A Tale of Two Recessions: Decomposing Trade Patterns During the Pandemic and the Financial Crisis

Paul Phillips

University of Minnesota Twin Cities

January 11, 2022

Click here to see most recent version

Abstract: I construct a multi-sector dynamic general equilibrium model of trade between the United States and the rest of the world to investigate why the pandemic affected services trade more adversely than goods trade, in contrast to trade patterns during and after the 2008 financial crisis. Different parameters in the model represent the different channels through which trade would have reacted to the two recessions. I calibrate parameter values to match trade and gross output data, and primary results come from holding a subset of these parameters constant and observing how closely the resultant trade patterns match the data. I find that trade frictions play the biggest role in explaining services trade; decreasing costs of conducting trade in services helped prevent losses in services trade during the financial crisis, while increasing trade frictions decimated services trade during the pandemic. A decline in consumer preferences for goods drove the losses in goods trade during the financial crisis, while the absence of such a decline limited the losses in goods trade during the pandemic. A brief analysis of consumer welfare suggests that policymakers concerned about a pandemic-like situation should focus on reducing barriers to trade rather than stimulating demand.

1 Introduction

An examination plot of trade in goods and services over the past twenty years reveals some striking observations. During the financial crisis, trade in goods fell sharply, while trade in services suffered a much slighter decline. The combined imports and exports of goods fell by 23%, while that of nondurables fell by seven percent. During the recession driven by the coronavirus pandemic, trade in goods and trade in services both fell, but trade in *services* was much more negatively affected[1]. In this paper, I ask why trade in goods and services behaved so differently after the two recessions, and what factors could have motivated the different trade patterns.

The answer to this question has important macroeconomic implications. First, trade in services has increased rapidly over the past two decades (FRED), and the extant trade literature has not given it a lot of attention, often simply assuming that services are non–traded. Learning what factors drive trade in services would provide invaluable insight into a rapidly growing phenomenon. Furthermore, an analysis of trade can provide some clarity on our present economic circumstances and inform policy decisions. For example, if a post–pandemic fall in services trade was driven entirely by lockdowns, policymakers should be especially desirous to avoid using lockdowns in the future. If pandemic measures played a relatively small role compared to consumer tastes, then policymakers need not be as restrained when consider lockdowns and might want to consider other measures to stimulate demand.

The easiest explanation for recent trade patterns is that lockdowns and border closures made trade in services virtually impossible to conduct, while having a weaker effect upon trade in goods. About ten percent of trade in services comes from tourism, for example, and U.S. tourism imports fell by ninety percent in the second quarter of 2020 (Census Bureau). However, trade in services still has not fully recovered even with the lifting of pandemic restrictions, and this explanation does not provide a holistic view of why 2020 would have been so different from 2008, when governments did not impose pandemic restrictions of any sort. Myriad other factors at play include consumer tastes, an increased reluctance to work in some sectors as opposed to others, and the difficulty of investing in durable goods. Descriptive evidence supports the role each of these factors could have played in trade behavior, but endogeneity issues make disentangling these roles a difficult task. For example, consumers might have lowered their expenditure in a certain sector as a result of a decline in trade, rather than a decrease in consumer tastes causing trade to decrease. There is also a possibility that both a decline in consumption expenditure and a decline in trade could be explained by a third factor, such as pandemic–induced trade frictions.

Because the factors explaining patterns in trade are difficult to disentangle, a structural model can provide

[1]Data comes from the Federal Reserve Economic Database

useful assistance in determining what causes what. I construct a dynamic trade model with two countries and a representative consumer in each country. Goods and services sectors are broken down into two more sectors–durables and nondurables, in–person and remote services respectively–to represent the differential response that various types of goods and services had to economic shocks. Production occurs in a roundabout fashion, and the representative consumer will have preferences over both labor and leisure. Important dynamics come from the consumer's disutility of labor preference in each sector and the preferences placed on each sector when consuming, in addition to iceberg trade costs and productivity. I infer the effect each factor had on goods and services trade by holding various subsets of factors constant and observing how closely the resultant trade time series align with the time series observed in the data. For example, if trade in the absence of changes in trade frictions behaves differently from trade in the data, one could infer that those trade frictions play a large role in explaining trade movements.

Preliminary results indicate that trade frictions play the biggest role in explaining trade movement for goods, while consumer tastes and the disutility of labor play the biggest role in explaining trade patterns during the financial crisis.

1.1 Literature Review

This paper complements scholarship on the decline in trade after the 2008 recession, a decline disproportionate to the decline in GDP. Bems, Johnson, and Yi (2013) survey this literature, concluding that a collapse in aggregate expenditure on trade–intensive durable goods was the main driver of the trade collapse, followed by shocks to credit supply. Eaton, Kortum, Neiman and Romalis (2016) use a structural model to counterfactually decompose recession–era trade by the factors that could have caused it. Levchenko, Lewis and Tesar (2009) take a more reduced–form approach, using disaggregated U.S. trade and production data to evaluate various explanations for the recessionary trade decline. Other papers that examine the influence of financial frictions on the trade collapse are Amiti and Weinstein (2011), Chor and Manova (2012) and Paravisini et al. (2012), and other papers focusing primarily on expenditure effects are Bems, Johnson, and Yi (2010, 2011) and Bussière et al. (2013). Kee et al. (2013) and Gawande, Hoekman and Cui (2011) take a look at post–recessionary protectionsim, concluding that since most countries liberalized trade during the crisis, protectionism does not satisfactorily explain any declines in trade during the Great Recession. I will expand this analysis to the more recent economic downturn and determine what factors would have behaved differently in 2008 compared to 2020. Furthermore, many of these papers do not discuss the difference between trade in goods and services, often simply assuming that services are non–traded. I add to the trade literature by building a model that explicitly incorporates services and making a comparison between the factors contributing to goods trade and the factors contributing to services trade.

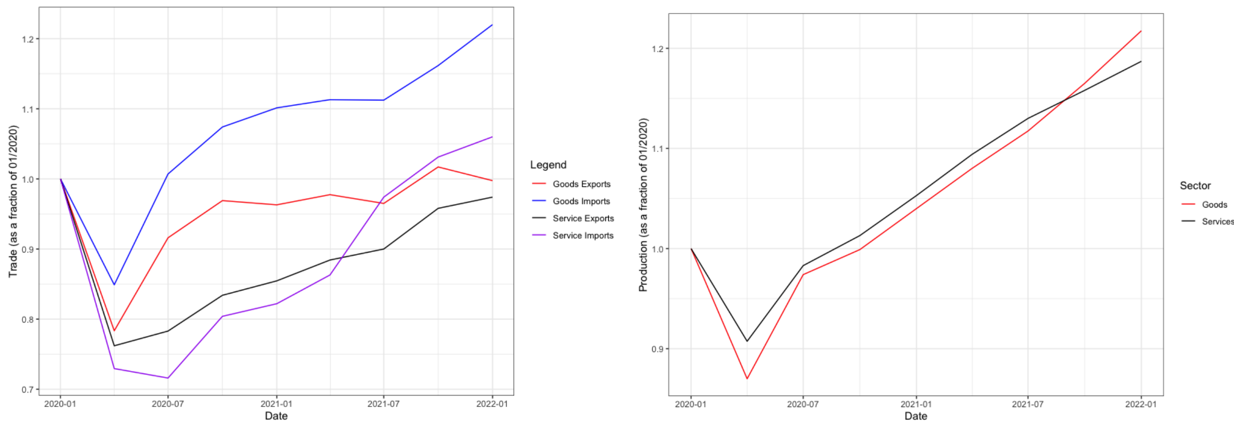
My research also contributes to a more recent body of research on how the pandemic disrupted supply chains. Jiang, Rigobon and Rigobon (2021) use a stylized model of a supply chain to find that in the presence of substantial supply uncertainty, multinational firms choose to orient their supply chains in a manner that is not optimal for each individual producer but minimizes the possibility of supply disruptions. Data–driven papers on supply chain disruptions include Bonadio, Huo, Levchenko, and Pandalai–Nayar (2021), which looks at supply chains among sixty–four countries, and Meier and Pinto (2020), which shows that sectors that were more exposed to Chinese intermediate goods imports suffered larger contractions in production and trade during the pandemic. Other papers, such as Cavallo and Kryvtsov (2021), Santacreu and LaBelle (2021), and Ha, Kose and Ohnsorge (2021) focus more on how supply chain disruptions contributed to inflation. My paper does not directly discuss supply chains or inflation, but by using a roundabout production structure to explain why trade fell in certain sectors more than others, we gain a better understanding of *why* supply chains broke down and derive policy implications from that understanding.

An extensive body of structural literature before the pandemic also focused on global value chains. My model framework borrows heavily from Alessandria, Kaboski, and Midrigan (2012), a paper that uses inventories to explain trade wedges between standard models and the data. Zhou (2021), Carreras–Valle (2022), and Lee and Yi (2018) also analyze global value chains in the context of external shocks such as trade wars or storage uncertainty.

The rest of the paper proceeds as follows. Section 2 introduces stylized facts behind goods and services trade in the 2008 and 2020 recessions, as well descriptive evidence of what factors might have driven them. Section 3 introduces the model. Section 4 explains how I calibrated and estimated the model, while Section 5 displays results. Section 6 concludes.

2 Descriptive Statistics

Figure 1a) shows that while both goods trade and services trade declined substantially in 2020, goods trade fell to eighty to eighty–five percent of its pre–pandemic value while services trade fell to seventy–five percent of its pre–pandemic value. Furthermore, goods trade has since recovered to its pre–pandemic level, while services trade has not. However, Figure 1b) shows that this post-pandemic pattern in trade does not follow a similar pattern in output. Gross output in the U.S. displayed a slightly *lower* proportional decline for services than for goods, with services only decreasing by less than ten percent between Q1 2020 and Q2 2020 and goods decreasing by about thirteen percent. These observations suggest that there must exist some factor unique to trade that does not apply to the economy as a whole.



(a) U.S. Trade since 2020

(b) U.S. Production since 2020

Figure 1: Pandemic–Era Production and Trade

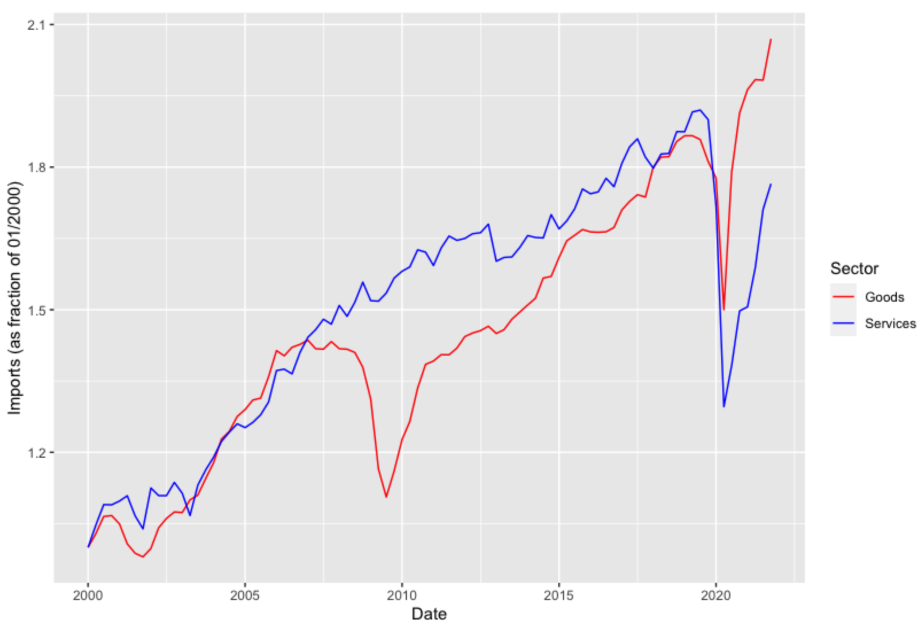


Figure 2: U.S. Imports since 2000

As shown in Figure 2, goods and services also display quite different trade patterns in the two major financial crises that have occurred in the past twenty years. While service imports were virtually unaffected by the 2008 financial crisis, goods imports dropped from around 140% of their 2000 levels to 110%. This statistic provides a clear contrast with goods and services trade in the past couple of years.

