China as an instrument.

In the facts below, we report estimates after standardizing the ∆ IPW uit. That is we demeaned this measure and divided by its standard deviation. As in Autor, Dorn, and Hanson (2013) all labor market outcomes are converted to 10 year changes.

Fact 3: Import Exposure Decreased Household Income The first column in Table 1 reports Autor, Dorn, and Hanson’s (2013) estimate of the response of commute zone household level income to trade exposure. What this coefficient means is that a one standard deviation increase in trade exposure reduced wage growth by four percent over 10 years. To put this in context, average wage growth over the period 2000–2007 was only about six percent (converted to 10 year change). In other words, these estimates suggest that moderate exposure to trade eliminates 2/3 of expected wage growth.

Fact 4: Import Exposure Increased Non Participation The second column in Table 1 reports the response of commute zone nonparticipation in the labor force in response to trade exposure. The magnitude of this coefficient means is that a one standard deviation increase in trade exposure reduced participation in the labor market by 1.11 percentage points. Average non-participation across commute zones, across all time periods was about 25 percent.

Fact 5: No Out migration from Import Exposure The third column in Table 1 reports the estimate of the response of commute zone population to trade exposure. What this coefficient
means is that a one standard deviation increase in trade exposure reduced a commute zone’s population by $-0.05 \log$ points, moreover this effect is not statistically different than zero. What this implies is that trade exposure did not induce households to reallocate across labor markets as standard trade theory would predict.

1.3. Discussion

Taken together, these facts suggest a compelling narrative: At the macro level, there was a large increase in import exposure from China and no corresponding increase in export opportunities. And at the micro level, the evidence suggest this wreaked havoc on labor market in the United States—households did not move, they absorbed loses in labor income, and stopped participating in the labor market.

How to interpret this evidence? First, there is an issue about the interpretation of the cross-sectional estimates in (1) and how to map them into aggregate conclusions. The model that we develop below plays an important role here. And as we describe in Section 4 the model bridges this gap, clarifies what these estimates are informative about, and provide key inputs into our qualitative analysis.

Second, a model is needed to jump from changes in income and non-participation to statements about welfare. Our presumption is that households have a myriad of ways to smooth out negative labor market outcomes. One is self-insurance, another is that leisure is a substitute for leaving the labor market. Thus, we develop a model that allows us to entertain multiple mechanisms for which households can mitigate the negative outcomes that may arise from international trade.

A final issue relates to the trade deficit. Traditional trade theory’s perspective on this suggests that increases in import penetration from China did not come with increases in export and employment opportunities for those displaced from trade. This perspective ignores the idea that a rising trade deficit implies households are increasing their consumption above and beyond their savings. In other words, the of China came with an expansion of both intra- and inter-temporal trading opportunities.

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 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
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,

$$ q(\omega) = z(\omega) \ell, \quad (3) $$

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

$$ \log z_{t+1} = \phi \log z_t + \epsilon_{t+1}, \quad (4) $$

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, consumers and firms face iceberg trade costs when importing and exporting their products. We allow for the import and export cost to differ with $\tau_{im} > 1$ being the cost to import a good from abroad and $\tau_{ex} > 1$ being the cost an export faces to ship goods onto the world market.

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

$$ Q = \left[ \int_0^1 q(\omega)^\rho d\omega \right]^{\frac{1}{\rho}}, \quad (5) $$

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. 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

\[
E \sum_{t=0}^{\infty} \beta^t \left\{ \log(c_t) - B h_t^{1-\gamma} \right\},
\]

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.

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 somewhere 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. In the following presentation, we normalize the value \( \bar{h} \) equal to one. If a household does not work, if receives home production \( wh \). The value of home production partially determines the value of being out of 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 \( m \) in units of the final good allows the household to change where it can work in next period. The value of the new location can take several forms. One is the best labor market, as in Lucas and Prescott (1974); an alternative is a random labor market. We 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 (6), 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. 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 $s$ denote the domestic productivity and world price combination associated with that island. Furthermore, because the CES aggregator is symmetric over varieties, it is sufficient to index islands by their productivity and world price state. The wage per efficiency unit a household earns is $w(s)$.

**Budget Constraints.** Given the description of the environment, the budget constraints are as follows. For households that are working, the household’s period $t$ budget constraint (all denominated in units of the final good) is

$$a_{t+1} + c_t + t_{m,t}m \leq Ra_t + w_t(s),$$

(7)

where the left-hand side are expenditures on new assets, consumption, and possibly moving costs with $t_{m,t}$ 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, with $t_{n,t}$ being an indicator function equaling one if a household works.

If a household is not working, then the budget constraint is modified to ensure that home production is not used to accumulate assets or pay for moving costs. In this case, a non-working households budget constraint is

$$c_t \leq w_h + |Ra_t - a_{t+1} - t_{m,t}m|^{+},$$

(8)

where the right-hand side is home production plus any positive income from asset holdings.

