NBER WORKING PAPER SERIES

TRADE POLICY

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Working Paper 29051
http://www.nber.org/papers/w29051

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
July 2021

This paper has been prepared for the Handbook of International Economics, Volume V, edited by Gita Gopinath, Elhanan Helpman and Kenneth Rogoff. All errors are our own. We thank Pol Antras, Costas Arkolakis, David Atkin, Mostafa Beshkar, Paola Conconi, Arnaud Costinot, Swati Dhingra, Pablo Fajgelbaum, Robert Feenstra, Cecilia Fieler, Elhanan Helpman, Samuel Kortum, Brian Kovak, Mario Larch, Giovanni Maggi, Andres Rodriguez-Clare, Peter Schott, and Robert Staiger for useful comments. We thank Charles Cai and Yuta Suzuki for research assistance. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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JEL No. F1,F10,F11,F12,F13,F14,F15,F16,F19

ABSTRACT

We review recent theoretical and empirical research on trade policy. We start by presenting reduced-form evidence of the effects of trade policy in the presence of supply-chain linkages, on the short-run and persistent effects of trade policy across local labor markets, and on the effects of trade policy uncertainty on employment and firms. We describe the shift-share method for trade policy analysis, discuss the interpretation of the estimated effects, and provide a theoretical foundation. We then describe new quantitative frameworks, methods, and data used to study the aggregate and distributional effects of trade policy in general equilibrium. We discuss how to take into account supply-chain linkages, local labor markets, and different sources of dynamics. As an illustration, we quantify the aggregate and distributional effects of the 2018 trade war between the United States and its trading partners. Finally, we present recent theoretical insights on optimal unilateral trade policy with firm and product heterogeneity in the context of large and small open economies with perfectly and imperfectly competitive product markets. We also discuss how optimal trade policy is shaped by the presence of multiple sectors, intermediate goods, and supply-chain linkages. We close the chapter by discussing the scope of future research.

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An online appendix is available at http://www.nber.org/data-appendix/w29051

Trade Policy*

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Abstract

This chapter reviews a recent body of theoretical and empirical work that studies the normative and positive aspects of trade policy. We start by presenting reduced-form evidence of the effects of trade policy in the presence of supply-chain linkages, on the short-run and persistent effects of trade policy across local labor markets, and on the effects of trade policy uncertainty on employment and firms. We describe the shift-share method for trade policy analysis, discuss the interpretation of the estimated effects, and provide a theoretical foundation. We then describe new quantitative frameworks, methods, and data used to study the aggregate and distributional effects of trade policy in general equilibrium. We discuss how to take into account supply-chain linkages, local labor markets, and different sources of dynamics. As an illustration, we quantify the aggregate and distributional effects of the 2018 trade war between the United States and its trading partners. Finally, we present recent theoretical insights on optimal unilateral trade policy with firm and product heterogeneity in the context of large and small open economies with perfectly and imperfectly competitive product markets. We also discuss how optimal trade policy is shaped by the presence of multiple sectors, intermediate goods, and supply-chain linkages. We close the chapter by discussing the scope of future research.

1 Introduction

Trade policy analysis has been a central focus of research since at least the pioneering optimal tariff analysis in Bickerdike (1907).[1] Recent research in the international trade field has led to an explosion of new empirical methods that can be used to study the aggregate and distributional consequences of many types of changes to the economic environment (e.g., non-tariff trade costs, local productivity changes, changes in infrastructure). The recent backlash against international trade has shifted the focus back towards the analysis of trade policy, making the study of the effects of trade policy one of the most relevant subject areas.

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[1] One could even argue that the topic has been important since the Wealth of Nations where Adam Smith discussed the use of trade duties.

This chapter introduces researchers to recent developments and findings in the literature on trade policy. We structure this chapter in three main sections describing the new empirical, quantitative, and theoretical findings in the literature.

In Section 2, we review and discuss recent reduced-form evidence on the impact of trade policy. We first focus on research that studies the consequences of the changes in tariffs as a consequence of the recent trade war between the United States and its trading partners. This trade policy shock, together with the availability of detailed cross-country trade and tariff data, has allowed researchers to estimate the effects of increased trade protectionism on the U.S. economy. We then review studies that are motivated by the increasing importance of global value chains in the world's trade structure. The rapid progress in data and methods for measuring sectoral and country linkages has made the study of the effects of trade policy on global value chains a growing line of research. We review recent research that provides new evidence on how trade policy changes shape the global value chains and how the global value chains shape trade policy across countries.

Another fast-growing line of research is the study of the local labor market effects of trade policy. Motivated by the fact that economic activity is unevenly distributed across space, researchers have exploited the differential exposure to trade policy across local labor markets to study the distributional effects of trade policy. The reduced-form research in this area has revived the use of shift-share analysis for investigating the effects of trade policy on outcomes such as wages, employment, and poverty across space. We review reduced-form studies that find evidence of the distributional effects of trade policy across local labor markets. We describe the shift-share specifications used in recent trade policy analyses, as well as the findings regarding the distributional effects across regions, and the persistent effects, of trade policy. We also review the methodology and present a theoretical foundation that justifies the shift-share specifications, discuss the interpretation of the results, and present extensions to show how the shift-share design could be adapted to take into account other margins of adjustments like non-tradable goods, sectoral linkages, and more general production functions.

Trade policy has also become a major source of uncertainty. For instance, the United States threatened its trading partners and eventually increased its tariffs on China, the same country to which the United States had given normal trade partner status several years before. We conclude this section by reviewing new empirical evidence on the significant effects of trade policy uncertainty on relevant outcomes such as employment and investment.

In Section 3, we discuss quantitative frameworks developed to study the general equilibrium effects of actual and counterfactual trade policy changes. Guided by the reduced-form evidence we reviewed in Section 2, we focus on the progress made in recent quantitative trade literature to incorporate the roles of supply-chain linkages, local labor markets, uncertainty, and different sources of dynamics into general equilibrium. We describe a list of building blocks and model assumptions that have been used in recent quantitative trade literature, and we discuss the mechanisms we consider especially relevant to trade policy analysis.

Our starting point is a static multi-sector trade model with intermediate goods and input-output linkages. From there, we expand the framework to incorporate the uneven distribution of local economic activity across space, which can be used to study the spatial effects of trade policy. We then argue that static frameworks in which workers are assumed to be either freely mobile or perfectly immobile say little about important, inherently dynamic issues identified in the empirical literature, such as: How long do labor markets take to adjust to a change in trade policy? Does the spatial distribution of economic activity cause a lasting differential impact on workers in different sectors and regions? In response to these questions, we expand the framework to incorporate labor market dynamics and show how the framework can be used to study the effects of trade policy on employment location across sectors, regions, and time.

The connection between the theory and the quantitative analysis requires progress on two additional fronts: computation methods and data availability. We review existing methods used to conduct trade policy counterfactuals in multi-country static quantitative trade frameworks; we then review recent research that has extended these methods to frameworks with local labor markets, and more importantly, to dynamic quantitative frameworks. We also discuss new databases that have facilitated the connection of these models to the data, allowing researchers to perform quantitative trade policy evaluations. At the same time, we show how to apply these new tools to study the economic effects of the recent trade war between the United States and its trading partners in frameworks that take into account value chains, local labor markets, and dynamics.

We then turn to the normative analysis of trade policy, and in Section 4, we discuss recent theoretical tools and results related to optimal unilateral trade policy. The main advances in this area are twofold. First, there has been substantial progress in understanding optimal trade policy in a variety of neoclassical and monopolistic competition environments that involve product or firm heterogeneity, in large or small open economies, with trade in final and intermediate goods. Second, there has been progress in understanding the implications of global value chains for optimal trade policy structure. In attending to these advances, we describe new methods for the analysis of optimal trade policy and identify some benchmark results in recent literature. At the end of the section, we discuss the scope for further progress in this area, especially in terms of the connection between the new results on optimal trade policy and the quantitative analysis described in Section 2 and Section 3. Further research in this direction could help understand better the economic motives behind the actual trade policy changes in episodes such as the recent trade war between the United States and its trading partners.

2 Empirical Effects: Reduced-form Approach

We start the section by reviewing recent empirical findings on the effects of the recent tariff increases as a consequence of the trade war between the United States and its trading partners. We then review recent empirical work on the incidence of trade policy on global value chains. After doing so, we discuss the recent revival of shift-share analysis to study the distributional effects of trade policy on local labor markets. We finish the section by describing recent work on the effects of trade policy uncertainty on different outcomes. We see this section as building on and complementing the reviews performed by Goldberg and Pavcnik (2016) and Pavcnik (2017) that focus on the distributional effects of globalization in developing countries.[2]

2.1 Reduced-form Evidence of the 2018 Trade War

Although protectionist measures have been imposed throughout U.S. history, the recent trade war between the United States and its main trading partners is somewhat unprecedented in terms of the scope and magnitude of the tariff changes.[3] Tariffs with rates ranging from 10 to 50 percent on more than 12,000 products covering around $300 billion of U.S. imports were imposed in 2018 (the average statutory tariff rate in affected imports increased from 2.6 percent to 16.6 percent). In response to these U.S. tariffs, several U.S. trading partners, including China, the European Union, Canada, Mexico, and Turkey, among others, retaliated and imposed tariffs averaging 16 percent on approximately $121 billion of U.S. exports (see Amiti, Redding, and Weinstein 2019, and Fajgelbaum, Goldberg, Kennedy, and Khandelwal 2019 for additional empirical facts).

This trade war, together with the recent emergence of detailed cross-country trade and tariff data, has created a unique opportunity to study the effects of trade protectionism. Indeed, recent literature has provided new insight into the effects of trade protectionism through the lens of the 2018 trade war. In this subsection we review reduce-form evidence and in the next section we provide a general equilibrium analysis of this recent increase in trade protectionism.

Amiti, Redding, and Weinstein (2019) use monthly U.S. census data collected from 2017-2018 on import quantities and values at the HTS10-country level to estimate the effects of the trade war on U.S. prices and quantities that in turn are used to compute deadweight losses. The authors regress changes in import unit value (that do not include the tariff change) over changes in applied tariffs on imports, controlling by product

[2] Recent studies have also provided evidence on the effects of distortions related to trade policy in developing countries. In particular, research has documented substantial tariff evasion in developing countries that impacts tariff revenues and the welfare effects of trade policy (e.g., Rijkers, Baghdadi, and Raballand 2015; Sequeira and Djankov 2014; Sequeira 2016). Also, Atkin and Khandelwal (2020) review other important distortions, institutional weaknesses, and market failures that shape the effects of trade policy in developing countries.

[3] Irwin (2017) presents a comprehensive review of the history of U.S. trade policy.

and country-year fixed effects. They find no impact of tariffs on the prices received by foreign exporters; in other words, they find that the tariff changes have been almost entirely passed through to domestic prices, leaving relative exporter prices unchanged.[4] Although this result might be surprising for a large economy like that of the United States, it is in line with similar estimates made using different methodologies in Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2019) and Cavallo, Gopinath, Neiman, and Tang (2021).

Using micro-data from the Bureau of Labor Statistics (BLS) collected at the border and at retailers, Cavallo, Gopinath, Neiman, and Tang (2021) document that the increase in U.S. import tariffs were almost fully passed through to total prices paid by importers, suggesting that the incidence of the tariffs has fallen on U.S. consumers. Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2019) use census data as in Amiti, Redding, and Weinstein (2019) but follow a different methodology to find evidence of the effects of the trade war on U.S. prices. The authors estimate a U.S. demand system that accommodates substitution across imported varieties (defined as country-product pairs), across imported products (defined as 10-digit Harmonized System product codes), and between imported and domestic products within a sector (defined as 4-digit NAICS industry codes), and they combine this demand system with foreign export supply curves for each variety. Similar to Amiti, Redding, and Weinstein (2019), their results are suggestive of a perfectly elastic export supply curve. In the following sections, we describe in more detail the estimation methodology and results in Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2019). In line with these results, Flaaen, Hortacsu, and Tintelnot (2020) also estimate a high tariff pass-through to retail prices for washing machines.

As discussed in these studies, the finding of the complete pass-through of tariffs to duty-inclusive import prices does not imply that the United States is a small open economy that is not able to affect its terms of trade. One possible interpretation is that a complete pass-through is a short-run effect, as relative prices may change over longer horizons. In addition, the fact that the relative price of imports does not change, it does not imply that the relative price of imports to exports are unchanged. For instance, changes in the level of exports to the United States may still be associated with a change in the U.S. wage relative to the wage in all countries; a terms of trade effect that would differentiate out in the reduced-form regressions.