I consider four major explanations for why trade behaved in this manner:

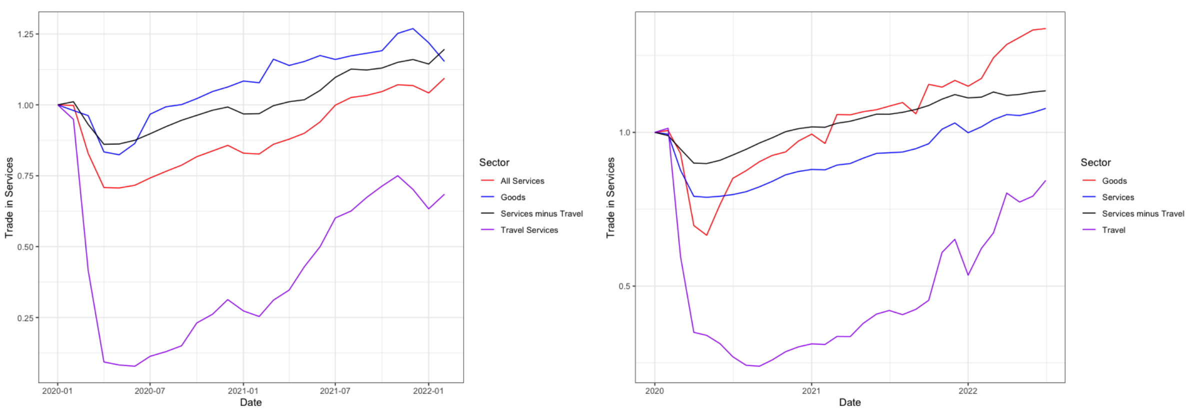
1. The pandemic introduced new frictions to trade that affected services more adversely than goods. These frictions were not present during the financial crisis.

2. Consumers' tastes shifted from goods to services during the financial crisis, and from services to goods during the pandemic.

3. Either the financial crisis or the pandemic altered the productivity of investing in durable goods, a heavily traded sector.

4. The disutility of labor rose for employees in service sectors during the pandemic, and for employees in goods sectors during the financial crisis.

Throughout the remainder of this section, I will introduce some descriptive evidence supporting each of these explanations.



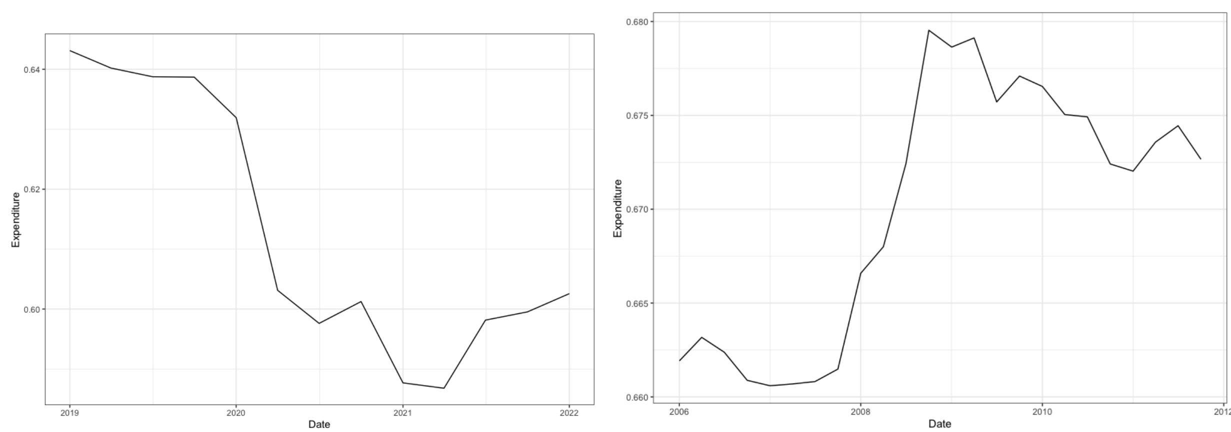
(a) Imports

(b) Exports

Figure 3: Services by Industry

The perhaps most obvious explanation for recent trade patterns is that pandemic–era policies such as border closures and lockdowns increased trade frictions, rendering several types of service trade virtually impossible. At the start of the pandemic, most countries, including the United States, closed their borders and shut down normal business operations. These measures would affect both goods and services trade, but goods trade could continue, albeit with substantial frictions, while some types of services trade such as tourism or transportation services would disappear almost entirely. We observe this phenomenon in Figure 3; while aggregate services declined by eighteen percent between January 2020 and April 2020, travel services (synonymous with tourism) fell by almost a hundred percent. Meanwhile, services without travel services declined by less than goods did. However, while the initial (likely pandemic–induced) drop was more severe for goods than services without travel, service imports and exports have still had a slower recovery than goods imports and exports. Furthermore, travel services have still not recovered to their pre–pandemic levels even after countries re–opened, suggesting that some other force is at work than people simply not being able to conduct services trade. Did trade in travel services plummet because agents *couldn't* conduct trade in services, or did trade in services fall because they, for multiple potential reasons, chose not to?

One final observation is that no external shock of this nature occurred during the financial crisis, so border closures and lockdowns cannot provide a full account of the contrast in trade patterns between the 2008 and 2020 recessions.



(a) Pandemic (b) Financial Crisis

Figure 4: Services as Fraction of Total Expenditure

Figure 4 supports an "expenditure" explanation for patterns in trade. Bems et al. (2013) and Eaton et al. (2016) document that during the 2008 recession consumer demand for investment in durable goods fell, and since durable goods are heavily traded, this fall in demand drove caused goods trade to plummet. Figure 4b) corroborates this story by showing that consumer expenditure on services as a fraction of total consumer expenditure rose by around two percentage points during the financial crisis before tapering off, and Figure 4a) shows that the fraction of expenditure spent on services *fell* by about five percentage points between the first quarter of 2019 and the first quarter of 2021. Because the consumption of in–person services presented an especially high risk of contracting the coronavirus, agents might have shifted their preferences from services to goods after the shock of the pandemic hit, and they might have been particularly unwilling to consume foreign services. Consumer expenditure on services therefore mimics the behavior of trade in services during both recessions. However, Figure 4 only shows a correlation between consumer preferences and imports, not a causation, and alternative explanations are plausible. Perhaps consumers spent less of their income on services because a fall in trade restricted the amount of services they could consume, and this fall in trade occurred for some other reason such as trade frictions.

Another important consideration comes from the nature of consumer spending on durable goods, which are notable because consumer spending on durable goods constitutes an investment rather than a static transaction. Did the documented decline in durable goods spending during the financial crisis occur because consumers' preferences for investment in durable goods fell, or because investing in durable goods became less productive? To address this issue, I include in my model a parameter representing the productivity of investment in durable goods as well as a parameter representing preferences for durable goods.

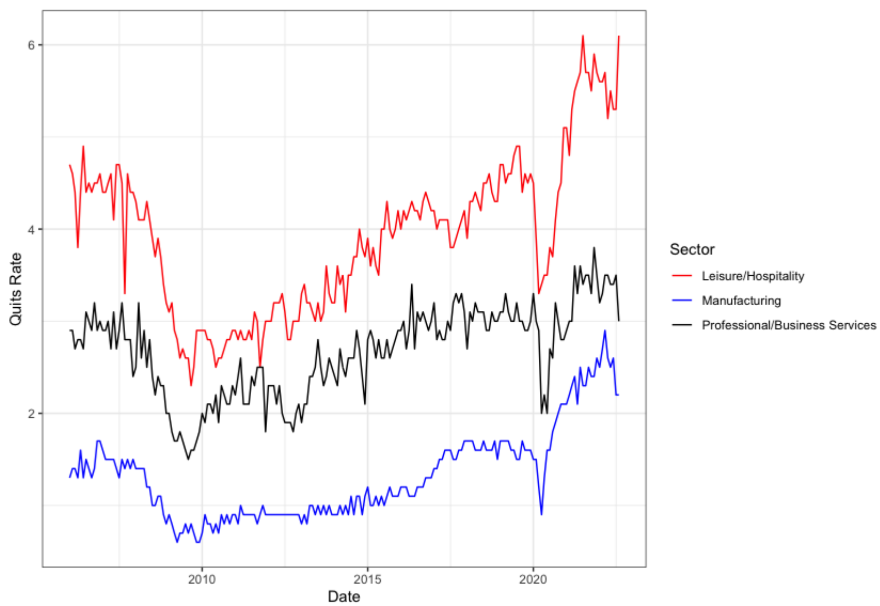


Figure 5: Quits Rate in Selected Industries

The second consumer choice explanation for a fall in services trade is complementary to the first, and concerns agents' preferences for which sectors to work in. Figure 5 shows the quits rate for selected industries, where the quits rate is the number of job resignations per month as a percentage of total employment. The quits rate, while higher in general for service industries than for manufacturing, fell more steeply for service industries during the Great Recession, and the quits rate in service industries that rely on face–to–face contact has skyrocketed since the pandemic. If Americans in trade–exposed service industries left the labor force at high rates, this "Great Resignation" could negatively affect U.S. service exports, and by a similar logic a high quits rates among foreign service workers would negatively affect U.S. imports. Just like consumer preferences, this relationship suffers from strong endogeneity concerns. If trade in services falls during the pandemic for some other reason, employment in trade–exposed sectors would decline. Moreover, other factors such as consumer expenditure or trade frictions could lead to both a higher quits rate among service workers and a decline in services trade.

The stylized facts presented in this section indicate multiple possible explanations for why services trade declined more during the pandemic and goods trade declined more than services trade during the financial crisis. It is not clear which explanation dominates the others, and determining causality can be difficult. A structural model can therefore provide some invaluable clarity in disentangling the precise contribution that each effect has on recessionary trade patterns, and I turn next to the elaboration of such a model.