**Recursive Formulation.** The recursive formulation of the household’s problem is

$$V(a, s) = \max \{V^{s,w}, V^{s,nw}, V^{m,w}, V^{m,nw}\}.$$  

(9)
that 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. Unpacking each of these four options is the following. The value of staying and working is

\[ V^{s,w}(a, s) = \max_{a' \geq -\bar{a}} \left[ u(Ra + w(s) - a') - B + \beta EV(a', s') \right], \tag{10} \]

where \( u \) is the utility value over consumption. The value of staying and not working is

\[ V^{s,nw}(a, s) = \max_{a' \geq -\bar{a}} \left[ u(w_h + |Ra - a'|^+) + \beta EV(a', s') \right]. \tag{11} \]

The value of moving and working is

\[ V^{m,w}(a, s) = \max_{a' \geq -\bar{a}} \left[ u(Ra + w(s) - a' - m) - B + \beta V^m(a') \right], \tag{12} \]

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

\[ V^{m,nw}(a, s) = \max_{a' \geq -\bar{a}} \left[ u(w_h + |Ra - a' - m|^+) + \beta V^m(a') \right]. \tag{13} \]

### 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.\(^3\)

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

\[ \log p_w(\omega)_{t+1} = \phi \log p_w(\omega)_t + \epsilon(\omega)_{t+1}, \tag{14} \]

where \( \epsilon(\omega)_t \) 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 \( \pi(s) \) as the stationary distribution of productivity states and world prices induced by (4) and (14). And denote \( \mu(s) \) as the measure of households working on an island with state \( s \).

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\(^3\)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 specific about the interaction between trade flows and capital flows.
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.** The final-goods producer’s problem is:

\[
\max_{q(s)} P_h Q - \int p(s) q(s) \pi(s) ds, \tag{15}
\]

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

\[
q(s) = \left( \frac{p(s)}{P_h} \right)^{-\theta} Q. \tag{16}
\]

where \( Q \) is the aggregate demand for the final good; \( P_h \) is the price associated with the final good which will be carried around briefly, but is ultimately normalized to the value one.

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

\[
\max_{q(s), \ell(s)} p(s) q(s) - w(s) \ell(s) \tag{17}
\]

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

\[
w(s) = p(s) z \tag{18}
\]

or the value of the marginal product of labor. Only at the wage in (18) 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 \( p(s), \hat{\tau}_p w \). The final-goods producer purchases intermediate goods from the low-cost supplier. This decision gives rise to three cases with three different market-clearing conditions: if the good is non-traded; if the good is imported; and if the good is exported.\(^4\)

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: \( \frac{p_h}{\tau_{ex}} < p(s) < \tau_{im} p_w \). That is, from the home country’s perspective, it is optimal to source the good domestically and not optimal for the home

\(^4\)This is more nuanced than the standard formulation in Eaton and Kortum (2002) due to the frictional labor market. In our model, 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.
country to export the product.

In this case, the market-clearing condition is:

\[
\left( \frac{p(s)}{P_h} \right)^{-\theta} Q = z \left( \mu(s)/\pi(s) \right)
\]

or that domestic demand equals production. The left-hand part is demand and the right-hand side is supply. That is 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 \( p(s) = \tau_{im} p_w \). Why? If the price were lower, then it would not be imported. If the domestic price were higher, then the good will be imported with not domestic production and, thus, the prevailing domestic price will equal the imported price. With frictional labor markets, there may be some domestic production so the quantity of imports is

\[
\left( \frac{\hat{\tau} p_w}{P_h} \right)^{-\theta} Q - z \left( \mu(s)/\pi(s) \right) > 0.
\]

That is home demand (net of home production) is met by imports of the commodity. Rearranging gives

\[
\left( \frac{\hat{\tau} p_w}{P_h} \right)^{-\theta} Q = z \left( \mu(s)/\pi(s) \right) + \text{imports}(s)
\]

or domestic demand equals domestic production plus imports.

- **Exported.** If the good is exported, then the prevailing price must be \( p(s)\tau_{ex} = p_w \). Why? If the home price were larger, then the good 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, not the tariff, matters here. At this price, the quantity of exports is

\[
\left( \frac{p_w/\pi}{P_h} \right)^{-\theta} Q - z \left( \mu(s)/\pi(s) \right) < 0
\]

or domestic demand net of production which should be negative, implying that the coun-
try is an exporter. Rearranging gives
\[
\left( \frac{p_w/\tau}{P_h} \right)^\theta Q = z(\mu(s)/\pi(s)) - \text{exports}(s)
\] (23)
or domestic demand equals domestic production minus exports.

**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
\[
Q = C = \int_s \int_a c(s, a)\lambda(s, a),
\] (24)
where \(c(s, a)\) is the market consumption part of the consumption policy function that satisfies the households’ problem, and \(\lambda(s, a)\) is the mass of consumers with state \(s\) and asset holding \(a\) (defined below in (25)). This relationship says that household-level market consumption—aggregated across all households—must equal the aggregate production of the final good \(Q\).