Recent empirical studies have estimated the effects of the 2018 trade war on outcomes other than U.S. prices. Amiti, Kong, and Weinstein (2020a) estimate the effects of the trade war on investment. Notably, the authors propose a methodology that builds on a variant of a stock-market event study. Using this methodology, they estimate the effects on both treated and untreated firms. The authors find that the trade

[4] More recently, Amiti, Redding, and Weinstein (2020b) explore further the trade war effects of tariffs in a longer period and find complete passthrough to domestic prices except for steel inputs. In particular, they find complete passthrough in the short-run for tariffs on steel inputs and that the passthrough falls to 50 percent after a year.

war lowered the investment growth rate of listed U.S. companies by around 1.9 percentage points.

2.2 Trade in Intermediate Goods: Global Value Chains

The large increase in trade in intermediate goods has led to the globalization of value chains (see Johnson and Noguera 2012, and Antràs and Chor 2021). When it comes to supply chains, the incidence of a tariff may be larger because tariffs affect the input of goods that are used for the production of goods that are later exported.[5] There is a fast-growing body of empirical literature studying the effects of changes on import tariffs that takes into account supply chains.

Two recent studies, Handley, Kamal, and Monarch (2020) and Flaaen and Pierce (2019), use the 2018-2019 U.S. import tariff increase to learn about the effects of the change in trade policy taking into account supply chain linkages. Handley, Kamal, and Monarch (2020) find that firms that were impacted by the change in tariffs accounted for 84 percent of U.S. exports and represent 65 percent of manufacturing employment. In addition, the effect of the change in policy cost an average of $900 per worker in new duties. Flaaen and Pierce (2019) find evidence that the import protection received by U.S. manufacturing industries that were more exposed to tariff increases was offset by larger negative effects from rising input costs and retaliatory tariffs. These results speak to the importance of taking into account sectoral linkages when studying the effects of import tariffs.[6]

Import tariffs are not the only trade policy instrument that can disrupt supply chains. Recent papers study the effects of other trade policies, including rules of origin (Conconi, Garcia-Santana, Puccio, and Venturini 2018) and anti-dumping duties (e.g., Bown, Conconi, Erbahar, and Trimarchi 2021; Erbahar and Zi 2017).[7] In particular, Conconi, Garcia-Santana, Puccio, and Venturini (2018) show that rules of origin in free trade agreements lead to a sizeable reduction in imports of intermediate goods from third countries relative to member countries. Bown, Conconi, Erbahar, and Trimarchi (2021) propose an instrument for anti-dumping duties to study the effects of trade policy along supply chains. The instrument builds on the idea that U.S. politicians have incentives to use trade policy to favor important industries in swing states (e.g., Conconi, DeRemer, Kirchsteiger, Trimarchi, and Zanardi 2017; Ma and McLaren 2018; Muuls and Petropoulou 2013).

[5] A clear example is the result in Bond, Crucini, Potter, and Rodrigue (2013). The researchers find that once sectoral linkages are taken into account, the average Smoot–Hawley tariff rate of 46 percent in 1933 is equivalent to a uniform tariff rate of 70 percent.

[6] In related research, Barattieri and Cacciatore (2020) find empirical evidence that temporary trade barriers (antidumping, countervailing duties, and safeguards) implemented in the United States during the last two decades had small beneficial effects in protected industries, while the effects in downstream industries were negative and significant.

[7] Other recent related research considers the effects of trade preferences given to developing countries on trade flows (Cherkashin, Demidova, Kee, and Krishna 2015), firms' incentives to comply with the rules of origin (Ju and Krishna 2005), and the impact of China's falling tariffs on the organization of its exports between ordinary and processing trade (Brandt and Morrow 2017).

Looking beyond the effects of trade policy on global value chains, recent work by Blanchard, Bown, and Johnson (2017) provides empirical evidence of how global value chains shape trade policy. Combining data on bilateral import protection and value-added content, the authors estimate the influence of value-added content on tariff setting across countries. The authors find that higher domestic value added in foreign final goods results in lower applied bilateral tariffs and that higher foreign value added in domestic final goods results in lower applied bilateral tariffs. Bown, Erbahar, and Zanardi (2020) provide additional supportive evidence and find that anti-dumping duties are more likely to be removed when domestic value added in foreign production grows faster.

We now turn to review another set of important empirical findings in the empirical trade policy literature.

2.3 The Effects of Trade Policy Across Local Labor Markets

Different regions in a given country have different exposure to sectoral changes in import tariffs. With frictions to the mobility of goods and factors across space, changes in trade policy may have heterogeneous outcomes according to one region's level of exposure relative to another region's. The distributional consequences of trade policy across local labor markets is a theme in the recent empirical literature. We now discuss the econometric approach applied to study the spatial effects of trade policy, the approach's advantages and challenges, and how to interpret the findings.

2.3.1 Shift-share Analysis

One of the most popular econometric frameworks over the last decade for studying the effects of trade policy across space builds on the literature on shift-share analysis. This branch of research started in the 1940s (Creamer 1943), mostly as an accounting exercise to predict regional growth and the regional effects of tax and regulation policies. The method is simple and has gained traction as a framework for analyzing the effects of trade policy on outcomes such wages, employment, and poverty. The method exploits the fact that trade policy changes are usually heterogeneous across sectors and that sectoral economic activity is unevenly distributed across space.

The basic idea of shift-share analysis is to model the impact of shocks, or "shifters," on given outcomes in regions that have differential exposure, or "shares," to the shock. Shift-share regressions commonly take the following specification:

$$y_n = \alpha_0 X_n + \alpha_1 \sum_j \omega_{nj} Z_j + e_n$$

In this specification, y_n is an outcome of interest, X_n is a set of controls, and e_n is an error term. The variable Z_j is a set of shocks, or "shifters," that are heterogeneous across sectors j, and ω_{nj} is the employment share of sector j in region n. In the context of trade policy, tariffs are used as shifters.

To explain the method further, we follow Topalova (2010) who applies the shift-share method to study the effects of trade liberalization on poverty in rural districts in India. To carry out the analysis, the author exploits both the sectoral composition of economic activity across 450 districts in India and the sectoral variation in trade liberalization (the average import tariffs dropped from 80 to 37 percent from 1990 to 1996, while the standard deviation of tariffs fell by 50 percent). The study runs the following specification:

$$y_{dt} = \alpha_0 + \alpha_1 Tariff_{dt} + Post_t + \delta_d + e_{dt}.$$

In this specification, y_{dt} is the outcome of interest at the district level d and time t, α_0 is a constant, $Post_t$ controls for aggregate shocks or trends that affect the economy, and δ_d are district fixed effects. The term $Tariff_{dt}$ captures the level of protection at the district level. This term takes a shift-share form, namely

$$Tariff_{dt} = \sum_j \omega_{dj,1991} \left(\tau_{j,t} - 1\right),$$

where $\tau_{j,t}$ are one plus the sectoral ad-valorem tariffs and the "shares" (weights) $\omega_{dj,1991}$ are defined as the employment share of industry j in district d in the pre-shift period of 1991.[8] Concretely,

$$\omega_{dj,1991} = \frac{L_{dj,1991}}{\sum_j L_{dj,1991}}.$$

The coefficient of interest is α_1. This coefficient captures the average effect of trade liberalization on the district-level outcome. As correctly emphasized in Topalova (2010), the estimation strategy does not identify the overall impact of trade liberalization on the outcome, but it instead measures whether some districts are affected more than others. Using this econometric specification, Topalova (2010) finds that rural districts in which the sectors were more exposed to tariff changes experienced a slower decline in poverty and lower consumption growth relative to the other regions.

[8] In the specification, Topalova (2010) ignores workers in non-traded production sectors. Her argument is that since $Tariffdt$ is scaled by tariffs, the measure is sensitive to the share of people involved in the non-traded sectors in which tariffs are zero. Thus, $Tariffdt$ might be related to initial poverty levels and could confound the empirical strategy for many reasons (e.g., if there was convergence in district outcomes for reasons unrelated to trade policy).

More recently, Kovak (2013) uses a similar shift-share analysis to study the effects of trade liberalization on wages across Brazilian regions. In particular, the specification in Kovak (2013) is

$$\mathrm{d}\ln(w_r) = \zeta_0 + \zeta_1 RTC_r + e_r \tag{1}$$

where $\mathrm{d}\ln(w_r)$ is the log wage in region r, RTC_r stands for region-level tariff changes, ζ_0 is a constant, and e_r is an error term orthogonal to tariffs. The coefficient of interest is ζ_1, which measures the effects of changes to regional tariffs on earnings across regions. As in Topalova (2010), RTC_r takes a shift-share form, in particular

$$RTC_r = \sum_j \omega_{rj} dln(\tau_j),$$

where the shifter $dln(\tau_j)$ is the change in one plus tariffs across sectors j. The share ω_{rj} is the weight of each industry in each region, given by

$$\omega_{rj} = \frac{\frac{L_{rj}}{L_r}\frac{1}{1-\beta_{rj}}}{\sum_{j'}\frac{L_{rj'}}{L_r}\frac{1}{1-\beta_{rj'}}},$$

where β_{rj} is the share of labor payment in gross output in industry j. Notice that these shares map onto the ones used by Topalova (2010) if $\beta_{rj} = \beta$; namely, if there is no heterogeneity in the labor payment in gross output across industries.

Kovak (2013) finds that regions exposed to the largest tariff declines experienced smaller wage growth relative to regions that experienced smaller tariff cuts. In addition to this empirical finding, Kovak (2013) makes an important methodological contribution. The paper presents an economic theory that can justify the empirical specification of the shift share. In the next section, we build on Kovak (2013) and present a theory behind the shift-share analysis. We also extend the theory to richer settings and derive the correspondent shift-share specifications.

Shift-share analysis poses two main issues for the interpretation of the results from the shift-share regressions. First, as discussed in Topalova (2010), the coefficient in shift-share regressions, as in any differences-in-differences estimates, captures differential effects; namely, the impact of tariff changes in regions that have greater exposure to changes in trade policy relative to regions that have less exposure. Therefore, on their own, shift-share regressions do not provide information about aggregate effects. In Section 3, we discuss general equilibrium frameworks that allow to recover level or aggregate effects of trade policy changes. Second, shift-share analysis raises the question of the underlying economic model that justifies the shift-share specification. In the next subsection, we study the connection between shift-share regressions and economic models, and we provide further details about the interpretation of shift-share estimates.

2.3.2 Theory Behind Shift-share Analysis

In this section, we derive an economic model that gives rise to the shift-share formulation. The economic model we present is based on the small-open economy, specific-factor model described in Kovak (2013), which in turn builds on Jones (1975). We extend this baseline model to allow for imperfect regional labor mobility. We also discuss how to extend this model to show how the shift-share specification depends on the underlying structure of the model.

Consider an economy with R regions indexed by n and J sectors indexed by j. Assume that labor is freely mobile across sectors within a region and imperfectly mobile across regions. Firms produce with a constant return-to-scale technology that uses local factors of production: labor (L) and a fixed factor (H). We assume that labor and the fixed factor are aggregated with Cobb-Douglas technology. Denote by Y_{nj} the output in sector j and region n, given by

$$Y_{nj} = A_{nj} L_{nj}^{\beta_{nj}} H_{nj}^{1-\beta_{nj}},$$

where A_{nj} is the Total Factor Productivity (TFP) in sector j and region n, β_{nj} is the share of labor in output, and $1 - \beta_{nj}$ is the share of the fixed factor in output. The demand for labor and the fixed factor in sector j and region n are given by L_{nj} and H_{nj}, respectively. From the firm's cost-minimization problem, we obtain that the optimal labor demand in nj is given by

$$L_{nj} = \frac{\beta_{nj} P_{nj}}{w_n} Y_{nj},$$

where P_{nj} is the price of output in sector j and region n.

Using the optimal labor demand, we obtain that the regional labor market clearing condition can be written as

$$L_n = \sum_j \frac{\beta_{nj} P_{nj}}{w_n} Y_{nj} \text{ for all } n.$$

Totally differentiating the labor market clearing condition, using the first-order condition of the firm's cost-minimization problem, and solving for the change in wages, we obtain (see Section A of the online appendix for further details)

$$dln w_n = -\delta_n dln L_n + \sum_j \omega_{nj} dln P_{nj} + \sum_j \omega_{nj} dln A_{nj}, \tag{2}$$

where $\delta_n \equiv \left(\sum_j \frac{L_{nj}}{L_n}\frac{1}{1-\beta_{nj}}\right)^{-1}$ and $\omega_{nj} \equiv \delta_n \frac{L_{nj}}{L_n}\frac{1}{1-\beta_{nj}}$.