3 Model

The model is dynamic and consists of a representative consumer in two countries, corresponding to the United States and the rest of the world.[2] There are four sectors: durable goods, nondurable goods, in–person services, and remote services. Remote services include activities like financial services or information technology that can be produced remotely, while in–person services are services like hospitality or tourism that cannot. The representative consumer allocates their time in each of these sectors between labor and leisure[3]. Firms produce goods and services using a roundabout production method where one of the inputs is a composite intermediate good made with final output from all four sectors.

3.1 Production

A continuum of producers in country i, sector s at time t will use labor and a composite intermediate to produce output with the following Cobb–Douglas formulation

$$X_{ist} = A_{is}(m_{ist})^{\sigma_{is}}(l_{ist})^{1-\sigma_{is}}$$

where our Cobb–Douglas parameter varies across countries and across time. m_{ist} is a composite intermediate comprised of final production from all four sectors, reflecting the fact that services are often needed to produce goods and vice versa. As a function of inputs from all four sectors, m_{ist} is given by

$$m_{ist} = \prod_{n=1}^{4} \left(\frac{m_{inst}}{\mu_{ins}}\right)^{\mu_{ins}}$$

[2]The "rest of the world" here refers to the U.S.'s top twenty trade partners. I exclude Vietnam and Malaysia, for which I could not find data, and include Indonesia.

[3]I could also have set up the model using a constant total stock of time, which must be divided between labor in all four sectors and leisure. My current formulation is both more tractable and means that the total potential amount of labor–hours in each sector is constant over time, a more realistic assumption than completely flexible total labor–hours because the composition of the workforce cannot drastically shift every quarter

where m_{inst} is some amount of final output in sector n that will go into the production of sector s.The market is perfectly competitive, so producers have the profit function

$$\pi_{ist} = p_{ist}X_{ist} - \sum_{n=1}^{4} p_{int}m_{inst} - w_{ist}l_{ist}$$

taking prices and wages as given.

3.2 Aggregation

Each country has one representative consumer. This consumer in each country takes in both imported goods and home–produced goods in every sector. They then aggregate the goods to form a composite that will either be consumed or recycled as an intermediate in production. The below function gives US aggregation, and aggregation in the ROW would be defined similarly.

$$y_{Hst} = \omega_{is}\big(\Omega_{Hs}y_{HHst}^{\frac{\gamma-1}{\gamma}} + (1-\Omega_{Hs})(\frac{y_{FHst}}{\tau_{st}})^{\frac{\gamma-1}{\gamma}}\big)^{\frac{\gamma}{\gamma-1}} \tag{1}$$

This aggregation uses a CES technology to combine home goods, denoted by H, and foreign goods, denoted by F. y_{HHst} refers to goods produced in the US and consumed in the US, and y_{FHst} refers to goods produced abroad and sent to the US for ultimate consumption. This CES technology is governed by elasticity parameter γ and iceberg transportation costs τ_{st}, the latter of which I will calibrate so that y_{HHst} and y_{FHst} match production and export values in the data. Trade costs are assumed to be symmetric. ω_{is} and Ω_{is} are utility weights, calibrated so that prices in some base period are one. The aggregated y_{ist} is either consumed/invested or recycled as an intermediate input in one of the four sectors.

3.3 Consumption

The representative consumer in country i chooses their consumption, labor, and leisure to maximize their utility:

$$U_{ist} = \sum_{t=0}^{\infty} \beta^t \big[\big(c_{it}^{\frac{\theta-1}{\theta}} + \sum_{s=1}^{4}(H_{ist} - \phi_{ist}h_{ist})^{\frac{\theta-1}{\theta}}\big)\big] \ \forall t$$

$$c_{it} = \prod_{s=1}^{4}(\frac{c_{ist}}{\eta_{ist}})^{\eta_{ist}}, \ \sum_{i=1}^{4}\eta_{ist} = 1$$

The consumer has a certain stock H_{is} of time available for each sector, and they must decide to allocate that time either to leisure or to working. ϕ_{ist} determines the consumer's disutility of labor in sector s; since there is one representative consumer, we may also interpret this parameter as governing agents' preferences for where to work.

Sector 1 here is durable goods, which accumulate over time. Durable goods build up according to the accumulation equation

$$k_{i,t+1} = \chi_{it} c_{i1t}^{\alpha} k_{it}^{1-\alpha} + (1-\delta) k_{it} \tag{2}$$

In other words, the stock of durable goods next period is equal to un–depreciated durable goods from this period in addition to a Cobb–Douglas function of investment (c_{i1t}) and the durable goods stock this period. χ_{it} governs the efficiency of investment, α governs adjustment costs, and δ is the depreciation rate. Consumers have perfect foresight when making their investment decisions.
The consumer's budget constraint is

$$\sum_{s=1}^{4} p_{ist} c_{ist} \leq \sum_{s=1}^{4} w_{ist} h_{ist} + E_{it} \tag{3}$$

where E_{it} is a lump-sum payment from the representative consumer of one country to another equivalent to the value of the trade deficit.

3.4 Equilibrium

A competitive equilibrium in this economy consists of the following:

- Consumers maximize utility subject to their budget constraint.
- Firms maximize profit.
- Final good markets clear:

$$y_{ist} = \sum_{n=1}^{4} m_{inst} + c_{ist} \ \forall s \tag{4}$$

Equation (4) states that durable goods aggregates in country i will either be invested or recycled as intermediate goods to be used in production. Aggregates in all other sectors will be either consumed or recycled as intermediate goods.

- Input market clears:

$$X_{ist} = y_{iHst} + y_{iFst} \ \forall i \ \forall s \ \forall t \tag{5}$$

(5) states that production in country i is either consumed in country i or sent abroad as an export.

- Labor market clears:

$$l_{ist} = h_{ist} \ \forall i \ \forall s \ \forall t$$

3.5 Equilibrium Conditions

Here, I will lay out all the equilibrium conditions that will be used in calibration and estimation. The conditions are broken down by the part of the model to which they belong.

3.5.1 Firms

Firms maximize profit over the composite intermediate good and labor, so with the Cobb–Douglas production function we get two first–order conditions and a price index.

$$P^f_{ist} = A_{is} p_{ist} \sigma_{is} m_{ist}^{\sigma_{is}-1} l_{ist}^{1-\sigma_{is}} \tag{6}$$

$$w_{ist} = A_{is}(1-\sigma_{is}) p_{ist} m_{ist}^{\sigma_{is}} l_{ist}^{-\sigma_{is}} \tag{7}$$

$$P_{int} m_{inst} = \mu_{int} P^f_{ist} m_{ist} \tag{8}$$

$$P^f_{ist} = \prod_{n=1}^{4} P_{int}^{\mu_{int}} \tag{9}$$

where P^f_{ist} is the composite price index paid by the firm in sector s for intermediate goods.

3.5.2 Aggregation by Origin

Consumers use a CES function to combine home and foreign goods. We can set this up as a cost minimization problem as in Alessandria et al. (2012):

$$\begin{aligned}
\min_{y_{Hist}, y_{Fist}} \quad & p_{Hst} y_{Hist} + p_{Fst} y_{Fist} \\
\text{s.t.} \quad & y_{ist} = \omega_{is} \big(\Omega_{Hs} y_{HHst}^{\frac{\gamma-1}{\gamma}} + (1-\Omega_{Hs})(\frac{y_{FHst}}{\tau_{st}})^{\frac{\gamma-1}{\gamma}}\big)^{\frac{\gamma}{\gamma-1}} \geq \overline{Y} \\
& y_{Hist}, y_{Fist} \ \geq 0
\end{aligned}$$

where $\overline{Y}$ is some arbitrary minimal level of production. The first–order conditions from this problem give us

$$y_{Hist} = \big(\frac{\Omega_{is} p_{Fst}}{p_{Hst}(1-\Omega_{Hs})}\big)^{\gamma} \tau^{\gamma-1} y_{Fist} \tag{10}$$

as well as a price index

$$P_{ist} = \frac{1}{\omega_{is}} \Big(\big(\frac{\Omega_{is}}{1-\Omega_{is}}\big)^{\gamma} P_{Hist}^{1-\gamma} + (\tau_{st} P_{Fist})^{1-\gamma} \Big)^{\frac{1}{1-\gamma}} \tag{11}$$

3.5.3 Consumers

At the level of aggregate consumption, the representative consumer has the FOC

$$\phi_{ist}(H_{st} - l_{ist})^{\frac{-1}{\theta}} = \frac{c_{it}^{\frac{-1}{\theta}}}{P_{it} w_{ist}} \ \forall s \tag{12}$$

where P_{it} is the aggregate price level across all sectors. This equation relates consumption to labor and leisure. Going down to the sector level, first–order conditions are

$$\eta_{ij't} P_{ijt} c_{ijt} = \eta_{ijt} P_{ij't} c_{ij't}, \ \ j, j' \in \{2, 3, 4\} \tag{13}$$

$$\frac{c_{it}\eta_{i2t}}{\beta c_{i2t}} \frac{P_{i1t}}{\chi_{it}\alpha(\frac{c_{i1t}}{k_{it}})^{\alpha-1}} = \big[(1-\delta) + (1-\alpha)\chi_{it+1}\big(\frac{c_{i1t+1}}{k_{it+1}}\big)^{\alpha}\big] \frac{P_{i1t+1}}{\chi_{it+1}(\frac{c_{i1t+1}}{k_{it+1}})^{\alpha-1}\alpha} \frac{c_{it+1}\eta_{i2t+1}}{c_{i2t+1}} + \frac{c_{it+1}\eta_{i1t+1}}{c_{i1t+1}} \tag{14}$$

If durable goods can't be stored across periods, then (14) goes away and all sectors would be described by (13). We can also write a price index for consumption: $P_{it} = \prod_{s=1}^{4} P_{ist}^{\eta_{ist}}$.

Finally, we have market clearing conditions for production and final goods (see Section 3.4) as well as the budget constraint. This completes our characterization of the equilibrium.

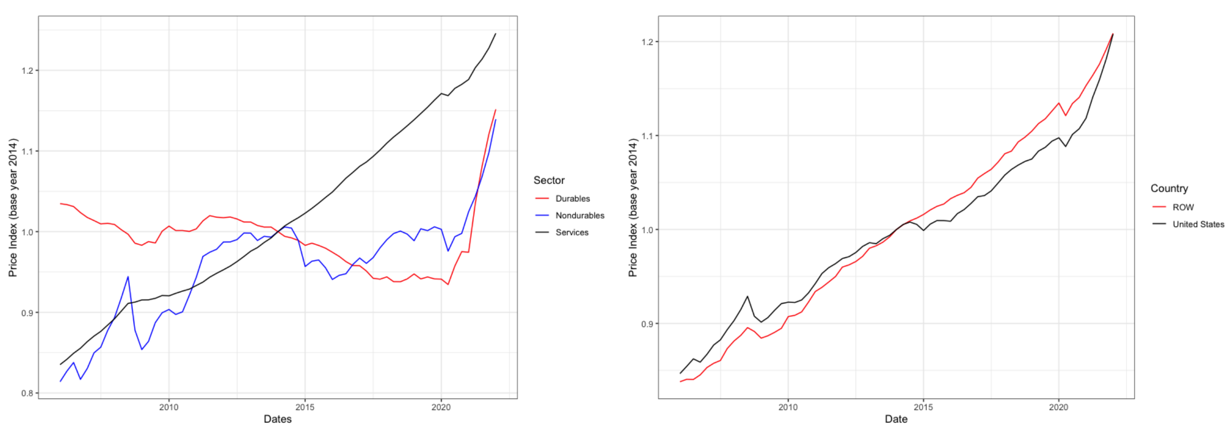
4 Calibration and Solving the Model

This section proceeds in three steps. First, I describe the data that I used to calibrate the model. The solution method then follows in two steps; I first find parameter values that allow my data to satisfy the equilibrium conditions detailed in section 3.5, and then I solve the model given those parameters to reverse–engineer the data. I can then consider various counterfactual equilibria to determine how factors in the model affected American trade.