Market-clearing conditions for the intermediate goods in (19),(21), (23) and the aggregate final good in (24) 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—\(\{\iota_m(s, a), \iota_n(s, a), g_a(s, a)\}\)—as the move, work, and asset policy functions that satisfy the households’ problem in (9).

**Population and Labor Supply.** We define the probability distribution of households across assets and states as \(\lambda(s, a)\). Furthermore, define the probability distribution of households in the next period as \(\lambda'(s, a)\). The distribution of households evolves across time according to the following law of motion:
\[
\lambda'(s', a') = \int_{a:a' = g_a(s, a)} \lambda(s, a)(1 - \iota_m(s, a))\pi(s', s) + \lambda(s, a)\iota_m(s, a)\bar{\pi}(s').
\] (25)
Equation (25) says the following: in the next period, the mass of households with asset holding \(a'\) in state \(s'\) equals the mass of household that do not move multiplied by the transition probability that \(s\) transits to \(s'\). This is the first term in equation (25). Plus the mass of households that do move, multiplied by the probability that they end up in state \(s'\). This is the second term in equation (25). The probability, \(\bar{\pi}(s')\), is given by the moving protocol—i.e., random assign-
ment across islands according to the invariant distribution associated with $\pi(s', s)$. All of this is conditional on those households that choose asset holdings equal to $a'$. This is denoted by the conditionality under the integral sign.

Given a distribution of households, the supply of labor to intermediate good producers with productivity state $s$ is,

$$\int_a \nu(s, a) \lambda(s, a) = \mu(s),$$

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 (19)-(23).

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

$$\mathcal{A}' = \int_a \int_s \nu_a(s, a) \lambda(s, a).$$

A couple of points about this are warranted. First, this is in aggregate—some households in the home country may have positive holdings, while 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 (27) we can work from the consumers’ budget constraint and derive aggregate market consumption:

$$C = -\mathcal{A}' + R\mathcal{A} + \int_a \int_s \left\{ \tilde{w}(s) \nu_a(s, a) - m\nu_m(s, a) \right\} \lambda(s, a).$$

In words, aggregate market consumption equals net asset purchases (the first two terms) plus wage income net of moving costs.

### 3.3. 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 $\{p_w, R\}$, a stationary Small Open Economy Equilibrium is domestic prices $\{p(s)\}$, policy functions $\{g_a(s, a), \nu_a(s, a), \nu_m(s, a)\}$, and a probability distribution $\lambda(s, a)$ such that

i Firms maximize profits, (15) and (17) ;
ii The policy functions solve the household’s optimization problem in (9);

iii Demand for the final and intermediate goods equals production, (19), (20), (22) and (24);

iv The probability distribution \( \lambda(s,a) \) is a stationary distribution associated with

\[
\{ g_a(s,a), \iota_m(s,a), \pi(s',s) \}. \quad \text{That is, it satisfies}
\]

\[
\lambda(s',a') = \int_{a:a'=g_a(s,a)} \lambda(s,a)(1 - \iota_m(s,a))\pi(s',s) + \lambda(s,a)\iota_m(s,a)\bar{\pi}(s').
\] (29)

The idea behind the equilibrium definition is the following. The first bullet point (i) gives rise to the equilibrium conditions for the demand of intermediate goods in (16) and wages (18) at which firms are willing to produce. The second bullet point (ii) says that households are optimizing.

At a superficial level, bullet (iii) says that demand must equal supply. It’s meaning, however, deeper. The households’ choices of the 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 (iv) requires stationarity. Specifically, the distribution of households across productivity and asset states is not changing. Mathematically, this means that distribution \( \lambda(s,a) \) must be such that when plugged into the law of motion in (25), the same distribution is returned.

Finally, note that there is no requirement that the asset market clears—i.e., that (27) 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. This implies that trade need not balance, as the trade imbalance will reflect asset income on foreign assets and the acquisition of assets. After adjusting for moving costs, this implies that the current account and capital account are always zero in a stationary equilibrium, but that trade may be imbalanced.

**Computation.** Computing a stationary equilibrium for this economy deserves some discussion. First, this economy is unlike standard incomplete markets models in which 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 \( p(s) \). Thus, the iterative procedure is to (i) guess a price function; (ii) solve the household’s dynamic optimization problem; (iii) construct the stationary distribution \( \lambda(s,a) \); (iv) check whether markets clear; and (v) update the price function. See, e.g., Krusell, Mukoyama, and Şahin (2010), who solve a similar problem.

Second, an important observation is that the inequalities in (20) and (22) impose additional structure on an equilibrium. 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 the problem of finding a price function 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. Below we focus on three issues (i) the pattern of trade across labor markets (ii) how trade exposure affects wages and how our model relates to the empirical approach/specification of Autor, Dorn, and Hanson (2013). Finally, we use these results to motivate our quantitative exercise.