We now discuss the regional supply of labor. In particular, we introduce imperfect labor mobility by assuming that moving to location n entails a multiplicative cost ε_n that is an $i.i.d.$ draw from an extreme-value Frechet distribution with shape parameter ν (the cost draw in measured in utils and can also be interpreted as an amenity shock).[9] Using the properties of the Frechet distribution, we see that the labor supply in location n is given by

$$L_n = \frac{(w_n)^\nu}{\sum_i (w_i)^\nu} L,$$

where L is the country's total endowment of labor. Totally differentiating this expression, we obtain

$$dln L_n = \nu dln w_n - dln \Phi, \tag{3}$$

where we denote $\Phi \equiv \sum_i (w_i)^\nu$. We now substitute this new equilibrium relation into (2), and then solving for wages once more, we obtain

$$dln w_n = \frac{\delta_n}{(1+\delta_n\nu)} dln\Phi + \frac{1}{(1+\delta_n\nu)} \sum_j \omega_{nj} dln P_{nj} + \sum_j \frac{\omega_{nj}}{(1+\delta_n\nu)} dln A_{nj}.$$

The last important assumption is that each region is a small, open economy. As a result of this assumption, price changes are a function of tariff changes only; namely, $dln P_{nj} = dln\tau_j$. It follows, then, that

$$dln w_n = \frac{\delta_n}{(1+\delta_n\nu)} dln\Phi + \frac{1}{(1+\delta_n\nu)} \sum_j \omega_{nj} dln \tau_j + \sum_j \frac{\omega_{nj}}{(1+\delta_n\nu)} dln A_{nj}. \tag{4}$$

Notice that this relationship has the same structure as the shift-share regression. The identifying assumption in the econometric specification assumes that local exposure to tariffs is uncorrelated to changes in local labor supply and technology. In addition, researchers impose structure on the TFP shifters $\sum_j \frac{\omega_{nj}}{(1+\delta_n\nu)} dln A_{nj}$, which are usually controlled with fixed effects or modeled inside the error term.

[9] In a related setup, Gertler (2021) embeds a Roy model with imperfect sectoral mobility due to idiosyncratic Frechet draws into a specific-factors model. The author derives shift-share regressions to study the effects of the 1997 Asian crisis on the U.S. local labor markets.

From now on, we focus on the shift-share variable of interest, which we denote as

$$Shift\text{-}share_n = \sum_j \omega_{nj} d\ln\tau_j. \tag{5}$$

Note that if $\beta_{nj} = \beta$; the shift-share variable in the model we have specified is the same as the shift-share variable in Kovak (2013). In addition, for small changes in tariff such that $d(\tau_j - 1) \approx d\ln\tau_j$ the shift-share variable is the same as in Topalova (2010).

2.3.3 Discussion and Interpretation of the Shift-share Trade Policy Analysis

Shift-share analysis is a simple tool for studying the differential effects of trade policy across space. A main aspect of the analysis that merits highlighting is the interpretation of the estimated coefficients. The first takeaway, as mentioned earlier, is that the specification does not estimate level effects. The coefficient can only be interpreted as the deviation from aggregate effects; that is, the effect of a change in tariffs in a given market relative to the average effect of the change in tariffs in the economy $(\delta_n / (1 + \delta_n \nu) d\ln\Phi$ in equation (4)).

Shift-share analysis can shed light on relevant mechanisms or elasticities and in this way can be used to guide structural models. For instance, notice that the specific-factor model in which labor is not mobile across regions but perfectly mobile across sectors predicts a regression coefficient $\zeta_1 = 1$ in the regression equation (1). To see this, set $\nu = 0$. Then L_n is fixed and $d\ln L_n = 0$. Alternatively, under this restriction, from equation (3) we obtain $\nu d\ln w_n = d\ln\Phi$, and the coefficient multiplying the shift share in (4) is one. At the other extreme, with perfect labor mobility, wages are equalized across regions and therefore the regression should give a value of $\zeta_1 = 0$ (see Section A of the online appendix for details). Empirically, the analysis in Kovak (2013) finds a coefficient $0 < \zeta_1 < 1$. Therefore, the empirical estimate is suggestive of imperfect regional migration as opposed to free mobility or labor immobility.

Another important lesson from the literature is that the shift-share specification cannot be disconnected from the theory.[10] In particular, how the share variable is constructed can have important consequences for the estimated effects and interpretation. The share variable in (5) is not invariant to the structure of the model behind the analysis. Here we illustrate this point using three cases: with non-tradable industries, when the production function is not unit-elastic, and under the presence of intermediate goods and input-output linkages in production.

[10] In this context, Adao, Arkolakis, and Esposito (2019a) show how to structurally interpret shift-share regressions within a structural model and discuss the nature of the fixed effect. Moreover, Kim and Vogel (2021) present a structural model with labor market frictions to interpret the shift-share specification of Autor, Dorn, and Hanson (2013) and to study the effects of the China shock across different margins.

In the presence of non-tradable sectors, a practical approach has been to set the change in the price of the non-tradable goods equal to zero in the regression (e.g., Autor, Dorn, and Hanson 2013; Edmonds, Pavcnik, and Topalova 2010; Hakobyan and McLaren 2016; Topalova 2010). However, the assumption that changes in tariffs have no effects on the price of non-tradable goods might not be innocuous. To see this, suppose we add a non-tradable sector in the economy, then (2) becomes

$$d\ln w_n = -\delta_n d\ln L_n + \sum_{j \neq NT} \omega_{nj} d\ln P_{nj} + \omega_{nNT} d\ln P_{nNT} + \sum_j \omega_{nj} d\ln A_{nj}. \tag{6}$$

In order to derive the shift-share specification, we need to solve for the endogenous change in the price of non-tradable goods. To do so, we need additional structural relationships from the demand side of the economy. Consider the case in which local consumers have Cobb-Douglas preferences and spend a constant share of their income on goods from each sector j. Following the same derivations as before (see Section A of the online appendix for the derivations), we obtain

$$Shift\text{-}share_n = \sum_{j \neq NT} \left(\frac{\omega_{nNT} \vartheta_{nj}}{(1 - \vartheta_{nNT})} + \omega_{nj} \right) d\ln \tau_j,$$

where $\vartheta_{nNT} = (1 - \beta_{nNT}) \frac{Y_{nNT} P_{nNT}}{\sum_j P_{nj} Y_{nj}} + \beta_{nNT} \omega_{nNT}$ and $\vartheta_{nj} = (1 - \beta_{nNT}) \frac{Y_{nj} P_{nj}}{\sum_j P_{nj} Y_{nj}} + \beta_{nNT} \omega_{nj}$. Accounting for non-tradable goods changes the structural relationship between the shift share and the outcome of interest. Clearly, the theory suggests that the tariffs affect the price of non-tradable goods and that this indirect effect needs to be taken into account in the shift-share specification. Kovak (2013) does allow for non-tradable goods in his analysis and finds that the magnitude of the effects are quantitatively different if this margin is taken into account.

Another aspect that is omitted in the shift-share analysis is the role of intermediate goods and input-output linkages. We now extend our basic model and derive the shift-share equation with intermediate goods and input-output linkages. In particular, we assume that firms produce with a constant return-to-scale technology using labor, a fixed factor, and materials (M) from all sectors according to the input-output structure of the economy. Consider a Cobb-Douglas technology to aggregate across factors of production and materials, and denote by γ_{nj} the share of intermediate goods in production. Let $\gamma_{jk,n}$ denote the share of sector k in intermediate consumption in sector j and country n, with $\sum_k \gamma_{jk,n} = 1$. After deriving the shift-share specification, we end up with two shifters (see Section A of the online appendix for details): a shifter that reflects the direct impact of the change in tariffs in its own sector and another shifter that reflects how shifts in tariffs from other sectors impact the outcome. In particular, the shift-share equation is given by

$$Shift\text{-}share_n = \sum_j \omega_{nj}^{IO} d\ln\tau_j - \sum_j \tilde{\omega}_{nj}^{IO} \sum_{k\neq j} \gamma_{jk,n} d\ln\tau_k,$$

where

$$\omega_{nj}^{IO} = \omega_{nj} \frac{(1-\gamma_{nj}\gamma_{jj,n})}{(1-\gamma_{nj})}.$$

$$\tilde{\omega}_{nj}^{IO} = \omega_{nj} \frac{\gamma_{nj}}{(1-\gamma_{nj})} \sum_{k\neq j} \gamma_{jk,n}.$$

It is easy to see that when $\gamma_{jk,n} = 0$ and $\gamma_{jj,n} = 1$, then $\omega_{nj}^{IO} = \omega_{nj}$ and $\tilde{\omega}_{nj}^{IO} = 0$. There are two extreme cases in which the shift-share equation in a model with intermediate goods and linkages is isomorphic to the previously derived one. The first of these cases is when the changes in tariffs are the same across all sectors; namely, $d\ln\tau_j = d\ln\tau$. Another case in which the shift-share equation resembles the model with no input-output linkages is when the economy is perfectly symmetric across sectors; namely, $\gamma_{jk,n} = \frac{1}{J}$, $\gamma_{nj} = \gamma_n$, $\omega_{nj} = \omega_n$. In Section A of the online appendix, we provide these results. Importantly, note that with input-output linkages, the shift-share equation is in general very different. In fact, input-output linkages open up the possibility of opposing effects since changes in tariffs have a direct impact on final goods, and also impact the price of the goods used as materials in production.

Finally, suppose we consider a more general production function with an elasticity of substitution between labor and the fixed factor given by ρ_j. Then, it follows that the shift-share equation is

$$Shift\text{-}share_n = \sum_j \omega_{nj}^{CES} d\ln\tau_j,$$

with the share term given by

$$\omega_{nj}^{CES} = \frac{\frac{L_{nj}}{L_n}\frac{\rho_j}{1-\beta_{nj}}}{\sum_k \frac{L_{nk}}{L_n}\frac{\rho_j}{1-\beta_{nk}}}.$$

Note that when $\rho_j = 1$, then $\omega_{nj}^{CES} = \omega_{nj}$. In addition, if there is no sectoral variation in β_{nj} and $\rho_j = 1$, the expression collapses to the baseline case (Section A of the online appendix provides further details.)[11]

In addition to considering these examples, one might think about other relevant economic mechanisms such as internal trade, firms' entry and exit decisions, and dynamic factor accumulation, any of which could

[11] The derivation of the shift share with CES technology is similar to the one in the appendix in Kovak (2013).

make the shift-share specification even more difficult to interpret.

Moving beyond the interpretation of the shift-share analysis, there is another important set of issues that relates to the assumption of the exogenous variation in shifters and shares. Recent studies by Adao, Kolesar, and Morales (2019b), Borusyak, Hull, and Jaravel (2018), and Goldsmith-Pinkham, Sorkin, and Swift (2020) take up these issues and provide insight into the statistical properties of the shift-share designs. These studies are mainly concerned with shift-share specifications in which the exogenous variation of the shifters are not tariffs, as in the case of Autor, Dorn, and Hanson (2013). Redding (2020) reviews recent shift-share designs that study the effects of trade shocks beyond trade policy. Of course, if the variation in tariff changes is correlated with changes in the local labor supply and technology, then most of the econometric and inference issues presented in these studies will also apply when using tariffs as shifters.

2.3.4 Persistent Effects of Trade Policy

A central line of research in current trade policy literature is the study of the distributional employment, wage, and welfare effects of changes to trade policy over time. We now review new empirical evidence on the subject.

Menezes-Filho and Muendler (2011) examine the dynamics of local labor market adjustment in response to the 1990s trade liberalization episode in Brazil. The paper provides evidence that workers who were separated from their jobs due to import competition tended to take years in order to find jobs in new industries.[12] Autor, Dorn, Hanson, and Song (2014), using longitudinal data on U.S. manufacturing workers, provide evidence that the effect of increased import competition from China impacted the incomes of blue-collar workers for more than a decade. Similarly, Hummels, Jorgensen, Munch, and Xiang (2014) study the effects on Danish firms exposed to offshoring. They find a negative effect on blue-collar wages that persisted for almost four years. More related to a change in trade policy is the study of Dix-Carneiro and Kovak (2017), which we now describe in greater detail.

Dix-Carneiro and Kovak (2017) also use the 1990s trade liberalization episode in Brazil to study dynamic labor market outcomes. Relative to Menezes-Filho and Muendler (2011), they use a longer panel and more years. The authors perform a dynamic shift-share analysis. In particular, the paper exploits variation in unilateral tariff reductions across industries and variation in the industry mix of local employment across Brazilian regions to measure changes in local labor demand induced by liberalization. Concretely, Dix-

[12] In related research, Devlin, Kovak, and Morrow (2021) use matched employer-employee data to assess the long-run effects of the 1988 Canada-U.S. Free Trade Agreement (CUSFTA) on Canadian workers, finding relatively smooth transitions across employers and industries.

Carneiro and Kovak (2017) run a specification similar to that of Kovak (2013) with time lags; namely,

$$y_{rt} - y_{r,1991} = \theta_t RTC_r + \alpha_{st} + \gamma_t \left(y_{r,1990} - y_{r,1986} \right) + e_{rt}.$$

Here y_{rt} is the outcome of interest, either earnings or employment. The term α_{st} is a time-varying-state fixed effect, and $\gamma_t \left(y_{r,1990} - y_{r,1986} \right)$ controls for pre-trends. Here the shift-share RTC_r is the same as the one in Kovak (2013), but by allowing θ_t to change over time, they are able to capture the effects across time. Dix-Carneiro and Kovak (2017) find that changes in trade policy have varying regional effects in the short run but that the effects of trade liberalization on employment and earnings are persistent over time; namely, the coefficient θ_t increases over the years. Decades after Brazil's trade liberalization, the effects continued to be unevenly distributed across space. Some of these findings might reflect barriers to interregional mobility, and some might be a consequence of other frictions for industries to adjust to changes in policy.