4.1 Data

Each time period in the model corresponds to one quarter, and the two countries in the model correspond to the United States of America and the rest of the world (ROW). The ROW is an aggregation of around 20-30 countries in the U.S.'s top thirty trading partners, comprising about eighty percent of U.S. trade. I observe data on the value of U.S. imports and exports (ROW imports and exports are defined in reverse), the value of U.S. and ROW gross output, the value of U.S. and ROW durable goods investment, U.S. and ROW aggregate price levels, and U.S. price levels in durable goods, nondurable goods, and services[4]. All U.S. data comes from the Federal Reserve Economic Database, while sources for non–U.S. data are the OECD and Bloomberg [5].

Each allocation in the data corresponds to the *value* of that allocation in the model. For example, the data value for U.S. imports in durable goods is equal to $p_{F1t}y_{FH1t}$ in the model. I obtain values of $y_{HHst}p_{Hst}$ and $y_{FFst}p_{Fst}$–goods intended for domestic consumption–by subtracting the value of exports from the value of gross output for both regions. U.S. price indices, meanwhile, come from the sector–level consumer price index with Q1 2014 taken as the base period. To compute a price index for the ROW, I calculated the average of CPIs for all foreign countries in my sample during the relevant quarter, weighted by the amount of trade each country does with the United States.



(a) Sectoral U.S. price levels

(b) U.S. and ROW aggregate price levels

Figure 6: Price data

Figure 6 shows the U.S. price indices for durable goods, nondurable goods, and services over time. Durable goods show a steady decline in prices over the past sixteen years, while service prices show an even faster increase, reflecting increased expenditure demand for services and decreased demand for durables. Prices in

[4] I do not observe foreign price levels by sector, but by assuming symmetric trade costs I can calculate those price levels.
[5] See appendix for details on the construction of foreign output time series.

all three sectors have all shot up in recent months due to inflationary pressures.

4.2 Calibration

Table 1 displays an accounting of the parameters to which I assigned values externally, rather than computing values based on data and equilibrium conditions. These values come from Eaton et al. (2016).

Parameters	Interpretation	Value
θ	Consumption–leisure elasticity	.5
β	Discount factor	.987
α	Investment Cobb–Douglas	.5
δ	depreciation rate	.026
γ	elasticity	2

Table 1: Externally Calibrated Parameters

Table 2 displays an accounting of the parameters to which I do not assign values externally, along with the equations from the model that I use to calibrate them. The appendix goes into the equation–solving process in more detail.

Parameters	Interpretation	Calibration Strategy	
σ_{is}	Cobb–Douglas share for firms	World Input–Output Table	
μ_{ins}	Intermediate production shares	World Input–Output Table	
ω_{is}	CES multiplier in (1)	Base period trade	
Ω_{is}	CES weight in (1)	Base period trade	Time–invariant
A_{is}	productivity multiplier	wage FOC	
H_{is}	stock of time available	multiply labor in the first period by three	
η_{ijt}	consumer preference weights	(13) and data on inflation	
τ_{jt}	iceberg trade costs	trade equations (16)–(19)	
ϕ_{ijt}	disutility of labor	consumer FOC (12)	Time–variant
χ_{it}	productivity of investment in durable goods	inter–temporal equations (2), (14)	

Table 2: Externally Calibrated Parameters

I calibrate σ_{is} and μ_{ins} from the World Input–Output Table for 2014, taking advantage of the fact that the WIOT contains values for use of sector i in sector j and most other data sources do not. Firm first–order conditions give us that

$$P^f_{ist} m_{ist} = \sigma_{is} p_{ist} X_{ist}$$

$$m_{ist} \mu_{ins} = m_{inst}$$

I set the first quarter of 2014 to be the base period. In this base period, all prices are 1, so I use data on intermediate usage from the WIOT to calibrate all σs and μs. I calibrate ω_{is}, Ω_{is}, and A_{is} so that all prices and wages end up being one in the base period. A_{is} comes from (7), the first–order condition for wages. ω_{is} and Ω_{is} come from the trade equations (16)–(19); given data on trade and production and given that prices are all equal to 1, I can back out the CES weights. Details on the algebra may be found in the appendix.

H_{is} is set so that labor in the first period is one–third of the total time endowment, as is the case in the American Time Use Survey. I solve for labor allocations every period (details given in the appendix) and then I simply multiply the labor allocation in the first period by three.

I obtain time–varying parameters from the equilibrium equations using data that varies each period. There are twenty–two unknown parameter values and twenty–two data observations observed each period. I use equations (16)–(19), along with (11) and (12), to find iceberg transportation costs as well as foreign price indices and the sale price p_{ist}.

Table 4 displays mean trade cost values for each sector during financial crisis, the recovery from the financial crisis, the pandemic, and the recovery from the pandemic. Service sectors have substantially higher trade cost values than goods sectors, reflecting the enhanced difficulty of trading intangible products and the relative newness of services trade; decades of free trade agreements and advances in shipping technology have helped lower the cost of trading goods, but no such infrastructure exists for services trade. Comparing the two recessions, durable goods trade costs were higher during the financial crisis than they were during the pandemic, while trade costs for in–person services nearly doubled during the pandemic compared to the financial crisis. Trade costs for remote services were higher than trade costs for in–person services fifteen years ago, but the relationship has since reversed. Trade costs for remote services in each time period have been lower than they were in the previous period, potentially reflecting advances in technology.

	Financial Crisis (Q4 2007–Q4 2009)	Financial Crisis Recovery (Q1 2010–Q4 2012)	Pandemic (Q1 2020–Q1 2021)	Pandemic Recovery (Q2 2021–Q1 2022)
Durables	3.03	2.74	2.31	2.35
Nondurables	2.93	3.10	3.01	3.39
In–person services	129	128	226	216
Remote Services	188	176	177	172

Table 3: Iceberg Transportation Costs

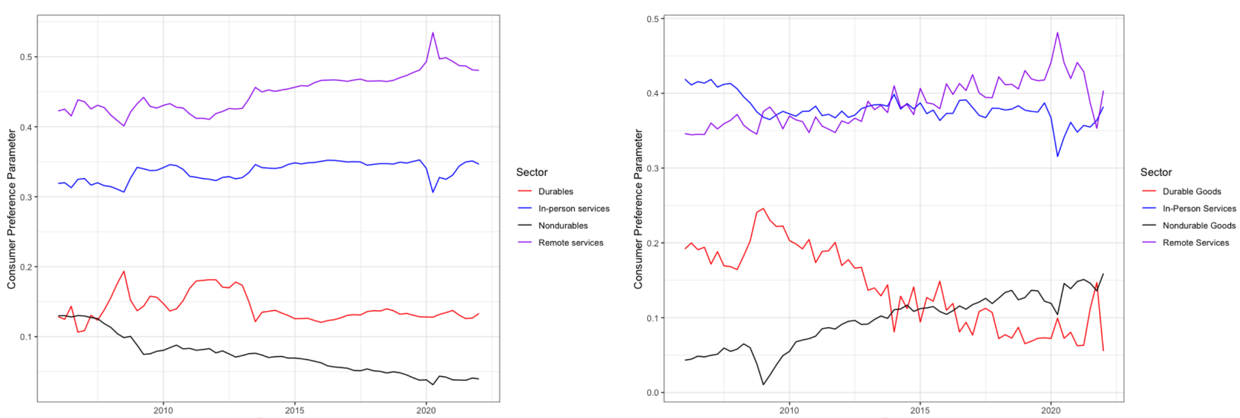
To calculate consumer preference parameters, I first need to calculate consumer expenditures for each sector. I can do so using the market clearing condition for final goods (4), multiplied by prices on both sides, as well as firm first–order conditions. Note that "consumption spending" in this model is equal to the sum of consumer expenditure, government expenditure, and investment expenditure observed in the data. It therefore does not match consumer expenditure data as reported by the BLS.

If durable goods cannot be invested across periods, then η_{ijt} would simply be equal to the share of consumption expenditure on sector j. However, with durable goods investment this is not the case. I solve for values of η by bringing in data on aggregate inflation and working with the price equation

$$P_{it}c_{it} = \sum_{j=1}^{4} P_{ijt}c_{ijt}$$

as well as the consumers' first–order conditions for the four sectors.

Figure 7 shows a time series plot of η_{ijt} organized by country and sector. Remote services preferences in both regions have gradually increased over time, reflecting an increased desire to consume remote services as standards of living have advanced. In the first two quarters of 2020, preferences for remote services rise and preferences for in–person services fall, as the pandemic caused consumers to eschew consumption of services that could make them sick. More surprisingly, consumer preferences for durable goods actually rose during the financial crisis; I postulate that the main mechanism behind the financial crisis might have been a difficulty of making productive investment in durable goods, rather than a decrease in desire to invest in durable goods. Preferences for non–durable goods have been decreasing over time in both the United States and the rest of the world.



(a) United States

(b) Rest of the World

Figure 7: Consumer preference parameters

With consumer expenditure weights, consumption, and prices (the latter two of which I use to get consumer expenditure), I am able to determine an aggregate consumption index for each country. That index, when incorporated into consumer FOC (12), gives me the disutility of labor ϕ_{ist} for each sector, as shown in Table 4 and Table 5.

Let us now turn our attention to the intertemporal aspect of the model in order to solve for the produc-

	Financial Crisis (Q4 2007–Q4 2009)	Financial Crisis Recovery (Q1 2010–Q4 2012)	Pandemic (Q1 2020–Q1 2021)	Pandemic Recovery (Q2 2021–Q1 2022)
Durables	.0121	.0107	.0132	.0111
Nondurables	.116	.110	.0670	.0503
In–person services	.173	.178	.163	.107
Remote Services	1.96	1.76	1.29	.961

Table 4: Disutility of Labor for the United States

	Financial Crisis (Q4 2007–Q4 2009)	Financial Crisis Recovery (Q1 2010–Q4 2012)	Pandemic (Q1 2020–Q1 2021)	Pandemic Recovery (Q2 2021–Q1 2022)
Durables	.0961	.0956	.0245	.0406
Nondurables	.581	.455	.367	.274
In–person services	.172	.170	.506	.0980
Remote Services	.596	.538	.996	1.105

Table 5: Disutility of Labor for the Rest of the World

tivity of durable goods investment χ_{it} and the durable goods stock k_{it}. I assume that the first quarter of 2006 and the first quarter of 2019 are steady states, and can use steady–state versions of the accumulation equation (2) and the Euler equation (14) to get $\overline{k}_i$ and $\overline{\chi}_i$, the steady state values of k_{it} and χ_{it}. With the steady state values in hand, I use (2) and (14) to generate sequences of χ_{it} and k_{it} for all subsequent periods.