4.1. Trade

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

\[ \omega(s) := \frac{p(s)z_{\mu}(s)h}{p(s)z_{\mu}(s)h + p(s)\text{imports}(s) - p(s)\text{exports}(s)}. \]

(30)

What does equation (30) represent? The denominator is the value of domestic consumption: everything domestically produced plus imports minus exports. The numerator is production. The interpretation of (30) is how much of domestic consumption at the island/variety level the home country is producing. This is similar to the micro-level “home share” summary statistic emphasized in Arkolakis, Costinot, and Rodriguez-Clare (2012). As we discuss below, this statistic (i) provides a clean interpretation of a labor market’s exposure to trade and (ii) is tightly connected with local labor market wages.

Figure 3 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 to the situation with low world prices or low home productivity—i.e. the economy has a comparative disadvantage in producing these commodities.

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 to high world prices or high home productivity. 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. 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 reason is trade costs. In this region, world prices and domestic productivity are not high enough for a producer to be an exporter of these commodities given trade costs. Furthermore, world prices and domestic
Figure 3: Trade: Home Share, $\omega(s)^{\frac{1}{\pi}}$

Figure 4: Wages
productivity are not low enough to merit importing these commodities either. Thus, these goods are non-traded.

Finally, unlike Dornbusch, Fischer, and Samuelson (1977) or Eaton and Kortum (2002), it is important to reflect on the stochastic nature of this economy. While the stationary equilibrium of the economy leads to the stationary pattern of trade seen in Figure 3, individual islands transit 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 (3) with the structure of wages in the economy. As we show in the Appendix and in Lyon and Waugh (2018a), pre-tax real wages in a market with state variable \( s \) equal

\[
\omega(s) = \omega(s) \frac{1}{\theta} \mu(s) \left( \frac{-1}{\theta} z \right) \frac{C}{\theta}.
\]  

Here \( \omega(s) \) is the home share defined in (30); \( \mu(s) = \frac{\mu_h(s)}{\eta(s)} \) is the number of labor units; \( z \) is domestic productivity; \( C \) is aggregate consumption.

Equation (31) connects the trade exposure measure in (30) with island-level wages. A smaller home share implies that wages are lower with elasticity \( \frac{1}{\eta} \). This means that if imports (relative to domestic production) are larger, then wages in that labor market are lower. Similarly, a larger home share means that wages are higher.

While this looks like the “micro-level” analog of the aggregate result of Arkolakis, Costinot, and Rodríguez-Clare (2012) it is different in one important respect: the micro-level wage response to micro-level trade exposure to trade takes the exact opposite sign.

Figure 4 illustrates these observations by plotting the logarithm of pre-tax wages by world price and home productivity so it exactly matches up with Figure 3. As equation (31) makes clear, there is a tight correspondence between wages and the home share in Figure 3. As in Figure 3, 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 way to understand this result is as follows: wages reflect the value of the marginal product of labor. In import competing islands, 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 islands. Finally, the center region is where commodities are non-traded. Here, the gradient of wages very much mimics the increase in domestic productivity. In contrast, where goods are imported or exported, the
wage gradient mimics 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 results in a stationary distribution of wages, individual islands (and households living on those islands) transit 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 will fall.

Finally, equation (31) connects with the aggregate gains from trade. Any change in aggregate trade exposure will also change in aggregate consumption, i.e. the $C$ term. That is all workers benefit from the "aggregate gains to trade", but the island-level incidence will vary with its trade exposure and may mitigate or completely offset the aggregate benefits from trade.

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

The preceding results relate closely to the empirical specification and evidence of Autor, Dorn, and Hanson (2013) and Acemoglu, Autor, Dorn, Hanson, and Price (2016) that link changes in trade exposure with labor market outcomes such as wages (see Section IV.B of Autor, Dorn, and Hanson (2013)). To do illustrate the connection, start with (31) and take log differences across time yielding

$$
\Delta \log w(s) = \frac{1}{\theta} \Delta \log \left( \frac{\omega(s)}{\hat{\mu}_h(s)} \right) + \frac{1}{\theta} \Delta \log C + \Delta \log \left( z^{\frac{\beta-1}{\beta}} \right),
$$

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 aggregate consumption and (iii) the change in location-specific productivity.

Equation (32) is closely related to the empirical specification of Autor, Dorn, and Hanson (2013) (see equation (5)). Autor, Dorn, and Hanson (2013) relate various labor market outcomes at the commute zone level to commute-zone-level measures of trade exposure. Put in their terms, our theory connects changes in wages on the left hand side with trade exposure, an aggregate effect (which would be picked up by the constant/or time effect), and the error term in Autor, Dorn, and Hanson’s (2013) reflects unobserved commute-zone-level productivity shocks.

Consistent with their arguments, equation (32) makes clear that an instrumental variable strategy is necessary to identify the causal effect of trade exposure on wages. Commute-zone-level productivity shocks are unobserved, but correlated with trade exposure and, thus, trade exposure could increase either because of changes in world prices or domestic productivity.

The structure of the model suggests several instrumental variable strategies. One valid instru-
ment 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
that the stochastic process in (14) that is assumed to be orthogonal to \( z \).\(^5\) 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, but correlated with world prices. This, in
fact, is quite similar to the instrument proposed in Autor, Dorn, and Hanson (2013).