We have thus far reviewed empirical evidence of actual changes in trade policy. We now review another line of research that focuses on the effects of trade policy uncertainty.

2.4 Trade Policy Uncertainty

A recent and fast-growing stream of literature focuses on the economic effects of trade policy uncertainty. There are two pioneer papers in this literature: a reduced-form study performed by Pierce and Schott (2016) and a structural analysis by Handley and Limao (2017). In this section we review Pierce and Schott (2016), and in the next section we describe structural studies like that of Handley and Limao (2017) and their extensions.

Pierce and Schott (2016) find a link between the sharp decline in U.S. manufacturing employment in the 2000s and the United States' granting of permanent normal trade relations (PNTR) to China. The authors argue that the conferral of PNTR removed the uncertainty associated with these annual renewals by permanently setting U.S. duties on Chinese imports at normal trade relations (NTR) levels. To establish this link, the authors compute the "NTR gap," defined as the difference between the non-NTR rates to which tariffs would have risen if annual renewal had failed and the NTR tariff rates that were locked in by PNTR. Importantly, in the econometric analysis, the authors exploit the substantial variation in NTR gaps across industries. The baseline difference-in-differences (DID) specification is given by

$$ln(EMP_{it}) = \theta PostPNTR_t \times NTR\ Gap_i + PostPNTR_t \times X_i'\gamma + X_{it}'\lambda + \delta_t + \delta_i + \alpha + e_{it}.$$

The first term on the right-hand side is the DID term of interest, an interaction of the NTR gap and an indicator of the post-PNTR period, and the second term is an interaction of the post-PNTR dummy variable and time-invariant industry characteristics. The other terms in the regression are various control variables and fixed effects.

The authors' results reveal a statistically negative relationship between the change in U.S. policy and subsequent employment in manufacturing. The baseline specification implies that moving an industry from an NTR gap at the twenty-fifth percentile of the observed distribution to the seventy-fifth percentile increases the implied relative loss of employment by 0.08 log points.

In addition to considering the effects of trade policy uncertainty on manufacturing employment, recent research has addressed the impact of trade policy uncertainty on firm-level outcomes. For example, Greenland, Ion, Lopresti, and Schott (2020) use asset price reactions to trade policy events to compute abnormal returns as a measure of the policy exposure of firms; the authors then estimate the effects of abnormal returns on firms' outcomes. They find that the conferral of PNTR to China had differential effects on profits and employment in small and large U.S. firms but that the the Canada-United States Free Trade Agreement had small distributional effects across firms.

We conclude Section 2 by summarizing the main takeaways from the empirical studies discussed in the section. First, when there is tariff policy variation across sectors, one needs to take into account supply-chain linkages in order to evaluate the effects of trade policy. Second, trade policy has heterogeneous effects across spatially distinct labor markets. Third, the effects of trade policy may be long-lasting. Fourth, trade policy uncertainty has real economic effects.

While most of the previous studies identify differential effects of trade policy, and in particular how more exposed sectors and regions are affected relative to less exposed sectors and regions, researchers are also interested in understanding aggregate and general equilibrium effects. Recent advances in the trade literature have led to the development of quantitative tools to study these general equilibrium effects. We now review literature on quantitative trade policy models and use recent advances to develop a quantitative trade policy model that takes into account most of the margins that the reduced-form literature has identified as important.

3 Quantitative Trade Policy Analysis in General Equilibrium

One of the recent advances in the trade literature has been the use of quantitative trade models to quantify the different mechanisms by which trade policy affects trade and welfare. Of course, quantitative general equilibrium models have always been an important empirical tool of analysis, starting with the computable general equilibrium models (e.g., GTAP, Michigan Model, and others that are summarized in Dixon and Jorgenson 2012). The key innovation in recent decades has been the development of quantitative models that are more tractable for studying the role of different relevant mechanisms and these models' extensions in many dimensions. These recent quantitative models are built on the new models of international trade with perfect competition and heterogeneous productivity, as in Eaton and Kortum (2002), and with imperfect competition and heterogeneous firms, as in Melitz (2003). As such, the mechanisms emphasized, the data used, and the new techniques developed to estimate elasticities, calibration methods, and model estimation techniques make these developments in quantitative trade theory a valuable empirical tool for trade policy analysis that has gained traction in the literature.

Quantitative frameworks contain a variety of building blocks in terms of production structure, preferences, number and type of sectors (tradable and non-tradable), market structure, economic geography, source (or absence) of dynamics, treatment of trade deficits, and the mobility of goods and people. Several recent reviews provide a description of the alternative economic environments, or building blocks. For example, Costinot and Rodríguez-Clare (2014) and Ossa (2016) review static, one-sector, and multi-sector models of commercial policy. Redding and Rossi-Hansberg (2017) review quantitative spatial models that can be extended to study the spatial effects of trade policy. McLaren (2017) reviews frameworks with labor market dynamics that can also be extended to evaluate the effects of trade policy across labor markets, and Alessandria, Arkolakis, and Ruhl (2020) review frameworks with trade and firm dynamics that can also be used to study the effects of trade policy.

We now present a quantitative model that can be applied to study the aggregate, distributional, and general equilibrium effects of trade policy across sectors, across spatially distinct labor markets, and over time. We discuss recent advances in data availability, estimation, and solution methods that apply to most of the quantitative frameworks that we review. In addition, by way of example, we show how to apply the methods and data to perform trade policy counterfactuals and study the effects of the recent trade war between the United States and its trading partners across different margins.

3.1 Aggregate and Sectoral Effects of Trade Policy

The most common characteristic of the recent quantitative trade models is the gravity structure. We see gravity as an empirical and theoretical success of the literature since it has disciplined structural trade frameworks in terms of how fundamentals and trade barriers relate to trade flows. The micro-foundations that have given rise to the gravity structure differ in recent quantitative trade models; for example, see Eaton and Kortum (2002), Anderson and van Wincoop (2003), Bernard, Eaton, Jensen, and Kortum (2003), and Chaney (2008).

Building on these advances, recent studies have analyzed trade policy assuming different market structures with either homogeneous or heterogeneous goods in single-sector and multi-sector economies. For example, Ossa (2014) builds on the new economic geography literature with homogeneous goods (akin to Krugman 1980). Other frameworks allow for goods and sectoral heterogeneity. These frameworks build on Eaton and Kortum (2002) (e.g., Caliendo and Parro 2010; Caliendo and Parro 2015; Levchenko and Zhang 2016; Shikher 2012; for a comprehensive survey of recent extensions of the Ricardian model of trade, refer to Eaton and Kortum 2012). Other studies have performed trade policy evaluations using models with heterogeneous firms and multi-sectors, building on Melitz (2003), Chaney (2008), and Melitz and Ottaviano (2008); as in Balistreri, Hillberry, and Rutherford (2011), Caliendo, Feenstra, Romalis, and Taylor (2015), and Spearot (2016).

The majority of studies evaluating trade policy have assumed CES utility functions, either by assuming a unitary elasticity or different nests between foreign and domestic varieties. Spearot (2016) develops a quantitative framework that introduces non-homothetic preferences to evaluate the effects of trade policy.[13]

A strand of the literature has departed from a single factor of production to study the effects of trade policy changes on income inequality (e.g., Dix-Carneiro and Kovak 2017; Hakobyan and McLaren 2016), or more generally, the effects of other trade-related shocks on income inequality (e.g., Burstein, Cravino, and Vogel 2013; Burstein and Vogel 2017; Galle, Rodríguez-Clare, and Yi 2017; Lee 2020; Lyon and Waugh 2019; Parro 2013; Waugh 2019). When considering multi-input settings, one must also take a stand on the substitutability across inputs. Most of the recent quantitative work has followed the assumption of a unitary elasticity.[14]

There are different approaches to treating observed trade imbalances. Static frameworks follow alternative routes to address (partially) this issue. One approach is to assume that country-aggregate trade imbalances are constant relative to world GDP and lump-sum transferred to consumers (e.g., Caliendo and Parro 2015). A second approach is to use the equilibrium conditions to eliminate trade imbalances (e.g., Caliendo and Parro 2015; Ossa 2011; Ossa 2014). A third approach is to create a system of income transfers across locations to match observed imbalances (e.g., Caliendo, Parro, Rossi-Hansberg, and Sarte 2017; Fajgelbaum, Morales, Suárez Serrato, and Zidar 2018; Fajgelbaum and Gaubert 2020). A fourth approach is to consider

[13] More generally, in the context of studying the effects of trade shocks with non-homothetic preferences, see Fieler (2011), Fajgelbaum and Khandelwal (2016), and Caron, Fally, and Markusen (2020).

[14] See, for example, Costinot and Rodríguez-Clare (2014) for an analysis of the sensibility of the welfare implications of different elasticities of substitution across inputs in different classes of trade models.

imbalances as international transfers of income and profits due to multinational activity (e.g., Arkolakis, Ramondo, Rodríguez-Clare, and Yeaple 2018).

Recent dynamic trade frameworks have introduced endogenous trade imbalances through savings and investment decisions (e.g., Dix-Carneiro, Pessoa, Reyes-Heroles, and Traiberman 2021; Eaton, Kortum, Neiman, and Romalis 2016b; Eaton, Kortum, and Neiman 2016a; Reyes-Heroles 2017; Sposi 2012; Sposi 2021). Other recent quantitative trade frameworks with capital accumulation, but assuming balanced trade period-by-period, are Anderson, Larch, and Yotov (2019) in the context of a Armington-CES gravity model and Alvarez (2017), Ravikumar, Santacreu, and Sposi (2019), and Sposi, Yi, and Zhang (2020) in the context of a multi-country Eaton and Kortum (2002) model.

The range of assumptions about how mobile labor is across industries and locations in quantitative trade frameworks essentially covers all the possibilities, ranging from labor immobility across sectors and locations, perfect mobility across sectors, and regional labor immobility, to labor mobility frictions across industries and locations. Recent research has also included labor market dynamics to trade and regional/spatial models with homogeneous agents (e.g., Caliendo, Dvorkin, and Parro 2019) and with heterogeneous agents (e.g., Caliendo, Opromolla, Parro, and Sforza 2021b).

In order to illustrate the developments in quantitative trade policy frameworks and to show how to use these frameworks, we choose one of the aforementioned quantitative models that includes trade in intermediate goods, multiple sectors, and sectoral supply-chain linkages. Our starting point is Caliendo and Parro (2015), a multi-country, multi-sector trade policy model with input-output linkages that also captures macro aspects of global value chains.[15] From there, we expand the framework to incorporate the uneven distribution of local economic activity across space that will allow us to speak about the spatial effects of trade policy. We then add labor market dynamics to study the effects of trade policy on the location of employment across space and over time.

3.1.1 Intermediate Goods, Multiple Sectors, and Sectoral Supply-Chain Linkages

Consider a world economy with N countries that are indexed by i and n. In each country i, there are J sectors that are indexed by j and k. Denote by x_i^j the unit cost to produce a good in country i. The unit cost varies across sectors. Assuming a production function that uses labor and materials from all sectors according to the input-output structure of the economy, we have

$$x_i^j = [w_i]^{\gamma_i^j} \prod_{k=1}^{J} \left[P_i^k\right]^{\gamma_i^{jk}}, \tag{7}$$

[15]See Antràs and Chor (2021) for a discussion of recent macro and micro frameworks developed to study global value chains.

where $\sum_{k=1}^{J} \gamma_i^{jk} = 1 - \gamma_i^j$, w_i are factor prices and P_i^k is the price of materials from sector k.

Trade between countries is costly, and we denote by k_{in}^j the trade frictions that goods produced in sector j face when shipped from n to i. These costs may entail non-tariff barriers or geographical frictions and are modeled as "iceberg" trade costs, where $k_{in}^j \geq 1$. In addition, we assume that countries face ad-valorem import tariffs, where τ_{in}^j denotes one plus the ad-valorem tariff that country i applies to n in sector j.

Denote the share that country i spends on goods produced in sector j in country n, by λ_{in}^j. The bilateral trade share in each sector is given by

$$\lambda_{in}^j = \frac{A_n^j \left[\tau_{in}^j \kappa_{in}^j x_n^j\right]^{-\theta^j}}{\sum_{h=1}^{N} A_h^j \left[\tau_{ih}^j \kappa_{ih}^j x_h^j\right]^{-\theta^j}}. \tag{8}$$

Here θ^j is the trade elasticity in sector j, and A_n^j represents sector j country n-specific fundamental TFP (a country-sector productivity shifter). Equation (8) represents a gravity relationship in trade flows between countries i and n.