Figure 7 shows the evolution of the stock in durable goods for both the United States and the rest of the

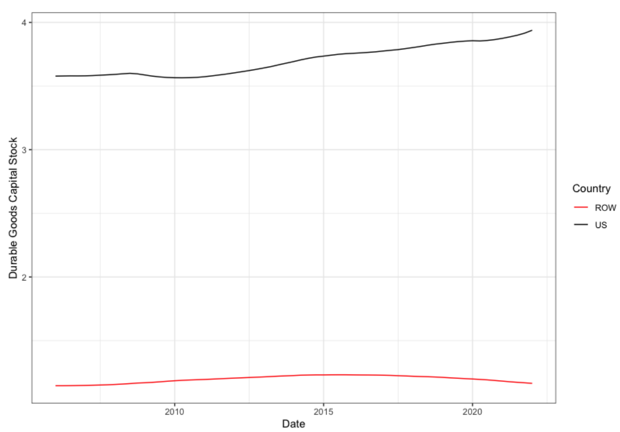


Figure 8: Stock of Durable Goods

world, starting from a steady state in the first quarter of 2006. The American representative consumer has a much larger stock of durable goods on hand, with $\overline{k}_{0,US}$ being around three times as high as $\overline{k}_{0,ROW}$. The American durable goods stock dips during the financial crisis and rises thereafter, while the foreign durable goods stock follows a more parabolic shape.

4.3 Solving the Model

In the previous section, I discussed how to use equilibrium conditions to infer parameter values from data. After performing that exercise, I solve the model and reverse–engineer data values given the parameters I have obtained. I then perform counterfactual exercises by holding certain parameters constant and observing any resultant changes in the equilibrium outcomes.

My "reverse–engineering" methodology consists of a system of eight unknown prices and eight equations given by the final good market clearing conditions (4). I then use equilibrium first–order conditions and market clearing conditions to express total production X_{ist} and right–hand side variables y_{iHst} and y_{iFst} as a function of prices and calibrated parameters. See section 8.4 in the appendix for more details.

The counterfactual methodology is simple. Taking my initial periods (2006 Q1 and 2019 Q1) to be steady–states, I find a steady–state value for χ_{it}, and I have calibrations for the other parameters τ_{ist}, ϕ_{ist}, η_{ist}. My calibration method implies that the solution to the model with these parameters will be almost identical to the allocations observed in the data. My counterfactuals involve holding each parameter constant in turn–for example, considering a case where consumer preferences do not change–and observing how the resultant equilibrium trade allocations differ from those in the data. If the counterfactual trade allocations still hew closely to the data, the parameter being held constant must not be hugely influential in trade. If, however, the counterfactual trade allocations strongly diverge from the data, the parameter being held constant may be an important cause of patterns in trade.

5 Results

5.1 Goods and Services

I first consider aggregated goods and aggregated services. The y–axis quantity in each figure is the sum of real U.S. imports and real U.S. exports for the given sector.

In Figure 9b), each counterfactual time series closely resembles the benchmark case except for the counterfactual with trade costs held constant, implying that without increases in trade frictions services trade would have fallen much less and recovered more quickly during the pandemic. If trade frictions had not changed, services trade in the first quarter of 2022 would have been about the same as services trade in the first quarter of 2019, instead of five percent lower. The counterfactual without changes in disutility of labor closely resembles the benchmark except in the very early days of the pandemic, when trade would have been significantly higher without changes in ϕ. In the early days of the pandemic when little was known about the spread of the virus, the perceived penalty of working for those in service industries increased significantly.

The results presented in Figure 9b) imply that trade frictions were almost solely responsible for the collapse in services trade that transpired during the coronavirus pandemic. In other words, agents did not trade services because the pandemic and related policies made trading services much more difficult, not because the agents did not want to consume services or because their desire to work in service sectors diminished. These findings are not surprising, but the dominance of trade frictions in determining services trade is striking, and does not occur to the same extent for goods sectors or for either sector during the financial crisis.

Figure 9a) also suggests a decent role for trade frictions in goods trade, but trade frictions do not play as large of a role in explaining goods trade as they do in explaining services trade. The most influential factors for goods trade were trade frictions and the disutility of labor, and both factors pushed goods trade in opposite directions. With the disutility of labor held constant at its level in quarter 1 2019, goods trade between Q1 2019 and Q2 2020 would have decreased by around twenty percent as opposed to slightly under ten percent. Furthermore, it never have recovered from the pandemic recession, and in fact would have contracted slightly. As the pandemic pushed workers to move from service industries to goods industries, this shift mitigated the recessionary effects of the pandemic on goods trade. In the absence of changes in trade frictions, however, goods trade would have been higher. This result suggests that pandemic policies such as border closures and lockdowns hindered goods trade as well as services trade, but less so.

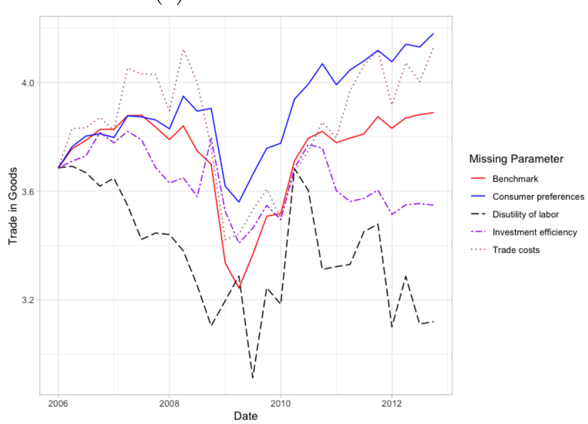
Consumer preferences played a small role in explaining goods and services trade during the pandemic. Although we do observe a downward shift in consumer expenditure on goods relative to services, the results of my model imply that this shift was not causal. Changes in investment productivity also made little difference to pandemic–era trade, with the exception of goods trade after the third quarter of 2020. Goods trade would have declined precipitously without any changes in the productivity of durable goods investment, and I propose that more time spent at home raised the efficiency of consumers' durable goods spending, counteracting the effects of inflation and supply chain bottlenecks.

Let us turn our attention now to Figures 9c) and 9d), which display counterfactual time series for trade during the financial crisis. The most influential parameters determining goods trade were those governing consumer preferences and the disutility of labor. Without changes in consumer preferences, goods trade would have been consistently higher during the financial crisis and subsequent recovery. As consumers lost their desire to purchase non–durable goods or invest in durable goods, trade in these sectors suffered. The omission of changes in the disutility of labor parameter had the opposite effect. Somewhat surprisingly, the omission of changes in the investment productivity parameter did not substantially alter equilibrium allocations.

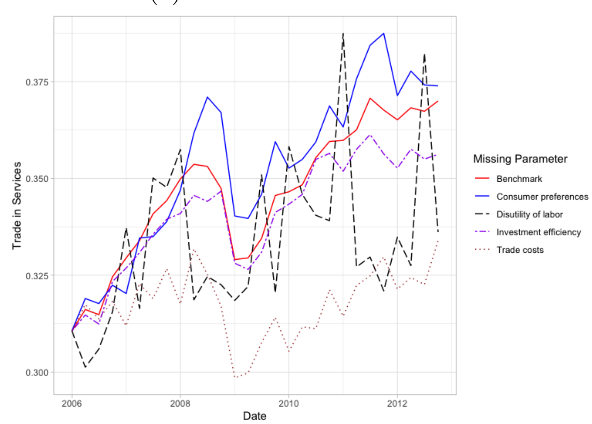
The omission of trade costs made a large difference to financial crisis–era services trade, but not goods trade. As goods trade was more well–established and subject to myriad trade deals (NAFTA, CAFTA, etc.),

(a) Pandemic Goods Trade

(b) Pandemic Services Trade



(c) Financial Crisis Goods Trade

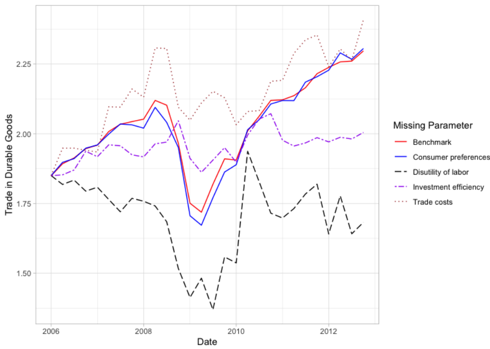


(d) Financial Crisis Services Trade

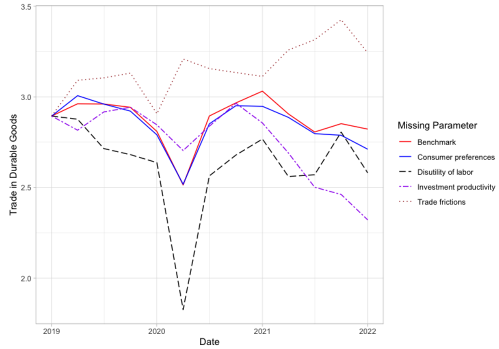
Figure 9: Counterfactual Trade

trade frictions in goods industries would have been less affected by economic shocks than trade frictions in service industries. This result dovetails with the findings of previous literature, which concluded that protectionism was rather muted during the financial crisis. Services trade, on the other hand, would have much lower if trade costs were fixed at their Q1 2006 levels, implying that the technology for trading services continued to improve even as the world economy stagnated.

Overall, trade frictions played a kingmaker role in influencing services trade during both the financial crisis and the pandemic, but in opposite directions. During the pandemic, covid–related measures caused the cost of trading services to skyrocket and trade to fall precipitously. During the financial crisis, trade frictions in services continued the declining trend that they had followed before the recession, preventing the large trade losses that occurred in goods sectors. As for goods sectors, the contrast between the financial crisis and the pandemic comes from the behavior of consumer preferences. Consumer preferences for goods plummeted during the financial crisis, hindering trade, but did not have any large effect on trade during the pandemic.