These qualitative results paint the following picture: Different islands have different exposures
to trade due to comparative advantage as in a traditional Ricardian models of trade. Frictional
labor markets imply that differential trade exposure passes through to wages with more import
expose islands facing lower wage. And our theory predicts than an island’s “home share“ is a
summary statistic for this trade exposure.

With that said, there are several open questions. While our model will predict heterogenous
responses, how the aggregate gains from trade offsets these responses it not clear. Second,
our model has several margins which households can potentially partially offset reductions in
wages — borrowing, labor supply adjustments, and moving. The quantitative analysis below
explores these issues.

5. Calibration

This section outlines our calibration approach. We divide our calibration approach into essen-
tially two steps. First, there is a subset of parameters that are determined outside of the model
and based on prior evidence. Second, the remaining parameters that calibrated so that our
economy replicates aggregate and micro-level facts about the US economy prior to the China
shock and then the economy’s response to the China shock. The latter point makes the calibra-
tion procedure difficult and non-standard in that we are matching moments as the economy
transitions and adjusts to China—this is not a calibration based on steady state to steady state
responses.

5.1. Predetermined Parameters

Time and Geography. The time period is set to a year. Given the time period we set discount
factor equal to 0.95. This is value is at the top end with those used in Krueger, Mitman, and Perri
(2016). Geographically, in our model, there is an abstract notion of an island, households living
on that island, and working within its local labor market. Per the discussion in Section 4.3, we

\(^5\)Moveover, the model makes clear that one should be concerned, in general equilibrium, that a change in
domestic productivity would feed into world prices and, thus, invalidate this strategy.
want to tightly connect our model’s implications with empirical evidence of Autor, Dorn, and Hanson (2013). Thus, we will think of the empirical counterpart to an island as a Commuting Zone (see Tolbert and Sizer (1996)) and as used in Autor, Dorn, and Hanson (2013)).

**Productivity and World Price Process.** The productivity process in (4) and (14) leaves three parameters to be calibrated: \( \{\phi, \sigma_z, \sigma_w\} \), the parameter controlling the persistence of the shocks and the size of the innovations. For now, we set the persistence parameter \( \phi \) to 0.95. 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 uninsurable these shocks are. 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.

We calibrate \( \sigma_z \) to match the standard deviation of growth rates in commute zone level labor earnings. Using the decennial Census data from Autor, Dorn, and Hanson (2013) and focusing on the period between 1990 and 2000 (prior to the large rise in Chinese trade), we find that standard deviation of growth rates in commute zone level labor earnings is 6.5 percent.

We then pick \( \sigma_w \) to

The final world price that we must calibrate is the gross real interest rate, \( R \) in the initial stationary equilibrium. We set this equal to 1.02 which corresponds with a two percent annual interest rate.

**5.2. Calibrated Parameters**

We calibrate the remaining parameter values so that moments in the initial stationary equilibrium and moments along the transition to a new stationary equilibrium match moments about the period prior to and post China’s rise. In particular, we think of the initial stationary equilibrium period as corresponding with the first time period of 1990 to 2000 used in Autor, Dorn, and Hanson (2013); the China shock period (i.e. the transition) corresponds with the second

### Table 2: Predetermined Parameter Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Target Moment/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount Factor, ( \beta )</td>
<td>0.95</td>
<td>—</td>
</tr>
<tr>
<td>World Interest Rate, ( R )</td>
<td>1.02</td>
<td>—</td>
</tr>
<tr>
<td>Persistence of ( z ) and ( p_w ) process</td>
<td>0.95</td>
<td>—</td>
</tr>
<tr>
<td>Std. Dev. of innovations to ( z )</td>
<td>0.06%</td>
<td>Std. cmz. wage growth, 7.0%</td>
</tr>
</tbody>
</table>
time period or 2000-2007.

The following parameters are chosen: the disutility of work, home production, the migration cost, the borrowing constraint, pre-China shock trade cost, post-China shock trade cost, and the demand elasticity; call this parameter vector \( \Theta = \{ B, \bar{a}, m, \tau_{im}, \tau_{im}', \sigma_w, h, \theta \} \). This parameter vector is then chosen to minimize the distance between eight moments in the model and eight moments in the data. Below we describe the eight moments and the parameters they are most tightly linked with.

- **Labor force participation.** We target a labor force participation rate of 67 percent which corresponds with the average value across the period of 1990-2000 in US data. We target this value in the initial stationary equilibrium. This moment is most informative about the disutility of work.

- **Migration rate.** We use the IRS migration data which uses the address and reported income on individual tax filings 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 commuting zone at a yearly frequency. We target this value in the initial stationary equilibrium. This moment is most informative about the migration cost.

- **Fraction of households with households have zero or negative wealth.** Krueger, Mitman, and Perri (2016) report from the Survey of Consumer Finances that approximately 40 percent of households have zero or negative wealth. We target this value in the initial stationary equilibrium. This moment is most informative about the borrowing constraint.