We denote by P_i^j the sectoral price index that in an Eaton and Kortum (2002) structure with heterogeneous goods takes the functional form

$$P_i^j = \left[\sum_{n=1}^{N} A_n^j \left[\tau_{in}^j \kappa_{in}^j x_n^j\right]^{-\theta^j}\right]^{-1/\theta^j}. \tag{9}$$

The next equilibrium condition defines the goods market clearing condition. The total expenditure on goods traded in sector j and country i is denoted by X_i^j. Households have income I_i, and they spend a share α_i^j of their income on goods from sector j. Firms also spend a share of their costs purchasing intermediate goods from all sectors. Total expenditure on sectoral goods in country i, therefore, is given by

$$X_i^j = \sum_{k=1}^{J} \gamma_i^{kj} \sum_{n=1}^{N} \lambda_{ni}^k \frac{X_n^k}{\tau_{ni}^k} + \alpha_i^j I_i, \tag{10}$$

where γ_i^{kj} is the cost share in country i and sector k on goods from sector j, and where $\sum_{n=1}^{N} \lambda_{ni}^k \frac{X_n^k}{\tau_{ni}^k}$ is the world total expenditure (net of tariffs) on goods produced in sector k and country i (which equals the value of production of sector k goods produced in i).

Trade is unbalanced; hence,

$$\sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\lambda_{in}^j X_i^j}{\tau_{in}^j} = \sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\lambda_{ni}^j X_n^j}{\tau_{ni}^j} + D_i,. \tag{11}$$

In this equation, the left-hand side is country $i's$ total imports and the right-hand side is country $i's$

exports plus the trade deficit D_i, which we take as an exogenous transfer that captures trade imbalances.

Finally, tariff revenue is collected and lump-sum transferred to households. Together with the income households obtain from supplying labor, national income is given by

$$I_i = w_i L_i + TR_i + T_i, \tag{12}$$

where $TR_i \equiv \sum_{j=1}^{J} \sum_{n=1}^{N} \left(\tau_{in}^j - 1 \right) \lambda_{in}^j \frac{X_i^j}{\tau_{in}^j}$ is tariff revenue and T_i are net transfers from the rest of the world. In the case of this model with exogenous trade imbalances, $T_i = D_i$. We now formally define the equilibrium in the model.

Equilibrium of the multi-country, multi-sector model. Given endowments $\left\{L_i\right\}_{i=1}^{N}$, transfers $\left\{D_i\right\}_{i=1}^{N}$, fundamentals $\left\{A_i^j, \kappa_{in}^j\right\}_{i=1,n=1,j=1}^{N,N,J}$, parameters $\left\{\gamma_i^j, \gamma_i^{kj}, \alpha_i^j\right\}_{i=1,j=1,k=1}^{N,J,J}$, and trade elasticities $\left\{\theta^j\right\}_{j=1}^{J}$, an equilibrium under a tariff structure $\left\{\tau_{in}^j\right\}_{i=1;n=1;j=1}^{N,N,J}$ is a wage vector $\mathbf{w} \in \mathbf{R}_{++}^N$ that satisfies equilibrium conditions (7), (8), (9), (10), (11), and (12) for all i and j.

3.1.2 Using Tariff Variation to Estimate Trade Elasticities

Recent studies have used tariff policy variation to identify trade elasticities, which constitute an important parameter for computing the equilibrium in quantitative trade models. Setting aside potential issues with endogeneity, tariff changes could provide the variation needed to estimate these elasticities; however, only a handful of recent studies have used observed changes in tariffs to estimate them. For example, Head and Ries (2001), Romalis (2007), Spearot (2013), and Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2019) use time-series variation in tariffs to estimate trade elasticities, while Caliendo and Parro (2015) and Imbs and Mejean (2015) use cross-sectional variations in tariffs. In many structural models, there is a tight link between the trade elasticity and the import demand elasticity. Moreover, both import demand and export supply elasticities in response to tariffs play key roles for the welfare effects of trade policy (Dixit and Norman 1980). Hillberry and Hummels (2013) and Head and Mayer (2013) provide reviews of approaches that have been commonly used to estimate import demand and trade elasticities. In addition, Head and Mayer (2013) perform a meta-analysis using 744 coefficients obtained from a sample of 32 papers. This meta-analysis shows that when the trade elasticity is identified using tariffs/freight rates, it has an average value of -5.03 (median of -6.74). When using prices/wages/exchange rates, the average estimated value is considerably lower at -1.12 (median of -1.38). Empirical studies differ in the level of aggregation at which these elasticities are estimated and in the underlying micro structure, and therefore, as we discuss below, the estimated parameters in the literature do not always have the same interpretation.

One major challenge when estimating demand and supply elasticities, i.e. the slopes of the demand and supply curves, is that doing so requires at least two instruments (see Wright 1928): ideally, an exogenous shift to the supply curve that could be used to trace out the demand curve and an exogenous shift to the demand curve that could be used to trace out the supply curve. However, in certain circumstances, the particularities of the economic environment allow the researcher to use variation in one policy instrument to identify both the supply and demand elasticities.

For example, consider a case in which there is a change in trade policy. Tariffs create a price wedge between importers and exporters. As a result, for any price the exporter receives, the tariff shifts down the demand curve, and this shift can be used to locally identify the shape of the supply curve. Likewise, for any given price paid by consumers, the tariff shifts up the supply curve and can be used to identify demand elasticity. This idea, which was put forward in the context of changes in tax policy, goes back to Ramsey (1927), and it was recently formalized by Zoutman, Gavrilova, and Hopland (2018). Romalis (2007) applies this idea to estimate demand and supply elasticities in the context of studying the effects of the North American Free Trade Agreement (NAFTA), while Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2019) applies this insight to estimate demand and supply elasticities using the 2018 increases in import tariffs the United States imposed on its trading partners. To see this idea more formally, we follow Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2019). The authors assume an Armington structure in which product varieties are differentiated by country of origin. In particular, within each traded sector, aggregate demand adopts a nested CES structure, in which imported product varieties within a sector are aggregated with an elasticity σ. Denote by m_{in}^{g} the quantity imported of product g' variety by country i from n. Let $p_{in}^{g} = \tau_{in}^{g} p_{in}^{*g}$ be the domestic price of the variety imported from n, where p_{in}^{*g} is the CIF price of the variety imported from n, which also includes bilateral iceberg costs. The quantity imported of product g' variety is then given by

$$m_{in}^{g} = B_{in}^{g} \left[p_{in}^{g}\right]^{-\sigma}, \tag{13}$$

where $B_{in}^{g} \equiv m_g a_{ig} \left[P_M^g\right]^{\sigma}$, P_M^g is the price index of imported varieties, m_g is the total demand for good g, and a_{ig} is a demand shock. Now consider an inverse export supply curve of the following form,

$$p_{in}^{*g} = z_{in}^{g} \left(m_{in}^{g}\right)^{\omega^*},$$

where ω^* is the export supply elasticity and z_{in}^{g} is the foreign marginal cost shifter. Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2019) use time changes in tariffs to simultaneously estimate the import and export demand elasticities. The estimation is performed at the product variety level g assuming that σ is constant across product/sectors. Adding time subscripts to the variables and taking log time differences yields the estimating equations

$$\Delta \ln m_{in,t} = \alpha_t^M + \alpha_{n,t}^M + \alpha_{nj}^M - \sigma \Delta \ln p_{in} + \varepsilon_{in,t}^M$$

$$\Delta \ln p_{n,t}^* = \alpha_t^X + \alpha_{n,t}^X + \alpha_{nj}^X + \omega^* \Delta \ln m_{in,t} + \varepsilon_{in,t}^X,$$

where $\left(\alpha_t^M, \alpha_t^X\right)$ are product-time fixed effects, $\left(\alpha_{n,t}^M, \alpha_{n,t}^X\right)$ are country-time fixed effects, $\left(\alpha_{nj}^M, \alpha_{nj}^X\right)$ are country-sector fixed effects, and $\varepsilon_{in,t}^M$ and $\varepsilon_{in,t}^X$ are import demand and export supply shocks. The identifying assumption is that tariffs are uncorrelated with unobserved import demand and export supply shocks. In order to identify the import demand elasticity σ, one can use the change in tariffs to instrument for tariff-inclusive changes in prices p_{in}^g. Similarly, in order to identify the export supply elasticity, the change in tariffs can be used as an instrument for the change in imports. Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2019) use the 2018 increases in import tariffs imposed by the United States and estimate the elasticities using imports from the United States at the HS-8 product level. Their estimates imply that $\sigma = 2.53$ with a standard error of 0.26 and ω^*= -0.002 with a standard error of 0.05. These results allow them to conclude that they cannot reject a horizontal supply curve. With the estimated elasticities, and assuming complete tariff passthrough and no changes in both U.S. import and export prices, the authors perform a back-of-the envelope computation of the impact of the tariff changes in real income.

In the context of the model with an Eaton and Kortum (2002) structure presented in the previous section, two aspects are worth mentioning. First, each sector in the Eaton-Kortum model is a continuum of varieties that are aggregated under a CES structure, where each variety is produced by the lowest-cost supplier under perfect competition. It follows that $z_{in}^g = \kappa_{in}^g x_n^g$ and $\omega^* = 0$ at the variety level in the Eaton-Kortum model since producers cannot influence the world price of a variety (given that there are infinite potential suppliers of each variety). Second, the variety import demand elasticity σ estimated in Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2019) is not the same parameter as the sectoral trade elasticity θ^j in equation (8), since the latter also reflects how firms switch suppliers of varieties in a given sector.

An approach to directly estimate the trade elasticities θ^j is to use cross-sectional variation in tariffs and trade flows. Caliendo and Parro (2015) consider three countries indexed by n, i, and h.[16] Using equation (8), if we take the cross-product of imports between the three countries–from n to i, from i to h, and from h

[16]For further details on this method, see Caliendo and Parro (2015), Head and Mayer (2013), Costinot and Rodríguez-Clare (2014), and Imbs and Mejean (2015).

to n–and then the cross-product of the same goods shipped in the other direction–from n to h, from h to i, and from i to n,–all the terms involving prices and parameters are canceled out, leaving us with an equation that relates bilateral trade flows, tariffs, and iceberg trade costs. After parameterizing trade costs, Caliendo and Parro (2015) estimate the trade elasticity at the ISIC rev.3 sectoral level using 1993 trade flows and tariffs. The trade elasticities are very heterogeneous across sectors, and the estimated average elasticity for the manufacturing sector is 4.5.

Recent approaches have provided estimates of trade elasticity using tariff policy variation at different time horizons. Notably, Boehm, Levchenko, and Pandalai-Nayar (2020) exploit tariff policy variation using changes to most-favored-nations tariffs as an exogenous tariff change to small countries. The study estimates short-run and long-run trade elasticities that are somehow smaller than the values typically used in quantitative trade literature. In consequence, quantifications with these numbers result in larger gains from trade.

Given the recent changes in trade policy across countries, we expect more studies to use trade policy variation to estimate this key parameter. We now shift to explain how to perform trade policy counterfactuals using a quantitative model like the one described in Section 3.1.1.

3.1.3 Trade Policy Counterfactuals

In this section we explain how to perform trade policy counterfactuals (change in import tariffs) using the quantitative trade model presented in Section 3.1.1. One option for performing counterfactuals is to estimate the entire set of fundamentals, parameters, and trade elasticities and then solve for the equilibrium factor prices given a new tariff structure. Another approach is to use the exact-hat algebra methodology developed by Dekle, Eaton, and Kortum (2007).[17] In particular, the exact-hat algebra method consists of writing the equilibrium equations of an economy with a new set of policies relative to the economy with the actual fundamentals and policies.[18] Let us denote with a prime x' the unknown value of a variable under a counterfactual tariff structure $\{\tau_{in}^{\prime j}\}_{i=1;n=1;j=1}^{N,N,J}$. By x we denote the value of the endogenous variable under the actual set of fundamentals and tariff structure $\{\tau_{in}^{j}\}_{i=1;n=1;j=1}^{N,N,J}$, and by $\hat{x} = x'/x$ we denote the ratio between the counterfactual and actual endogenous variables. Namely, $\hat{x}$ is the change in the equilibrium values as a result of the changes in tariffs $\{\hat{\tau}_{in}^{j}\}_{i=1;n=1;j=1}^{N,N,J}$. Using this notation, the equilibrium conditions

[17] Costinot and Rodríguez-Clare (2014) coined the term "exact-hat algebra" and showed how many quantitative models, even under the presence of fixed costs, can be expressed this way. This representation can also be applied to models with nested CES functional forms (e.g. Parro 2013). See also Caliendo, Parro, and Tsyvinski (2021c) for an example of an application of the exact-hat algebra in a model with cross-country and cross-industry endogenous input-output shares in a gravity structure. Moreover, Adao, Costinot, and Donaldson (2017) show that the exact-hat algebra can also be applied to non-CES environments.