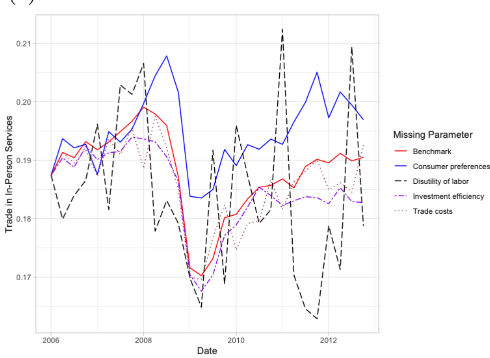
(a) Financial Crisis Durable Goods Trade



(b) Pandemic Durable Goods Trade

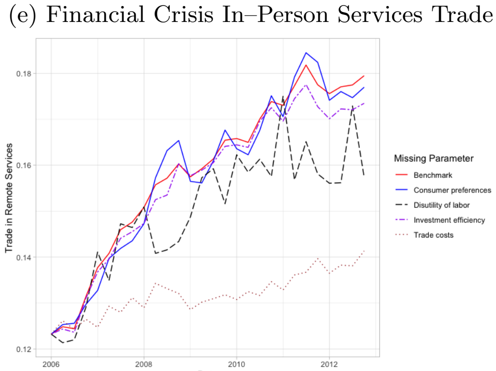
(c) Financial Crisis Nondurable Goods Trade

(d) Pandemic Nondurable Goods Trade

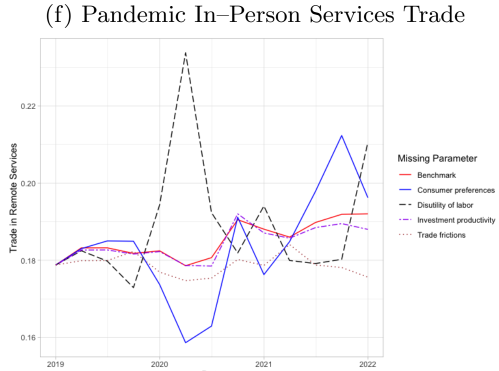


(e) Financial Crisis In–Person Services Trade

(f) Pandemic In–Person Services Trade



(g) Financial Crisis Remote Services Trade



(h) Pandemic Remote Services Trade

Figure 10: Disaggregated Counterfactual Trade

5.2 Disaggregated Goods and Services Trade

Next, I disaggregate goods and services sectors into their respective constituent components: durable goods and nondurable goods and in–person services and remote services. I perform the same exercise of holding one parameter constant at a time and observing how the resulting time series differ from the benchmark case. Figure 10 on the previous page shows results of this exercise.

Durable goods trade during both the financial crisis and pandemic was driven primarily by the disutility of labor and trade costs. In both cases, trade in durable goods would have been much lower if the disutilities of labor for each sector were at their initial steady–state levels. This finding is somewhat surprising, as there would have been a shift in employment preferences from goods to services during the financial crisis. I can only suggest that the uncertainty of the recession caused durable goods employees to value their jobs more, and be less likely to leave them. Changes in investment productivity do not strongly affect the magnitude of trade in durable goods, but they are important for the shape of the time series plot. Without changes in χ, durable goods trade would not have fallen as much nor recovered as much in 2008–2012, and would have fared worse in the aftermath of the pandemic.

Nondurable goods tell a slightly different story. Trade in nondurable goods would have performed better without evolution in consumer preferences, reflecting a shift in preferences away from goods. During both the pandemic and the financial crisis, without movement in trade frictions trade in non–durable goods would reached a much lower point during the initial downturn, suggesting that that the ease of conducting trade in non–durable goods actually *improved* during these times. One possible explanation is that an overall economic slowdown could have reduced congestion levels. However, I do not know why these reduced congestion levels would not have affected durable goods trade.

One surprising observation is that during the financial crisis, consumer preferences appear to play a bigger role for nondurable goods trade than durable goods trade. A possible conclusion is that the observed decrease in consumer spending on durables was driven not by a decreased taste for durables but by a fall in the productivity of investment in durables, or alternatively a decreased ability to invest in durables. Non–durable goods, on the other hand, displayed a more straightforward decrease in consumer tastes after 2006.

Turning our attention to services, for in–person services during the pandemic virtually no parameter mattered but iceberg transportation costs. The observed pandemic decline in imports and exports of services such as tourism was almost entirely due to mechanical difficulties in the trading of those services. Disaggregation also lets us see that the slight divergence between benchmark services trade and the counterfactual case without changes in the disutility of labor was due to remote services, since the counterfactual without disutility, just like the counterfactuals without preference shocks or investment productivity shocks, was virtually identical to the benchmark case for in–person services. In the early days of confusion about how the virus is contracted, the willingness to work would have declined precipitously before people in unaffected industries realized that the pandemic wouldn't significantly hinder their productivity and consequently went back to work.

Trade frictions play a less important role with remote services during the pandemic, but their influence is still present. Without changes in trade frictions, remote services trade would have been consistently lower during the pandemic. I hypothesize that, due to investments in technology such as home offices and video-conferencing, trade barriers *fell* during this time, making remote services trade easier to conduct. More important factors were the disutility of labor (during the early months of the pandemic) and consumer preferences. Remote services trade would have skyrocketed in the second quarter of 2020 without changes in the disutility of labor. Meanwhile, shifts in consumer preferences would have benefited remote services trade, which carries a lower risk of disease, in 2020 and less so as time went on.

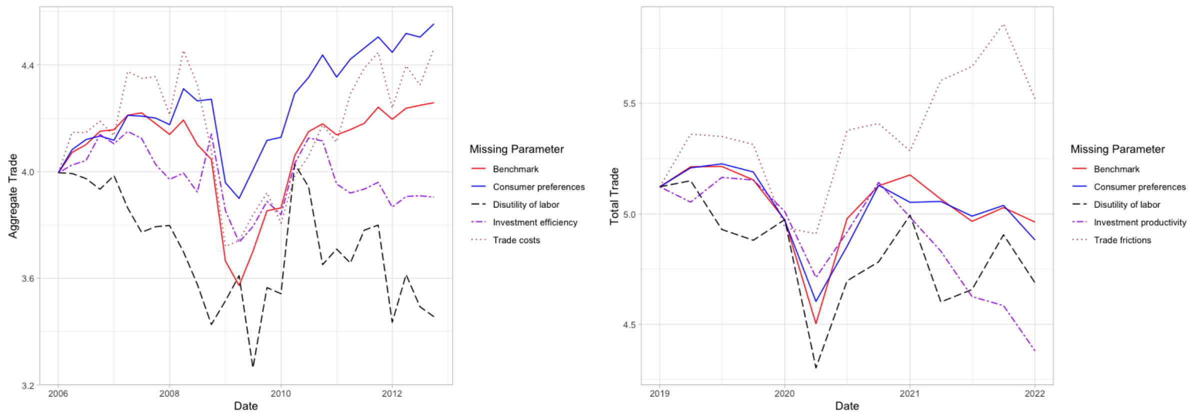
During the financial crisis, trade frictions did not play a big role with in–person services trade, but the disutility of labor did. The black line indicates that an increased disutility of labor during the downturn and subsequent decrease during the recovery help explain the V–shaped pattern in trade; without it, the V–shape goes away. I hypothesize that in–person service jobs are particularly vulnerable to the vicissitudes of the economy, and so the disinclination to work would have been especially strong during the crash (and, correspondingly, rebounded more strongly during the recovery than the disinclination to work for those employed in remote services).

Trade frictions primarily explain remote services trade during the financial crisis. Without changes in trade costs, remote services trade would have kept the same cyclical shape but would have been much lower. Trade frictions for remote services, but not in–person services, were easing during the financial crisis, as advancements in technology such as the development of the iPhone would primarily have benefited remote services trade, not in–person services trade. Interestingly, trade frictions play a crucial role in services trade during each recession, but for different types of services; a decline of trade costs helped remote services trade after 2008, while a dramatic increase in services trade costs hindered in–person trade during the pandemic.

A disaggregated look at goods and services trade reveals new insights that were not apparent before. During the financial crisis, consumer preferences for *non–durable* goods fell, rather than preferences for goods overall. The most relevant mechanism for durable goods was productivity of investment, not consumer preferences. Trade frictions were devastating for in–person services trade during the pandemic, beneficial for remote services during the Great Recession, and buoyed durable goods trade during both downturns.

5.3 Aggregated Trade

Economists have noted a rather muted trade response to the pandemic crisis as compared to the financial crisis. I aggregate goods and service sectors together to determine which factors were most instrumental in determining the magnitude and direction of aggregate trade. I present these results in Figure 11.



(a) Financial Crisis Aggregate Trade

(b) Pandemic Aggregate Trade

Figure 11: Counterfactual Aggregate Trade

The main drivers of aggregate trade during the pandemic were trade frictions. In the absence of trade frictions, aggregate trade would have recovered more quickly and been consistently higher after the first quarter of 2020. The disutility of labor and investment productivity parameters also play some part in explaining the recovery of trade after its initial downturn. The large differential between the data and the counterfactual without trade frictions from 2021 onward could reflect supply chain bottlenecks.

During the financial crisis, meanwhile, consumer preferences and the disutility of labor have the most predictive power over trade. In the absence of changes in consumer preferences, total trade would have been higher, and in the absence of disutility of labor, total trade would have been lower. These two results taken together suggest that trade fell during the financial crisis due to shifts in preferences away from highly traded goods sectors, a conclusion supported by the main results of Bems, Johnson, and Yi (2013). No such fall in preferences for goods occurred in 2020, and improvements in the productivity of durable goods investment enabled goods trade to recover quickly. Without changes in χ, total trade woudl have been on a steady decline beginning in the middle of 2020.

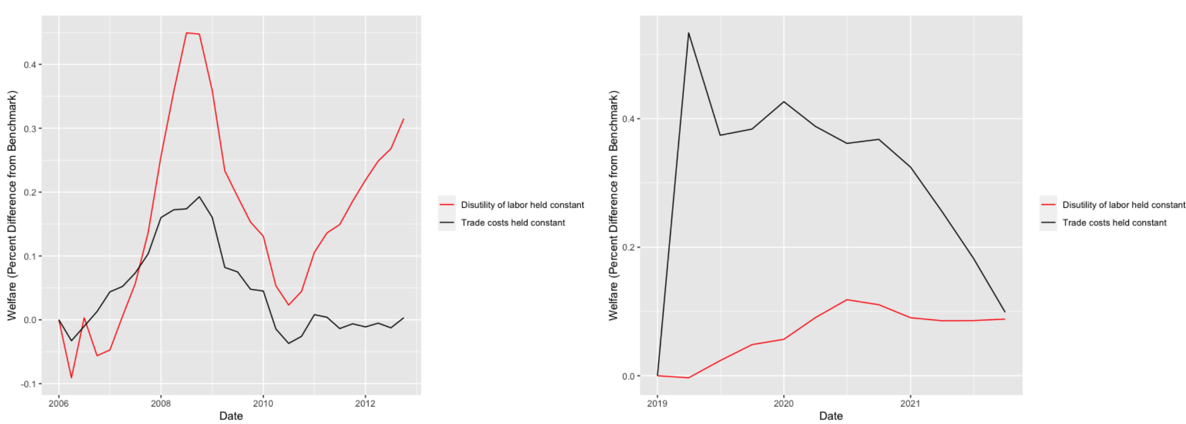
Perhaps the most valuable conclusion to be drawn from this exercise is that we lose nuance when looking at aggregate trade without breaking it down further by sector. As goods trade is around ten times higher than services trade, any aggregate results are impelled by the factors that drive goods trade. We likewise lose nuance when we assume that services are non–tradable or exclude services trade from the calculations altogether.

5.4 Welfare Analysis

I calculate period–by–period welfare for the American representative consumer in two situations: one where the disutility of labor ϕ is fixed at its initial level for all periods, and one where the iceberg transportation costs are fixed at their initial level for all periods. Welfare is represented as the value of the utility function first defined in Section 3.3. We can think of the first case as a type of government intervention that prevents people from losing their jobs, such as a furlough scheme. The second case is one where the government is focused on intervening to prevent trade frictions from rising, either by eschewing protectionism or investing in infrastructure to make sure supply chains run smoothly. I plot out utilities in both the twenty–eight quarters following Q1 2006 and the twelve quarters following Q1 2019.