- **Trade volumes pre China’s rise.** In the initial stationary equilibrium, we target an initial import to GDP ratio of thirteen percent. This latter value is consistent with the degree of openness seen in Figure 1 in the late 1990s prior to the acceleration of Chinese trade. This moment is most informative about the initial trade cost.

- **Trade volumes post China’s rise.** Along the transition path, we target an import to GDP ratio of seventeen percent seven years after the change in policy. This latter value is consistent with the degree of openness seen in Figure 1 in 2007. This moment is most informative about the final trade cost.

- **Aggregate trade elasticity.** We want ensure that the model has an aggregate trade elasticity of \(-4\). What this calibration strategy insures is that our model will have similar aggregate responses in output and trade as in an Eaton and Kortum (2002) model (or a broader class of models per the insight of Arkolakis, Costinot, and Rodríguez-Clare (2012)). This moment is most informative about the volatility of world prices, \(\sigma_w\). This may seem odd, but read on. The insight here is that variation in world prices determines how elas-
tic aggregate trade flows are to a change in trade frictions. For example, if world prices are very dispersed, then large changes in trade frictions are necessary to generate large changes in trade flows. In contrast, if if there is little variation in world prices, then small changes in trade frictions will generate large changes in trade flows. This insight is analogous to the behavior of the Eaton and Kortum (2002) model where the extent of technology heterogeneity controls how elastic trade flows are to changes in trade costs.

- **Wage and labor force participation elasticity from Autor, Dorn, and Hanson (2013).** Specifically, we target the elasticities described in Table 1. These moments are most informative about \( \theta \) and \( w_h \). The logic about the relationship between the Autor, Dorn, and Hanson’s (2013) wage elasticity result and \( \theta \) and follows from the discussion in 4, that is the elasticity of wages to changes in trade exposure is related to demand elasticity.

The home production parameter \( w_h \) is related to the labor force participation elasticity of Autor, Dorn, and Hanson (2013). The idea is that home production controls the opportunity cost of working in the market and, thus, it controls how households substitute in and out of the labor force in response to shocks. Given that Autor, Dorn, and Hanson (2013) have identified the elasticity of labor supply to a trade shock, this will inform our home production parameter.

### 5.3. Implementing the China Shock

We focus on two shocks. As alluded to above, we are thinking about a change in the ability to import goods, i.e., a reduction in \( \tau_{im} \). Mechanically, we implement the shock in the following way to generate the gradual rise in trade and to mimic the narrative around the change trade policy with China’s accession to the WTO. In year one, the change in trade costs is announced, but implementation is not immediate. Two periods later, the trade cost begins to linearly decrease from \( \tau_{im} \) to \( \tau'_{im} \) over five years. As mentioned above, the exact level of \( \tau'_{im} \) is chosen so that after seven years from announcement, imports to GDP resemble that seen in the US in 2007.

The second shock that we entertain is a “global savings glut” type shock (see, e.g., Bernanke (2005)) that reduces the world real interest rate \( R \). This will change the ability/desire of households to trade intertemporal. In year one, we lower the real interest rate so that \( R - 1 \) decreases by 200 basis points permanently. Immediately during the rapid rise in Chinese trade during the early 2000s, short-term real interest rates fell by 400 basis points. To be conservative, we change the real interest rate by only half this amount.

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\(^{6}\)Future versions will target the out-migration from trade exposed areas which is inconsistent with the evidence in Autor, Dorn, and Hanson (2013).
5.4. The Calibration Procedure

To implement the calibration procedure, we work through the following steps. Much of this is done in a simultaneous manner, but we describe the core steps to facilitate how we map our model into the data.

**Step 1.** Guess the parameters $\theta$, $w_h$, $\sigma_w$.

**Step 2.** We pick the parameters $\{B, \bar{a}, m, \tau_{im}\}$ so that the initial stationary equilibrium (pre-China shock period) replicates the labor force participation rate, migration rate, net worth of households, and the initial volume of trade.

**Step 3.** We pick the parameter $\tau_{im}'$ and then compute the new stationary equilibrium. We compute the transition path. That is starting from the initial stationary distribution we change the trade friction (and depending upon the exercise the real interest rate) and compute the transition path to the new stationary distribution. The trade friction is changed with perfectly foreseen, linear decreases from $\tau_{im}$ to $\tau_{im}'$. We then check two things: that seven years after the change, the volume of trade equals seventeen percent, and second that the aggregate trade elasticity implied by the model is consistent with our target.

**Step 4.** Given the transition path, we simulate data sets analogous to those in Autor, Dorn, and Hanson (2013) and estimate the wage and labor force participation elasticities with respect to the trade exposure metric. by constructing data analogs in our model as they are constructed in Autor, Dorn, and Hanson (2013) and estimate (2) on model generated data with a time effect and using a simulated trade flows for another country as an instrument.