[18] One can also use this method to study the effects of changes in fundamentals. However, given the theme of this chapter, we focus on explaining how to solve for counterfactual changes in trade policy while holding the fundamentals fixed.

in hat-changes are given by

$$\hat{x}_i^j = [\hat{w}_i]^{\gamma_i^j} \prod_{k=1}^{J} \left[\hat{P}_i^k\right]^{\gamma_i^{jk}}, \tag{14}$$

$$\hat{P}_i^j = \left[\sum_{n=1}^{N} \pi_{in}^j \left[\hat{\tau}_{in}^j \hat{x}_n^j\right]^{-\theta^j}\right]^{-1/\theta^j}, \tag{15}$$

$$\hat{\lambda}_{in}^j = \left[\frac{\hat{\tau}_{in}^j \hat{x}_n^j}{\hat{P}_i^j}\right]^{-\theta^j}, \tag{16}$$

$$X_i^{\prime j} = \sum_{k=1}^{J} \gamma_i^{kj} \sum_{n=1}^{N} \lambda_{ni}^{\prime k} \frac{X_n^{\prime k}}{\tau_{ni}^{\prime k}} + \alpha_i^j I_i^{\prime}, \tag{17}$$

$$\sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\lambda_{in}^{\prime j} X_i^{\prime j}}{\tau_{in}^{\prime j}} = \sum_{j=1}^{J} \sum_{n=1}^{N} \frac{\lambda_{ni}^{\prime j} X_n^{\prime j}}{\tau_{ni}^{\prime j}} + D_i^{\prime} \tag{18}$$

with $I_i = \hat{w}_i w_i L_i + TR_i^{\prime} + T_i^{\prime}$.[19]

A distinctive feature of the exact-hat method is that the system written in changes differentiates out the unobservable fundamentals. The information about the fundamentals is contained in the observed endogenous variables π_{in}^j, $w_i L_i$, while γ_i^j, γ_i^{kj} and α_i^j are parameters that have direct counterparts in the data. For example, γ_i^{kj} comes directly from an input-output table.[20] Hence, the computation of the general equilibrium effects of trade policy changes $\{\hat{\tau}_{in}^j\}_{i=1;n=1;j=1}^{N,N,J}$ requires information on the actual allocations π_{in}^j and $w_i L_i$, the input shares γ_i^j and γ_i^{jk}, the Cobb-Douglas shares α_i^j, and estimates of the trade elasticity θ^j, but it does not require the estimation of the unobservable fundamentals.

Another issue in the computation of counterfactuals is the treatment of the trade imbalances D_i. Since the previously described model does not take into account endogenous savings decisions by households, the country-aggregate trade deficits constitute another exogenous parameter in the system. Thus, the computation of counterfactuals requires an assumption about the country-aggregate counterfactual value $D_i^{\prime}$ after the trade policy change. As we described before, to address (partially) this issue, the literature using static frameworks has followed different approaches. One possibility is to assume that the country-aggregate trade imbalances are constant relative to world GDP, and lump-sum transferred to consumers (e.g., Dekle, Eaton, and Kortum 2007; Caliendo and Parro 2015). A second approach is to use the same system to eliminate the trade imbalances: that is, to first compute the equilibrium allocations under $D_i^{\prime} = 0$ and $T_i^{\prime} = 0$ and then compute equilibrium under the counterfactual trade policy (e.g., Caliendo and Parro 2015; Ossa 2011; Ossa

[19]See, e.g., Caliendo and Parro (2015) for the derivation of these equilibrium conditions in hat-changes.
[20]The method is based on the idea of inverting choice probabilities; see Hotz and Miller (1993) and Berry (1994).

2014). In this section we follow this second approach to treat trade imbalances. Later on we describe a third approach for managing trade imbalances in the context of spatial models. The approach consists of using tariff revenues or the income from other factors (e.g., landowners) to create transfers across locations that match the observed deficits.

Another issue that we subsequently discuss is the availability of data with which to obtain the initial allocations π_{in}^{j}, $w_i L_i$, γ_i^j, γ_i^{kj}, and α_i^j.

3.1.4 Data: Advances and Limitations

Taking the model to the data requires sectoral data on bilateral trade shares π_{in}^{j}, including domestic expenditure shares π_{ii}^{j}, value added $w_i L_i$, the share of value added in gross output γ_i^j, input-output coefficients γ_i^{jk}, final consumption shares α_i^j, and bilateral sectoral tariff data.

Part of the progress in quantitative trade policy analysis in recent years has been the result of advances in producing the publicly available, consistent, cross-country data at the sectoral level needed to undertake quantitative general equilibrium analysis. The development of the World Input-Output Database (WIOD; Timmer, Dietzenbacher, Los, Stehrer, and Vries 2015) has been particularly important in facilitating the data construction used to compute general equilibrium counterfactuals. The WIOD traces the flow of goods and services across countries at the NACE industry level. The 2013 release contains information for 35 industries, 40 countries, and a constructed rest of the world during the period 1995-2011. The 2016 release covers 56 industries, 43 countries, and a constructed rest of the world during the period 2000-2014. Since WIOD is a world's input-output matrix, it contains consistent information on cross-country and within-country transactions across sectors, which can be used to obtain the bilateral trade shares π_{in}^{j} and the domestic expenditure shares π_{ii}^{j}. It also contains value added and gross output across sectors and countries that can be used to obtain $w_i L_i$ and the share of value added in gross output γ_i^j. Finally, it presents information on input-output transactions and the final consumption data across sectors and countries, which is used to obtain the input-output coefficients γ_i^{jk} and the final expenditure shares α_i^j. The development of the WIOD has helped quantitative trade literature to overcome the large hurdle of standardizing different production and trade data across countries, sectors, and time.

Although the WIOD is the most complete and widely used database in frontier quantitative trade literature, it has some limitations. In particular, WIOD data construction relies on the assumption that industries use imports of materials proportional to their total use, the so-called "proportionality assumption".[21] More-

[21] Recent research by Kee and Tang (2016) and de Gortari (2019) discusses the quantitative implications of the proportionality assumption.

over, the WIOD uses input-output data from input-output tables that are not produced annually, and therefore part of the input-output data is imputed with annual trade and macroeconomic data. An alternative world's input-output table is EORA (see Lenzen, Kanemoto, Moran, and Geschke 2012) that traces input-output transactions for 26 sectors and 190 countries from 1990 to 2015. With this dataset one can use quantitative trade models to study the effects of trade policy in developing countries, something that is not possible with WIOD. However, the data in EORA is constructed with even more data imputations than the data in WIOD due to the lack of data for many of the small countries in the sample.

These publicly available datasets are an important advance in this literature and reveal the need for more consistent and comprehensive datasets for the world economy. Recent work by Borchert, Larch, Shikher, and Yotov (2021) is at the forefront of this task.

Finally, quantitative trade policy analysis has also been facilitated by the development of tariff databases, such as the World's Integrated Trade Solution (WITS) developed by the World Bank. This database contains detailed information on bilateral tariffs for nearly all the countries in the world as well as constructed regions and trading blocks for industries up to six digits of disaggregation, under different industry classifications, and covering several decades. The WITS data has increased substantially the coverage and reduced the number of missing observations over time, so that potential biases coming from non-random missing data are heavily reduced in the more recent years of data compared with the initial years of data. Recent work by Caliendo, Feenstra, Romalis, and Taylor (2015) and Feodora (2020) create comprehensive and longer span of tariff datasets.

3.1.5 Application: Evaluating the Aggregate Effects of the 2018 Trade War

We now show how to apply the framework to study the effects of an actual trade policy change, the 2018 trade war between the United States and its trading partners. Following the discussion in the previous subsection, we collect data on $\pi_{in}^j, w_i L_i, \gamma_n^j, \gamma_i^{jk}$, and α_n^j from the WIOD for the year 2014 (the last available year) and use the trade elasticities from Caliendo and Parro (2015). Initial bilateral tariffs at the industry level are collected from WITS for the year 2017. We collect data for 22 industries, 12 tradable and 10 non-tradable, for a sample of 43 countries and a rest of the world contained in the WIOD database.[22] In Section B of the online appendix, we present the list of sectors and countries used in the analysis and in Section C of the online appendix, we present the iterative algorithm we use to solve the model.

As mentioned in Section 2.1, the average statutory tariff rate in affected imports increased from 2.6

[22] We use a somewhat more aggregated collection of industries than the 56 industries contained in the 2016 WIOD release since we aim to keep the sample of countries and sectors constant throughout all the quantitative exercises performed in this chapter. We later see that at this level of aggregation, we are able to intersect all the datasets used in all the quantitative analyses we perform.

percent to 16.6 percent, which corresponds to about $300 billion of U.S. imports, or about 1.5 percent of U.S. GDP (1.1 percent of U.S. total expenditure). To aggregate the 2018 changes in tariffs (imposed by the United States and its trading partners) from the HS-8 tariff lines to the 12 tradable manufacturing industries in our sample, we use a concordance table to ISIC Rev 3 and import shares in the year previous to the tariff changes.[23] In Section B of the online appendix, we present the changes in tariffs applied by the United States and the retaliatory tariffs at our level of industry aggregation. To give a sense of the magnitudes, the trade-weighted average of the change in tariff applied by the United States to China across the entire manufacturing sector was 7.67 percentage points, while the trade-weighted average of the change in tariff applied by China to the United States across the entire manufacturing sector was 9.16 percentage points.

Table 1 presents the welfare effects of the 2018 trade war in the multi-sector framework with input-output linkages. The first column shows the effects on real wages, while the second column shows the effects on real income once the changes in tariff revenues are taken into account. Overall, the impact of the 2018 trade war on real wages and real income was small. We find that the 2018 trade war resulted in a decline in real wages in the United States of about 0.13 percent and in China of about 0.11 percent. When taking into account tariff revenues, we find that real income slightly declined in both countries. If other countries would have not retaliated, the United States would have been slightly better off, with an increase in real income of about 0.02 percent, and the decline in real wages would have been somewhat smaller. Among countries other than the United States and China (see Section D of the online appendix), we find that the big losers are some of the United States' main trading partners such as Canada and Mexico.[24]

Table 1: Welfare effects of the 2018 trade war (percent)

	2018 Trade war		No retaliation	
	Real wages	Real income	Real wages	Real income
United States	-0.128	-0.010	-0.097	0.024
China	-0.112	-0.093	-0.068	-0.090

Note: This table shows the real wages and real income effects of the 2018 trade war, as well as the effects without retaliation from trading partners.

Table 2 displays the trade effects of the 2018 trade war in the United States across manufacturing sectors, computed as the percentage change in U.S. total imports and U.S. total exports for each manufacturing sector. We find that aggregate manufacturing imports declined by 6.5 percent and manufacturing exports by about 8 percent as a result of the trade war. We also find very heterogeneous sectoral effects; for instance, the metals and computers and electronics industries were the most hurt sectors in terms of imports, and

[23] We obtain the changes in tariffs at the HS-8 level of aggregation applied by the United States and the retaliatory tariffs applied by trading partners from Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2019).

[24] The terms of trade adjustments computed with the quantitative frameworks presented in this section are not necessarily inconsistent with the reduced-form empirical findings described in Section 2.1. As we discussed before, terms of trade effects might not be captured in reduced-form regressions.

the non-metallic, wood and paper, and textile industries were the most hurt sectors in terms of exports. As emphasized in Caliendo and Parro (2015), sectoral trade effects are not only impacted by the size of the tariff change in a given industry, but also by sectoral trade elasticities. This is also shown in Ossa (2015). Sectoral trade effects are also affected by how linked an industry is with the other sectors through input-output linkages. We also find large effects on sectoral trade imbalances reflecting asymmetric effects on imports and exports in industries such as the textiles, non-metallic, and metals industries.

Table 2: Trade effects of the 2018 trade war (percent)

	Imports	Exports
Aggregate manufacturing	**-6.47**	**-7.86**
Food, Bev., Tobb.	-0.98	-4.97
Textiles	-0.55	-11.30
Wood, Paper	-1.96	-13.92
Petroleum, Coal	5.48	-4.38
Chemicals	-1.83	-1.42
Plastics, Rubber	-2.55	-6.99
Nonmetallic	-3.68	-23.21
Metals	-30.56	-2.61
Machinery	-4.20	-8.54
Computer, Electronics	-14.69	-2.13
Transport Mtg.	-0.61	-9.89
Furniture Mtg	-3.80	-1.21

Note: This table shows the effects of the 2018 trade war on imports and exports across U.S. manufacturing sectors.

These aggregate effects are important, but following the empirical studies we presented in Section 2.3, we also find it crucial to investigate the distributional effects of trade policy across labor markets in general equilibrium. We now extend the framework to do so.