Figures 12a) and 12b) show the percent differences quarter–by–quarter between utility observed in the counterfactual scenarios, when either trade frictions or employment preferences are held constant across time, and utility in the benchmark case when all parameters move normally. During the financial crisis period, a government intervention that prevented people's disutility of labor from changing would have led to higher utility than a government intervention that prevented trade costs from moving in every period after the first quarter of 2008. Both interventions would cause utility to go up relative to the benchmark case during the height of the financial crisis, but after Q3 2009 holding the trade costs constant would cause a net loss in welfare, because at that point trade costs were starting to go down.

The opposite pattern prevails during the pandemic. As shown in Figure 12b), holding trade costs



(a) Financial Crisis Welfare

(b) Pandemic Welfare

Figure 12: Counterfactual Welfare

constant leads to welfare increases of up to half a percent over the benchmark case, and consistently higher than the welfare increases generated by holding the disutilities of labor constant. The welfare increases generated by holding trade costs constant decrease over time, because trade policy interventions were more effective in the early months of the pandemic than they were once the pandemic and its resulting shocks to international trade had begun to subside. Both holding ϕ constant and holding τ constant generate higher utilities than the benchmark case where all parameters move freely.

6 Conclusion

In this paper, I use a general equilibrium model to examine various causes behind contrasting patterns in trade during the financial crisis and the pandemic. My model is dynamic and contains two countries, multiple sectors, and roundabout production. After calibrating the model to match U.S. data in imports, exports, prices and production, I perform counterfactual experiments where I isolate some subset of parameters in turn to see which plays the biggest role in explaining trade patterns. I find that trade frictions play the biggest part in explaining services trade, as services trade frictions rose substantially during the pandemic and declined during the financial crisis. The disutility of labor parameter, measuring consumers' willingness to work in each sector, plays a large role in goods trade during the downturn period of both recessions. However, the difference in goods trade can best be explained by differing consumer preferences. Consumer preferences rose for services relative to goods during the financial crisis, but no such large–scale shift in consumer preferences happened during the pandemic, which explains why goods trade took a bigger hit in the first two quarters of 2009 than it did in the first two quarters of 2020.

My welfare results imply that any policymaker wishing to maximize consumer utility in the wake of an event such as the pandemic should focus on easing trade restrictions, such as through easing border closures, rather than stimulating demand or motivating people to go back to work. The model does not consider the health or productivity effects of failing to protect people from the pandemic, so I do not mean to suggest that governments should avoid lockdowns or other pandemic response measures altogether; rather, the welfare-maximizing response would be to make such restrictions as limited as possible and explore ways to end them in a timely manner that still guarantees people's safety. Although this model does not explicitly consider inflation, its main result also implies that policymakers wishing to alleviate inflation might do so through the supply side, by considering ways to lower trade frictions. My results complement some earlier findings on the financial crisis: namely, that a drop in consumer expenditure on durable goods played a big role in the fall in goods trade, and declines in investment efficiency played a smaller one. However, this study also revealed that disutility of labor played a large part in explaining trade during the financial crisis–the literature has largely not considered elastic labor.

Future research on this topic can go into more detail about how elastic labor decisions affected trade. In addition, future scholarship could look at whether any of these results change in a model that incorporates inventories or delivery uncertainty. Papers such as Bems et al. (2013) have considered inventories to play a crucial role in trade patterns by exacerbating negative effects of a trade shock, and this model does not contain a mechanism for them.

7 References

Alessandria, G., J. Kaboski and V. Midrigan. 2012. Trade Wedges, Inventories, and Business Cycles. *Journal of Monetary Economics* 60(1): 1–20.

Amiti, M., and D. Weinstein. 2011. Exports and Financial Shocks. *Quarterly Journal of Economics* 126: 1841–77.

Bems, R., R. Johnson, and K. Yi. 2013. The Great Trade Collapse. *Annual Review of Economics* 5: 375–400.

Bonadio, B., Z. Huo, A. Levchenko, and N. Pandalai–Nayar. 2020. *Global Supply Chains in the Pandemic.* NBER Working Papers 27224.

Bussière, M., G. Callegari, F. Ghironi, G. Sestieri, and N. Yamano. 2013. Estimating Trade Elasticities: Demand Composition and the Trade Collpase of 2008–2009. *American Economic Journal: Macroeconomics* 5(3): 118–151.

Cavallo, A., and O. Kryvstsov. 2021. What Can Stockouts Teach Us About Inflation? Evidence from Online Micro Data. *Bank of Canada*: Working Paper.

Chor, D. and K. Manova. 2012. Off the Cliff and Back? Credit Conditions and International Trade during the Global Financial Crisis. *Journal of International Economics* 87: 117–33.

Chow, G. and A. Lin. 1971. Best Linear Unbiased Interpolation, Distribution, and Extrapolation of Time Series by Related Series. *The Review of Economics and Statistics* 53 (4): 372:375.

Gawande, K., B. Hoekman and Y. Cui. 2011. *Determinants of Trade Policy Responses to the 2008 Financial Crisis.* Policy Res. Work. Pap. 5862, World Bank.

Ha, Jongrim, M.A. Kose, and F. Ohnsorge. 2021. *Inflation during the Pandemic: What Happened? What is Next?* CEPR Discussion Paper No. DP16328.

Jiang, B., D. Rigobon, and R. Rigobon. 2022. From Just–in–Time, to Just–in–Case, to Just–in–*Worst* Case: Simple Models of a Global Supply Chain under Uncertain Aggregate Shocks. *IMF Economic Review* 70: 141–184.

Kee, H., C. Neagu and A. Nicita. 2013. Is Protectionism on the Rise? Assessing National Trade Policies during the Crisis of 2008. *Review of Economics and Statistics* 95(1): 342–346.

LaBelle, J., and A. Santacreu. 2022. Global Supply Chains and Inflation during the Covid–19 Pandemic. *Review–Federal Reserve Bank of St. Louis* 104(2): 1–14.

Levchenko, A., L. Lewis, and L. Tesar. 2010. The Collapse of International Trade during the 2008–2009 Crisis: in Search of the Smoking Gun. *IMF Economic Review* 58(2): 214–253.

Meier, M., and Pinto, E. 2020. Covid–19 supply chain disruptions. *Covid Economics* 48: 139–170.

Paravisini, D., V. Rappoport, P. Schnabl, and D. Wolfenson. 2015. Dissecting the Effect of Credit Supply on Trade: Evidence from Matched Credit–Export Data. *The Review of Economic Studies* 82(1): 333–359.

8 Appendix

8.1 Constructing Data

The 'rest of the world' consists of twenty countries that have been in the United States' top twenty trade partners in the twenty–first century. These countries include China, Canada, Mexico, Japan, Germany, South Korea, the United Kingdom, Taiwan, India, the Netherlands, Ireland, Switzerland, Italy, France, Brazil, Singapore, and Belgium. Vietnam and Malaysia are in the U.S.'s top twenty trade partners but were excluded due to lack of data. I replace them with Australia and Indonesia.

Goods data is often already broken down into goods and services. In the cases where it wasn't, I followed the NAICS guidelines as set out by Statistics Canada. Durable goods are composed of wood product manufacturing; non–metallic mineral product manufacturing; primary metal manufacturing; fabricated metal product manufacturing; machinery manufacturing; computer and electronic product manufacturing; electrical equipment, applicance and component manufacturing; transportation equipment manufacturing; furniture and related product manufacturing; miscellaneous manufacturing. Nondurable goods are composed of food manufacturing; beverage and tobacco product manufacturing; textile mills; textile product mills; clothing manufacturing; leather and allied product manufacturing; paper manufacturing; printing and related support activities; petroleum and coal products manufacturing; chemical manufacturing; plastics and rubber products manufacturing.

Services data is not broken down into in–person services and remote services, because I came up with these categories myself and had to create my own guidelines. In essence, in–person services are services that require face–to–face contact if one is to consume them, while remote services do not require such contact. In–person services therefore include transport services, travel services, construction, maintenance and repair services, and personal, cultural and recreational services. Remote services include insurance services; financial services; intellectual property services; telecommunications, computer and information services; other business services; government goods and services.

U.S. domestic production data was available at a quarterly level from the Federal Reserve Economic Database. Because the only two countries in the model are the U.S. and the rest of the world, I can model exports from the rest of the world as U.S. imports, and so do not need to obtain country–by–country trade data. However, data on gross output for most foreign countries is *not* available at the quarterly level, and so these time series require some statistical maneuvering beyond simply downloading the numbers. To obtain time series on gross output for the rest of the world, I downloaded country–by–country data from Bloomberg on production indices and production price indices, which *are* available in the data, and use the Chow–Lin procedure to disaggregate data values on annual production into monthly components. For more details, see Chow and Lin (1971).

The World Input–Output Tables (WIOT) provide invaluable data in calibrating the Cobb–Douglas parameters for firms. WIOTs appear annually until 2014 and break down how sector n in country i is used in the production of sector s in country j. I obtained the WIOT for 2014, my base year, from the World Input–Output Database, and aggregated the input–output data by sector (to get the four sectors I use in the model) and by country, combining data for the nations that comprise the rest of the world. 'Total intermediate consumption' corresponds to m_{ist} in the model, and m_{inst} corresponds to intermediate usage of sector n in the production of sector s. 'Value added at basic prices' corresponds to the use of labor in production, while 'Output at basic prices' corresponds to the total production X_{ist}. All prices are one in the base year, so I do not need to worry about nominal vs. real quantities.

I observe U.S. price data for the aggregate economy, durable goods, nondurable goods, and services. I calculate a price index for the rest of the world as a weighted average of price indices from the U.S.'s trading partners. Calculating price indices for in–person and remote services, however, is a bit more involved because those categories do not exist in the data. To impute such price indices, I use the formula

$$P_{ist} = \prod_{k=1}^{N} \left(\frac{P_{kst}}{\varepsilon_{kst}}\right)^{\varepsilon_{kst}}$$

I do not observe a price index for in–person services or remote services in the data, but I do observe price indices for the specific service sectors that comprise those categories, such as financial services or recreation services. I therefore construct a more aggregated service price index by putting those price indices into the above Cobb–Douglas formula. ε_{kst} is the share of in–person or remote services taken up by sector k and comes from consumer expenditure data. For example, to find ε_{kst} for financial services, a type of remote service, I divide consumer expenditure on financial services by consumer expenditure on remote services, of which financial services expenditure is one component.

In the consumer expenditure data, in–person services include health care services; transportation services; membership clubs, sports centers, parks, theaters, and museums; food services and accommodations; education services; personal care and clothing services; household maintenance; net foreign travel. Remote services include housing and utilities; audio–video, photographic, and information processing equipment services; financial services and insurance; communication; professional and other services.