Given the difference between the model and data elasticities, return to **Step 1.** and update the parameters $\theta$, $w_h$, $\sigma_w$

5.5. The Calibration Results

Table 3 reports the calibration results. There are a couple of points to mention. First, the last two rows of (3) illustrate that our model is able to match the micro-moments from Autor, Dorn, and Hanson (2013) exactly. Our interpretation of this is that moments are informative about parameters that underly and govern the data generating process.

The second point to note is that the estimated demand elasticity ($\theta$) is relatively high around at 11. The reason follows from the discussion in 4: elasticity of wages to changes in trade exposure is related to one over the demand elasticity. So if the demand elasticity is high, then changes in trade exposure will not pass-through strongly into wages. Hence, what this is telling us vis-a-vis the Autor, Dorn, and Hanson (2013) evidence, is that pass-through was not that strong.

Finally, Figure 5 plots the implied response of the model for imports. The initial jump comes
Table 3: Calibrated Parameter Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Data Moment/Notes</th>
<th>Model Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disutility of work, $B$</td>
<td>0.88</td>
<td>Aggregate participation rate, 66%</td>
<td>66%</td>
</tr>
<tr>
<td>Migration Cost, $m$</td>
<td>0.76</td>
<td>Cross cmz. migration rate, 3%</td>
<td>3%</td>
</tr>
<tr>
<td>Borrowing Limit, $-\bar{a}$</td>
<td>0.25</td>
<td>households with $\leq 0$ net worth, 40%</td>
<td>40%</td>
</tr>
<tr>
<td>Pre-China Trade Cost ($\tau_{ex}, \tau_{im}$)</td>
<td>1.37</td>
<td>1990s Imports/GDP, 13%</td>
<td>13%</td>
</tr>
<tr>
<td>Post-China Trade Cost ($\tau'_{im}$)</td>
<td>1.37</td>
<td>2007 Imports/GDP, 17%</td>
<td>16%</td>
</tr>
<tr>
<td>Std. Dv. of $p_w$ ($\sigma_w$)</td>
<td>$2.5\times\sigma_z$</td>
<td>Aggregate trade elasticity, 4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Demand Elasticity $\theta$</td>
<td>10.97</td>
<td>IPW on $\Delta$ Labor Earnings, -4.30</td>
<td>-4.30</td>
</tr>
<tr>
<td>Home production $w_h$</td>
<td>0.42</td>
<td>IPW on $\Delta$ NILF, 1.11</td>
<td>1.11</td>
</tr>
</tbody>
</table>

from the change in the real interest rate and it’s lining up with the data is pure accident. Given the changes in trade costs and interest rates that generates this rise in trade exposure, we now turn to analyzing the aggregate and welfare consequences of this shock.

6. The China Shock

This section analyzes the China shock.

6.0.A. Aggregate Outcomes

The top panel of Figure 6 illustrates the behavior of aggregate consumption and labor supply. In response to the China Shock, aggregate consumption rises by a large margin—nearly three percent within the first two years. The blue dashed line reports the change in labor supply. Here, labor supply initially falls, but then increases by a similar amount to the rise in consumption. In sum, the aggregate effects of the China Shock created a boom in the economy.

The bottom panel of Figure 6 illustrates this point by reporting the percentage point change in the trade deficit relative to the initial stationary distribution.\(^7\) Immediately after the trade shock the deficit declines by nearly two percentage points. This is nearly half of the actual

\(^7\)The level of the deficit is off in the model as the economy runs a surplus. This is to be expected as we are abstracting from investment and government spending.
The consumption boom and deterioration of the trade deficit are intimately related. This can be understood through the identity that the trade deficit equals the consumption minus savings. A decline in the real interest rate reduces savings and increases consumption today as assets become a less attractive store of value. This simple logic implies that the trade deficit must deteriorate in response. It can also be understood from the standpoint that the trade deficit equals exports minus imports. A consumption boom leads to an increase the demand for all goods (foreign and those domestically produced), thus imports increase—this is the jump in imports seen in Figure 5. Moreover given that production is essentially fixed in the short-run, an increase domestic consumption leads to an decrease in exports as product stays home rather than abroad. Thus, imports increase, exports decrease and the trade deficit deteriorates.

The important, driving force behind these results is the global savings glut type shock. To illustrate this point, we held all parameters fixed and fed into the model only the change the trade costs. Figure 7 illustrates the results.

The distinguishing feature of the trade cost only shock is that the consumption boom is very
Figure 6: Model: Consumption, Labor Supply, and Trade Imbalance
mild, its driven almost completely by increases in labor supply, and hence, there is essentially no response in the trade deficit.

What this suggests is that from an aggregate standpoint, a key issue is how the trade deficit is responding. If the China shock is both an expansion of static and intertemporal trade, then their arrival on the world seen lead to a massive boom. If on the other hand, it is merely about trade, then the aggregate effects are much more modest.