3.2 Spatial Model for Trade Policy Analysis

Guided by recent empirical evidence of the effects of trade shocks across local labor markets (e.g., Autor, Dorn, and Hanson 2013), researchers have developed quantitative spatial frameworks that can be connected to data in order to quantify the spatial effects of different type of trade-related shocks. These quantitative frameworks can naturally be applied to study the spatial effects of trade policy, as we show in this section.

We begin by adding to our baseline framework local labor markets. The geographic nature of the problem–namely, the presence of labor mobility, local fixed factors, costly trade across regions, and regional trade imbalances–introduces a different set of mechanisms through which changes in trade policy affect production, wages, and employment across sectors and space relative to an aggregate multi-sector model like the one we presented before.

To make notation less cumbersome, we continue indexing countries by i and n but also allow for these indexes to represent a location within a country. There are five key distinctions between the spatial model and the aggregate multi-sector model. First, in this latter model, locations within a country can trade with each other and with the outside world. We assume that trade across locations is subject to geographic trade costs, while trade between a location and a foreign country is subject to geographic trade costs and import tariffs. Second, we take into account that some inputs are immobile across locations. We assume that each location has a fixed factor of production (a composite factor comprising both land and capital structures) that creates congestion effects so that not all labor is located in the best place, and that this fixed factor is owned by local landowners. Third, we make assumptions about how labor moves across space: first, that labor is freely mobile across space, and second, that labor does not move across locations. Fourth, we make an assumption about how labor income, rents from the fixed factor, and tariff revenue are distributed across agents in the economy. Finally, we accommodate the large observed regional trade imbalances. To handle these last two issues, we assume that workers receive income from their factor rewards, and as a result, their labor mobility decisions are not distorted by other sources of external income. We assume that all the rents of the local fixed factors are sent to a global portfolio and then redistributed proportionally to local landowners in a manner that matches the observed imbalances in the data. Finally, we lump-sum redistribute the tariff revenue of each location to the local income that is used to purchase local goods. We now describe how the equilibrium conditions of the model change as a consequence of this new set of assumptions.

We start with a version of the model in which labor is freely mobile across sectors within a region but regional labor markets are segmented; namely, workers do not move across regions. We denote by w_i the labor factor payment in region i and by r_i the local rent of a unit of local fixed factor H_i. The unit cost in location i and sector j is now given by

$$x_i^j = \left[[w_i]^{\xi_i} [r_i]^{1-\xi_i} \right]^{\gamma_i^j} \prod_{k=1}^{J} [P_i^k]^{\gamma_i^{jk}}, \tag{19}$$

where the only difference compared to (7) is that a share ξ_i of the value added is generated by labor and the rest is generated by the local fixed factor (the source of congestion in this model).

The trade share equilibrium condition is the same as before. The only difference is that compared to the equilibrium condition (8), trade flows across regions in a country are not subject to import tariffs; namely, $\tau_{in}^j = 1$ for all i and n that belong to the same country. The same applies to the price index (9), which now represents a regional-sectoral price index. The goods market clearing condition (10) also remains unaffected. It now represents the total expenditure on goods in sector j and region i. Income I_i now represents the local income in location i, and the expenditure α_i^j is the share of income from workers and landowners spent on goods from sector j. Note that now we are allowing for regional input-output relationships, so the model features global and regional value-added chains. In this case, after adding across all regions and countries, $\sum_{n=1}^{N} \lambda_{ni}^{k} \frac{X_n^k}{\tau_{ni}^k}$ is the world total sector k expenditure on region i final goods. The trade balance equation (11) is an equilibrium condition in which now D_i is the endogenous trade imbalance at the regional level that we subsequently explain.

In this model, regional income I_i represents the income of workers, the income of landowners, and the lump-sum proportional transfer of tariff revenue to location i. The equilibrium condition is exactly like (12) at the regional level. The difference is that now tariff revenue is given by local tariff revenue, meaning that all the imports of a particular region are taken into account. In addition, in this model, local world transfers T_i are not exogenous as in (12). These transfers are given by what the local landowners collect from the global portfolio; namely, $T_i = \iota_i \chi$ where $\chi = \sum_{n=1}^{N} r_n H_n$. Note that imbalances are then given by $D_i = T_i - r_i H_i$.

Finally, the labor market clearing condition is given by

$$w_i L_i = \xi_i \sum\nolimits_{k=1}^{J} \gamma_i^k \sum\nolimits_{n=1}^{N} \lambda_{ni}^k \frac{X_n^k}{\tau_{ni}^k}. \tag{20}$$

The local land and capital structures market clearing condition is satisfied by Walras's law. We now formally define the equilibrium in the model with free labor mobility across sectors and no labor mobility across regions.

Equilibrium of the Spatial Model with Segmented Labor Markets. Given endowments $\{L_i\}_{i=1}^N$, $\{H_i\}_{i=1}^N$, fundamentals $\left\{A_i^j, \kappa_{in}^j\right\}_{i=1,n=1,j=1}^{N,N,J}$, parameters $\left\{\gamma_i^j, \gamma_i^{kj}, \alpha_i^j, \xi_i, \iota_i\right\}_{i=1,j=1,k=1}^{N,J,J}$, and elasticities $\left\{\theta^j\right\}_{j=1}^J$, an equilibrium of the spatial model under a tariff structure $\left\{\tau_{in}^j\right\}_{i=1;n=1;j=1}^{N,N,J}$ is a factor price vector $(\mathbf{w}, \mathbf{r}) \in \mathbf{R}_{++}^N$ that solves equilibrium conditions (19), (8), (9), (10), (11), (12), and (20) for all countries and regions i and sectors j.

For some applications, one might also want to study the effects of trade policy across space in a model in which agents can freely move from one labor market to another. In such an economic environment, workers sort to different labor markets up to the point at which they become indifferent of the location at which they are residing and supplying labor. As a result, real labor income is equated across regions in the spatial equilibrium. This involves assuming that w_i/P_i is equal for all i belonging to the same country. Imposing this condition, then using the labor market clearing condition together with the land and capital structures market clearing condition, we obtain the share of employment in each region in each country by

$$L_i = \frac{\frac{\xi_i}{1-\xi_i} \frac{r_i H_i}{P_i}}{\sum_n \frac{\xi_n}{1-\xi_n} \frac{r_n H_n}{P_n}} L, \tag{21}$$

where L is the total endowment of labor in the country and the summation in the denominator is over all the labor markets within the country.

The equilibrium of the spatial model with free mobility is formally defined.

Equilibrium of the Spatial Model with Free Labor Mobility. Given endowments for each country L, $\{H_i\}_{i=1}^{N}$, fundamentals $\{A_i^j, \kappa_{in}^j\}_{i=1,n=1,j=1}^{N,N,J}$, parameters $\{\gamma_i^j, \gamma_i^{kj}, \alpha_i^j, \xi_i, \iota_i\}_{i=1,j=1,k=1}^{N,J,J}$, and elasticities $\{\theta^j\}_{j=1}^{J}$, an equilibrium of the spatial model with free labor mobility under a tariff structure $\{\tau_{in}^j\}_{i=1;n=1;j=1}^{N,N,J}$ is a factor price vector $(\mathbf{w}, \mathbf{r}) \in \mathbf{R}_{++}^{N}$ that solves equilibrium conditions (19), (8), (9), (10), (11), (12), (20), and (21) for all countries and regions i and sectors j.

3.2.1 Policy Counterfactuals in a Spatial Trade Policy Model

In order to perform trade policy counterfactuals with this model, we use the exact-hat algebra method described in the previous section. In fact, the system of equilibrium conditions written in hat-terms is very similar to the one in Section (3.1.3). Hence, we present only the new equations in hat-changes. In the version of the model with perfect mobility across sectors and no mobility across locations, equation (14) now incorporates the rental rate of the fixed factor; namely,

$$\hat{x}_i^j = \left[[\hat{w}_i]^{\xi_i} [\hat{r}_i]^{1-\xi_i}\right]^{\gamma_i^j} \prod_{k=1}^{J} [\hat{P}_i^k]^{\gamma_i^{jk}}, . \tag{22}$$

In addition, the labor market clearing condition takes into account that value added is split into the payment to labor and the payment to the fixed factor; namely,

$$\hat{w}_i \hat{L}_i w_i L_i = \xi_i \sum_{k=1}^{J} \gamma_i^k \sum_{n=1}^{N} \lambda_{ni}'^{k} \frac{X_n'^{k}}{\tau_{ni}'^{k}}, . \tag{23}$$

In the version of the model with free mobility across locations, equation (21) pins down the distribution of employment across locations, which in hat-changes can be written as

$$\hat{L}_i = \frac{\frac{\hat{r}_i \hat{H}_i}{\hat{P}_i}}{\sum_n L_n \frac{\hat{r}_n \hat{H}_n}{\hat{P}_n}}.. \tag{24}$$

3.2.2 Data: Advances and Limitations

As can be seen from these equations, applying the exact-hat algebra method to compute the effects of trade policy changes using a spatial framework requires us to condition on additional regional and cross-country data. With the previously described structure, we need to obtain the share of the labor payment in value added ξ_i, as well as the payment to labor and the payment to the fixed factor $w_i L_i$, $r_i H_i$. In the case of free regional mobility, we also need to condition on the initial distribution of employment across locations L_i. Importantly, when applying this spatial model to the United States, unlike when applying the multi-sector model described in Section (3.1.1), bilateral trade shares π_{in}^j apply to trade flows across countries and locations; thus, additional internal and external trade data is needed.

The development of new detailed databases has expanded substantially the possibility of taking the spatial framework to the data and the range of questions to be answered in the quantitative trade and spatial literature. In particular, the Commodity Flows Survey (CFS) from the U.S. Census Bureau tracks shipments (trade flows) across different U.S. geographic definitions (U.S. regions, states, metropolitan areas) disaggregated up to NAICS four-digit manufacturing industries. The CFS has been released every five years since 1993, and it allows us to obtain π_{in}^j for i, n, which are locations within the United States.

Regarding the bilateral trade flows between U.S. locations and foreign countries, the U.S. Census released a database called USA Trade Online, that contains data on bilateral exports and imports between the U.S. states and each country in the world, disaggregated up to NAICS four-digit industries. This database allows us to directly construct π_{in}^j when i is a U.S. location and n is a foreign country. A downside of this database is its relative short time-series coverage from 2008 through the present. Given this limited coverage, researchers who have studied the effects of earlier trade shocks across U.S. labor markets have followed a different approach to input the bilateral trade flows between U.S. labor markets (locations) and foreign countries. For instance, Autor, Dorn, and Hanson (2013) measure the exposure of local labor markets to international trade by combining trade data with local industry employment. Specifically, bilateral trade flows at the country level are divided into bilateral trade flows between the U.S. locations and other countries by assuming that the share of each location in total U.S. trade with any country in a given sector is determined by the regional share of total employment in that industry.[25]

The regional production data needed to construct the payment to labor $w_i L_i$, and the share of labor payment in value added ξ_i can be obtained from the Bureau of Economic Analysis (BEA) database, which provides detailed regional statistics covering industries, geographic units, and years. The payment to structures $r_i H_i$ can be computed as the difference between the payment to labor and value added, and the initial

[25] Examples of recent research that extend the WIOD database to the 50 U.S. states using the databases described in this section are Caliendo, Dvorkin, and Parro (2019) and Rodríguez-Clare, Ulate, and Vasquez (2020).

distribution of employment L_n across U.S. locations is directly obtained from the BEA database. The corresponding data for other countries are available at the industry level in the OECD Structural Analysis Database (STAN) for the OECD countries and from national agencies analogous to the BEA for other countries.

Finally, regarding trade imbalances, we assume that the rents from the fixed factor are transferred to a global portfolio and that each location in the world is the owner of a fraction ι_n of the global portfolio. Hence, the difference between the transfers to the global portfolio, $r_n H_n$, and the remittances from it, $\iota_n \sum_i r_i H_i$, generate trade imbalances, where ι_n is disciplined by observed trade imbalances in the initial period. Under this formulation, trade imbalances become endogenous in the model since, for instance, productivity increases in a given location increase the demand for factors, revenues from the fixed factor, and therefore transfers to the global portfolio. Although clearly stylized, this is a convenient alternative to introduce endogenous trade imbalances in static spatial frameworks (e.g., Caliendo, Parro, Rossi-Hansberg, and Sarte 2017; Fajgelbaum, Morales, Suárez Serrato, and Zidar 2018).

3.2.3 Evaluating the Aggregate and Distributional Effects of the 2018 Trade War

We now take the spatial framework to a world with 43 countries and a rest of the world and the 50 U.S. states to compute the spatial effects of the 2018 trade war. We use the same cross-country data for the 22 industries as used in Section 3.1.3, and we obtain the regional production and input shares previously described for the year 2014. To obtain the regional bilateral trade shares, we use the 2017 release of the CFS.