8.2 Internally Calibrated Non–Time–Varying Parameters

Parameters that don't vary across time are the Cobb–Douglas production shares σ_{is} and μ_{ins}, as well as ω_{is}, Ω_{is}, and A_{is}; the latter group of parameters exist so that prices in the base period of Q1 2014 end up being one. I calibrate σ_{is} and μ_{ins} from the World Input–Output Table for 2014, taking advantage of the fact that the WIOT contains values for use of sector i in sector j and most other data sources do not. Firm first–order conditions give

$$P^f_{ist} m_{ist} = \sigma_{is} p_{ist} X_{ist}$$

$$m_{ist} \mu_{ins} = m_{inst}$$

In the base period, all prices are 1, so I use data on intermediate goods usage from the WIOT to calibrate all σs and μs.

I calibrate ω_{is}, Ω_{is}, and A_{is} so that all prices and wages end up being one in the base period. Let's start with ω_{is} and Ω_{is}. The equations for nominal imports and exports are given below:

$$USProduction_{st} = \Omega^{\gamma}_{US,s} \left(\frac{P_{US,s,t}}{p_{US,s,t}}\right)^{\gamma-1} Y_{US,s,t} \tag{15}$$

$$USImports_{st} = (1 - \Omega_{US,s})^{\gamma} \left(\frac{P_{US,s,t}}{p_{ROW,s,t}\tau_{st}}\right)^{\gamma-1} Y_{US,s,t} \tag{16}$$

$$USExports_{st} = (1 - \Omega_{US,s})^{\gamma} \left(\frac{P_{ROW,s,t}}{p_{US,s,t}\tau_{st}}\right)^{\gamma-1} Y_{ROW,s,t} \tag{17}$$

$$ROWProduction_{st} = \Omega^{\gamma}_{ROW,s} \left(\frac{P_{ROW,s,t}}{p_{ROW,s,t}}\right)^{\gamma-1} Y_{ROW,s,t} \tag{18}$$

Let's look at these equations for the specific time period of Q1 2014, when all prices are equal to 1. I observe all the LHS variables in the data, as well as $Y_{US,s,t}$ and $Y_{ROW,s,t}$. Using data on imports, production, and exports, I can calibrate all relevant parameters. First, (15) and (18) give

$$\Omega_{US,s} = (\frac{USDomestic_{s,01/14}}{Y_{US,s,01/14}})^{\frac{1}{\gamma}} \tag{19}$$

$$\Omega_{ROW,s} = (\frac{ROWDomestic_{s,01/14}}{Y_{ROW,s,01/14}})^{\frac{1}{\gamma}} \tag{20}$$

and (15) and (16) give us

$$\tau_{s,01/14}^{1-\gamma} = \frac{USImports_{s,01/14}}{USDomestic_{s,01/14}}(\frac{\Omega_{is}}{1-\Omega_{is}})^{\gamma}$$

Going to (11), the price index equation, I replace all prices with 1 and substitute out for τ and $\omega_{US,s}$ with the expressions given above. This enables me to solve for $\Omega_{US,s}$, and I find that

$$\Omega_{US,s} = (\frac{USProduction_{s,01/14}}{Y_{US,s,01/14}})^{\frac{1}{\gamma}}$$

where the second line comes from (20). To find $\Omega_{ROW,s}$, I go back to equations (16)–(19). Combining them all together to eliminate ωs and τ_{st},

$$\Omega_{ROW,s} = (\frac{ROWProduction_{s,01/14}}{Y_{ROW,s,01/14}})^{\frac{1}{\gamma}}$$

I set A_{is} so that the wage is equal to 1 in Q1 2014. Combining (6) and (7), I know that

$$w_{ist} = (\frac{P_{ist}^{f}}{\sigma_{is}})^{\frac{\sigma_{is}}{\sigma_{is}-1}}(A_{is}p_{ist})^{\frac{1}{1-\sigma_{is}}}(1-\sigma_{is}) \tag{21}$$

Setting wages and prices to one, I can solve for A_{is}.

8.3 Internally Calibrated Time–Varying Parameters

I start with data on the *value* of imports, exports, and production, as well as price indices for all sectors in the US. I directly observe price indices for durable goods and non–durable goods, and I impute price indices for the two service sectors based on Consumer Price Index data for their constituent service sectors. One sector is normalized to 1 as the numeraire good.

I observe η_{ijt} (8 observations), ϕ_{ijt} (8 observations), χ_{it} (2 observations) and τ_{jt} (4 observations) each period. This adds up to twenty–two parameter values, which I will calibrate to match the twenty observations found in the data. These data observations are production (4 observations per country, so 8 observations), US exports (4 observations), US imports (4 observations), US prices (4 observations), and US/ROW inflation

(2 observations).

I now move to the second–stage market clearing condition (5). Multiplying both sides of the equation by P_{int} and substituting for m_{inst} using the firm first–order conditions, we have

$$P_{int}c_{int} = P_{int}y_{int} - \sum_{s=1}^{4} \sigma_{is}\mu_{ins}p_{ist}X_{ist}$$

Since I know $P_{int}y_{int}$ and $p_{ist}X_{ist}$ from the data, and I have calibrated σ_{is} and μ_{ins}, I can solve for consumption spending $P_{int}c_{int}$.

I will use equations (15)–(18) to find foreign price indices, the sale prices p_{ist}, and iceberg transportation costs. Putting all four equations together gives

$$\tau_{s,t} = \left(\frac{USImports_{st}\Omega_{US,s}^{\gamma}}{USProduction_{st}\Omega_{ROW,s}}\frac{USExports_{st}}{USProduction_{st}}\right)^{\frac{1}{2(1-\gamma)}} \tag{22}$$

Then I use the price index equation (11) together with (10) to find all p_Hs and p_Fs. Since I do not observe data on foreign price indices, I assume that trade costs are symmetric and use equilibrium equations to back them out.

(15)–(18) will also get us price indices. Note that all price indices are normalized to 1 in the first quarter of 2014.

(a) U.S. price indices

(b) ROW price indices

Figure 13: Prices

Figure 13 compares calibrated prices in the U.S. to calibrated prices in the ROW. The price index for durable goods has been on a downward trend across time. The price index for remote services has been rising more or less linearly over time, reflecting increased demand, while the index for in–person services rose sharply for the ROW at the start of the pandemic, when such services became much harder to obtain. All sectors except in–person services have become more expensive in recent quarters, reflecting high inflation.

I solve for values of η by bringing in data on aggregate inflation and working with the price equation

$$P_{it}c_{it} = \sum_{j=1}^{4} P_{ijt}c_{ijt}$$
$$\Rightarrow P_{it}\prod_{j=1}^{4}\left(\frac{c_{ijt}\eta_{ijt}}{\eta_{ijt}}\right)^{\eta_{ijt}} = \sum_{j=1}^{4} P_{ijt}c_{ijt}$$

I know all expenditure values, and I also know all price levels, which enables me to find the real value of consumption in each sector. Using (13) I know that

$$\eta_{ij't} = \eta_{ijt}\frac{P_{ij't}c_{ij't}}{P_{ijt}c_{ijt}} \;\; j, j' \in \{2, 3, 4\}$$

so I can express η_{i3t} and η_{i4t} as functions of η_{i2t}. I also know that all $\sum_{j=1}^{4}\eta_{ijt} = 1$, which enables me to solve for all ηs in all periods and for all countries.

I now turn my attention to the intertemporal aspect of the model in order to solve for the productivity of durable goods investment χ_{it} and the durable goods stock k_{it}. I assume that the first quarter of 2006 and the first quarter of 2019 are steady states. In steady state, the two equations are

$$\frac{\overline{k}_i}{\overline{c}_{i1}} = \left(\frac{\overline{\chi}_i}{\delta}\right)^{\frac{1}{\alpha}}$$
$$\frac{\overline{\eta}_{i2}}{\beta\overline{c}_{i2}}\frac{\overline{P}_{i1}}{\alpha} = \left[(1-\delta) + (1-\alpha)\left(\frac{\overline{c}_{i1}}{\overline{k}_i}\right)^{\alpha}\right]\frac{\overline{P}_{i1}}{\alpha}\frac{\overline{\eta}_{i2}}{\overline{c}_{i2}} + \frac{\overline{\eta}_{i1}}{\overline{c}_{i1}}$$

which is a system of two equations and two unknowns, $\overline{\chi}_i$ and $\overline{c}_{i1}$. With the steady state values in hand, I use (2) and (14) to generate sequences of χ_{it} and k_{it} for all subsequent periods. Starting with the values for $t = 1$ (the steady state), (2) gives me $k_{i,t+1}$ and then (14) gives me $\chi_{i,t+1}$.

Finally, the disutility of labor parameter ϕ_{ist} comes from the consumer's first–order conditions. Rewriting (12) gives me

$$\phi_{ist} = \left(\frac{H_{is} - l_{ist}}{c_{it}}\right)^{\frac{1}{\theta}}\frac{w_{ist}}{P_{it}}$$

At this point, I have solved for all prices P_{ist} and hence I have the price index P_{it}. Similarly I have solved for all consumption allocations. I only need to derive labor allocations l_{ist}, aggregate consumption c_{it} and wages w_{ist}. Aggregate consumption comes from sectoral consumption c_{ist} and η_{ist}. (6) and (7) give the wage as a function of prices, and (7) combined with the production function gives labor as a function of wages, prices, and output. I can then back out ϕ_{ist}.

8.4 Solving the Model

The bulk of the program consists of a function to find prices. I use a Newton's method equation solver to find the roots of a function that takes eight origin–level prices as inputs. The knowledge of those prices enables us to get, among other equilibrium allocations, real US imports and exports. I start with the function argument and use the price index formula (11) to get sector–level prices and wages. ω_{is}, Ω_{is} and τ_{st}, the parameters that appear in (11), were all calibrated in section 4.2.

The price function nests another function that takes as its argument real consumption in nondurable goods and, given the durable goods aggregation I have already solved for, identifies the value of nondurable goods aggregation that fulfills the budget constraint. I start by backing out y_{i3t} and y_{i4t} using the calibrated η parameters and the first–order conditions (13), solving from labor from (12), and then using (6) and (7) to find total production X_{ist} in each sector and country.

Next, I get allocations for both imports and exports. These are necessary to find E_{it}, which goes on the right–hand side of the budget constraint. Using (10) together with the market clearing condition (5), we have a system of equations

$$X_{Hst} = (\frac{p_{Fst}}{\Omega_{Hs}p_{Hst}})^{\gamma}\tau^{\gamma-1}y_{FHst} + y_{HFst}$$
$$X_{Fst} = y_{FHst} + (\frac{p_{Hst}}{\Omega_{Fs}p_{Fst}})^{\gamma}\tau^{\gamma-1}y_{HFst}$$

This system of equations allows me to get y_{FHst} and y_{HFst}, or US imports and exports respectively. I now have everything that goes into the budget constraint (as a function of c_{H2t} and c_{F2t}), so I can solve for those consumption allocations.

The final step involves using market clearing conditions for final goods. I get y_{ist} using the price function arguments and values of imports and exports that come out of the nested function. Consumption comes out of the nested function as well, so only m_{inst} remains. I find m_{ist} with the production function $X_{ist} = m_{ist}^{\sigma} l_{ist}^{1-\sigma}$ and then use (8) to get m_{inst}. This yields eight equations as a function of eight unknown prices.