One question is about the role that the micro-evidence of Autor, Dorn, and Hanson (2013) plays in shaping these results. Our answer is speculative, but informed by previous calibrations. As discussed, the Autor, Dorn, and Hanson (2013) evidence informs the pass-through of trade shocks into labor earnings. When there is a large pass-through, this corresponds with the situation in which trade leads to large increase in the volatility of income (see, e.g. Krishna and Senses (2014) for evidence on this point). If this response is strong enough (this would correspond with a lower $\theta$), precautionary savings motives kick in and can result in a reduction in aggregate consumption and an increase in trade surpluses as savings demands rise.

### 6.1. Welfare

There is an interesting contrast between results in Figure (6) and the results of Table 1—which our model matches. In the baseline shock case, the economy is experiencing a boom with a dramatic rise in aggregate consumption and employment. Yet, Table 1 paints a dire picture of the economy. Consistent with the narrative put forth at the beginning of the paper, it appears that the China Shock wreaked havoc on labor market. How does this all add up in terms of welfare?

We compute welfare gains or loses as lifetime consumption equivalents, including the transition. That is the permanent increase in consumption that a household must receive to being made indifferent between living in the world prior to the shock and after.

Table 4 reports the welfare effects from the China Shock. Figure 8 provides a visualization of the welfare gains by island type and their trade exposure. The average welfare gains is reported in the first row. This is computed by integrating individual value functions across asset holdings and states and computing the consumption equivalent for the “average” individual. We find these are a bit more than half a percentage point in consumption equivalents. These average gains are not inconsistent with Arkolakis, Costinot, and Rodríguez-Clare (2012). Output per worker in our model increases by a bit more than two percent; simply using their formula and a trade elasticity of four gives a similar aggregate welfare gain.

As expected, the average value hides a lot of heterogeneity. The last three rows of Table 4 report the gains associated with initial condition of trade exposure and in brackets the fraction of the population that is classified as such. Five percent of the population was initially import exposed
Figure 7: Model: Consumption and Labor Supply
and they experienced meaningful welfare losses, almost -0.35 percent. In contrast, twenty percent of the population was initially export exposed and they experienced large welfare gains on the order of one percent. An interesting aspect is how those initially in non-trade exposed areas experienced large gains. This is purely through general equilibrium effects. This appears largely coming from the consumption boom induced by the shock. As equation 31 shows, a rise in aggregate consumption feeds into wages across all islands—including those that are not trade exposed.

The second column of Table 4 reports the \( \tau \) only shock. Here the average gains from trade are of the same order of magnitude. However, the extant of heterogeneity in gains far larger. The initially exposed loose almost 50 percent more, non-traded are similar, and then the export exposed gain much more; Figure 8 illustrates this point well. The comparison between the first and second column of Table 4 is interesting because of the stark differences in aggregate outcomes. In the first case, the China Shock led to a deteriorating trade deficit, yet a consumption boom. This manifests itself in larger welfare gains and those that do loose lose less than they would relative to a standard trade cost shock. This last observation suggests that the traditional view of the trade deficit are not warranted. If anything, the expansion of the trade deficit appears to have helped smooth out and spread the gains from trade.
Figure 8: Welfare
7. Conclusion

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.

Lots more work todo!
References


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.

\[ Y = \int_w w(s)\mu(s) \]  

Examining (28) and (33) allows us to connect aggregate income with consumption. Specifically, by integrating over the consumers budget constraint (ignoring home production), then noting how total value added must equal wages, one can substitute (33) into (28), then we arrive at the following:

\[ Y = C - RA + A' + \int_a \int_s m_{it}(s, a)\lambda(s, a) \]  

so aggregate income equals consumption (private and public) minus (i) returns on assets (ii) new purchases of assets (iii) plus moving costs.

This basically says that income/production must equal consumption net of income not associated with production (i.e. returns on assets) 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 \((A' < 0)\).

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

\[ Y = \int_p p(s)\mu(s) \]  

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 (19), imports in (21) and exports in (23) and
the equating final demand with consumption we have

\[ Y = C + \int_s p(s) \text{exports}(s) - \int_s p(s) \text{imports}(s). \]  

(36)

Or GDP equals consumption (market) 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 (34) and (36) we get the following relationship

\[ Y - C = \int_s p(s) \text{exports}(s) - \int_s p(s) \text{imports}(s), \]  

(37)

\[ = - rA + (A' - A) + \int_a \int_s m^m(s, a) \lambda(s, a), \]

where \( r \) is the net real interest rate. This relationship says the following: aggregate savings equals the trade imbalance. And this, in turn, we can connect the trade balance with the savings decisions of the households. That is the trade balance equals payments on net asset holdings plus net change in asset holdings (adjusted for moving costs). 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) 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

\[ Y - C = \int_s p(s) \text{exports}(s) - \int_s p(s) \text{imports}(s) = - rA + (A' - A). \]  

(38)

Here if exports are greater than imports, then this implies that the households are doing several things. The trade surplus may reflect that households (on net) are making debt payments (\( rA \) is negative). Second, the trade surplus may reflect that the households (on net) are acquiring foreign assets (\( A' - A \) 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.