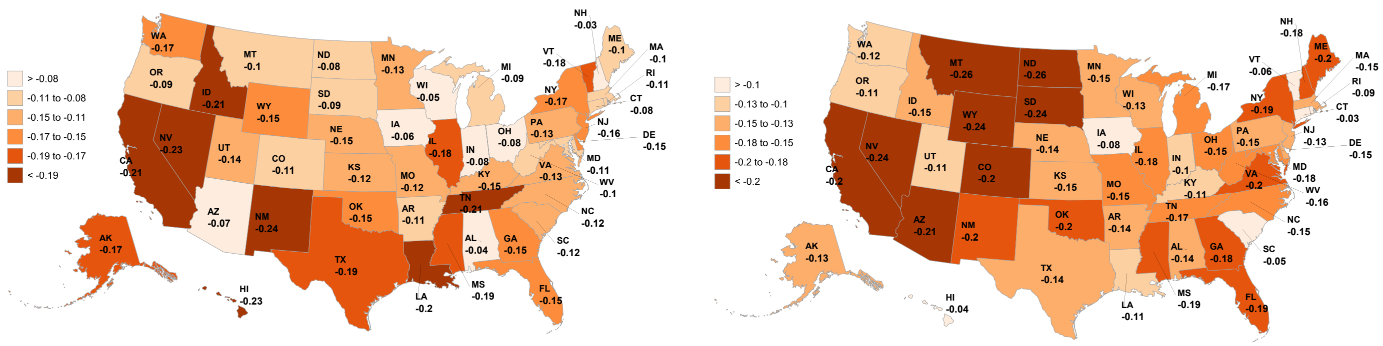
We first compute the effects on real wages and real income in the version of the model with free mobility across sectors but not across locations. Figure 1 shows the spatial effects across U.S. states; the left panel presents the effects on real wages and the right panel displays the effects on real income. We find that real wages decline in all the U.S. states as a consequence of the 2018 trade war, but the effects are very heterogeneous across space, ranging from real wage losses of less than 0.1 percent in states like Alabama, Iowa, New Hampshire, and Wisconsin, to losses of more than 0.2 percent in California, Idaho, Nevada, and New Mexico. We also find that while some states that suffer relatively large declines in real wages have high exposure to changes in tariffs in the manufacturing sectors (measured as import penetration), the correlation between the direct exposure to the tariff changes of each state and the effects on real wages is not high, which highlights the importance of input-output linkages as well as the general equilibrium effects in the quantification of trade policy changes. The right panel shows the effects on real income once we take into account not only wages as a source of income, but also tariff revenues and the endogenous trade imbalances.

We can see the same degree of heterogeneity across space, although we also see that tariff revenues and trade imbalances play some role in redistributing income across states.

We find that U.S. aggregate real wages decline by 0.16 percent as a consequence of the 2018 trade war while real income also declines by around 0.14 percent. The similar magnitudes of the declines in real wages and real income are explained by the fact that an increase in tariff revenues is offset by a reduction in trade deficits in our counterfactual analysis. In fact, if we eliminate trade imbalances as we did in the multi-sector framework, we find that U.S. aggregate real wages decline by 0.16 percent while real income only declines by 0.04 percent.

Figure 1: Welfare effects of the 2018 trade war across space

a) Changes in real wages (percent) b) Changes in real income (percent)



Note: The figures present the effects of the 2018 trade war on real wages and real income in a model with free labor mobility across sectors but no labor mobility across U.S. states.

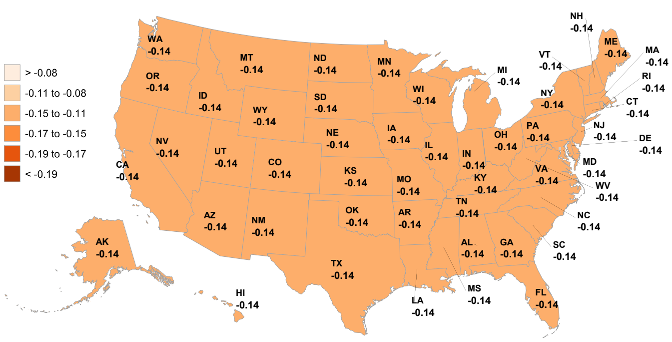
Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2019) compute the effects of the 2018 trade war through the lens of a similar spatial framework with labor, fixed factors, and input-output linkages. Unlike the analysis using the previously presented framework, the researchers' analysis is performed at the county and product levels under the assumption that labor cannot move across sectors or locations, and the quantitative analysis is performed taking foreign wages as exogenous. At the aggregate, similar to the results presented earlier, they find a small decline in U.S. aggregate real wages, also unmasked by a large spatial heterogeneity. The spatial effects are even more heterogeneous than the ones previously displayed as a consequence of labor immobility in their framework.[26] There are three additional results from their analysis that are worth mentioning. First, as described earlier, the study finds evidence of a complete pass-through of tariffs to duty-inclusive import prices that is systematic across products with heterogeneous characteristics. Secondly, Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2019) find evidence that U.S. import protec-

[26]In related research, Santacreu, Sposi, and Zhang (2021) also find heterogeneous effects of U.S. tariff increases across states through the lens of a spatial model with labor immobility.

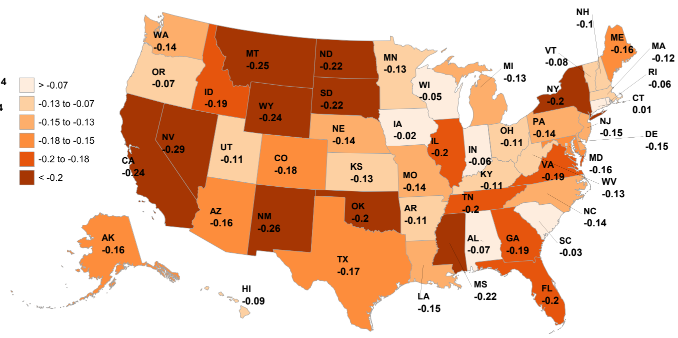
tion was biased toward products made in electorally competitive counties, as measured by the counties' 2016 presidential vote shares, a finding that is consistent with the insights provided in Grossman and Helpman (2005). Relatedly, Ma and McLaren (2018) show empirically that after controlling for other factors, the U.S. tariff structure is systematically biased toward industries located in swing states. Third, similar to us, the researchers find that due to input-output linkages across sectors, the reduction in the tradable sector real wages across space is imperfectly correlated with protection received through import tariffs.

Figure 2: Welfare effects of the 2018 trade war across space with free mobility

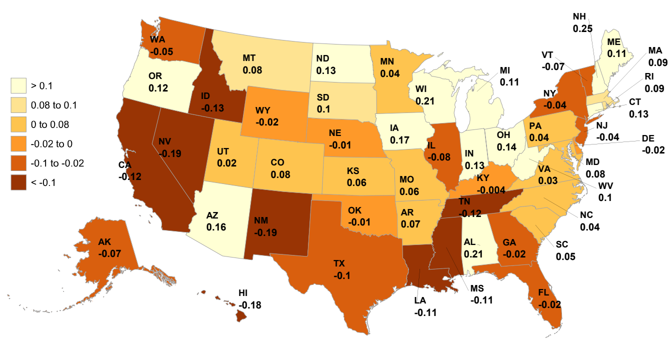
a) Changes in real wages (percent)



b) Changes in real income (percent)



c) Changes in labor allocations (percent)



Note: The figures present the effects of the 2018 trade war on real wages and real income in a model with free labor mobility across sectors and across U.S. states.

We now describe the results obtained using the spatial model with free mobility across sectors and across U.S. states. Figure 2 shows the effects on real wages in Panel (a), real income in Panel (b), and the labor allocation in Panel (c). Since there is free mobility and we assume that households do not receive direct transfers from deficits and tariff revenues, we see that the decline in real wages as a consequence of the 2018 trade war is uniform across U.S. states. The changes in real income are still heterogeneous across space. We also see that given the heterogeneous spatial effects on real wages previously described, with free regional mobility, labor tends to be redistributed to the U.S. states that experience relatively small real wages declines. Another interesting observation is that the aggregate effects on real wages and real income in the model with free mobility are very similar to those of the model with no regional mobility. One feature of the model that might explain this result is the absence of transition costs in the static framework, an aspect that we take into account in the dynamic framework that we discuss next.

3.3 Dynamic Spatial Model of Trade Policy

Motivated by the reduced-form evidence we described before, in this subsection our main focus is to present a framework with which to study how labor is reallocated across space and over time after a trade policy shock. To do this, we introduce labor market dynamics into a spatial framework. We build a regional version of Caliendo, Dvorkin, and Parro (2019) and Artuc, Chaudhuri, and McLaren (2010)'s dynamic discrete choice model of labor relocation. We present only the additional equilibrium conditions relative to the previous framework, and we discuss estimation and how to perform policy counterfactuals.

Time is discrete, and we denote it by t. At each moment in time, households in a location i can be employed in any of the active sectors in that location. Households are forward-looking, observe the economic conditions in all regions and sectors, and optimally decide at the end of each period where to supply labor and locate tomorrow. Moving across locations is costly. Households face moving costs that apply equally to all households in a given location that decide to move to another location. We also allow for idiosyncratic shocks that affect households' moving decisions. We denote by $v_{i,t}$ the value of a household located in i at time t. Households derive utility from consuming local goods and receive income from the unit of labor they supply. As before, we denote by w_i/P_i the real income of a household located in i and assume that households have log utility. The Bellman equation of a household located in i is given by

$$v_{i,t} = log\left(w_i/P_i\right) + \max_{\{n\}_{n=1}^{N}} \left\{\beta E\left[v_{n,t+1}\right] - m_{in} + \nu\epsilon_{n,t}\right\},$$

where β is the discount factor, m_{in} is the cost to relocate from i to n, and $\{\epsilon_{n,t}\}_{n=1}^{N}$ are the idiosyncratic stochastic preference shocks which are assumed i.i.d. and drawn from a Type-I extreme value distribution with zero mean. Finally, ν regulates the dispersion of the shocks and can be also interpreted as the migration elasticity. Both the presence of migration costs and idiosyncratic preferences generate a gradual adjustment of flows in response to changes to present and future real wages. To the extent that different regions are exposed differently to the changes in trade policy, some households relocate more often than others.

Denote by $V_{i,t} \equiv E[v_{i,t}]$ the expected (expectation over ϵ) lifetime utility of a household located in i.

Using the properties of the Type-I extreme value distribution, we obtain

$$V_{i,t} = log\big(w_i/P_i\big) + \nu log\Big(\sum_{n=1}^{N} exp\big(\beta V_{n,t+1} - m_{in}\big)^{1/\nu}\Big).. \tag{25}$$

As we can see, the first term in equation (25) represents the current period utility of households in i, and the second expression on the right-hand side captures the option value of moving to a different location. At each moment in time, some individuals, for idiosyncratic preferences and economic fundamentals, decide to change location. In particular, the fraction of households in i that relocates to region n, which we denote by $\mu_{in,t}$, is given by

$$\mu_{in,t} = \frac{exp\left(\beta V_{n,t+1} - m_{in}\right)^{1/\nu}}{\sum_{k=1}^{N} exp\left(\beta V_{k,t+1} - m_{ik}\right)^{1/\nu}}. \tag{26}$$

This equilibrium condition describes the gross flows of households across locations. It is clear from this expression that $1/\nu$ represents the elasticity of migration flows to changes in migration costs. Over time, the supply of households in any given location is given by $L_{i,t}$. This state variable evolves over time according to how individuals change locations; namely,

$$L_{i,t+1} = \sum_{n=1}^{N} \mu_{ni,t} L_{n,t}. \tag{27}$$

These three new sets of equilibrium relations, together with the equilibrium conditions of the spatial model, fully characterize the dynamics of the model.

Solving for the dynamic model requires solving for the infinite sequence of factor prices, value functions, and migration flows conditional on a sequence of fundamentals and trade policies. Caliendo, Dvorkin, and Parro (2019) show that solving the model is computationally straightforward and can be done easily by iterating the equilibrium conditions backwards starting from the steady state. The authors present a dynamic version of the method used to solve static models, the dynamic exact hat-algebra that we subsequently describe, which consists of expressing the model in relative time differences. Such a method reduces the computational burden considerably and facilitates the computation of counterfactuals. We now formally define the equilibrium of the model.

Equilibrium of the Dynamic Spatial Trade Policy Model. Given an initial distribution of workers $\left\{L_{i,0}\right\}_{i=1}^{N}$ and an endowment of structures, $\left\{H_i\right\}_{i=1}^{N}$, fundamentals $\left\{A_i^j, \kappa_{in}^j, m_{in}\right\}_{i=1,n=1,j=1}^{N,N,J}$, parameters $\left\{\gamma_i^j, \gamma_i^{kj}, \alpha_i^j, \xi_i, \iota_i\right\}_{i=1,j=1,k=1}^{N,J,J}$, and elasticities $\left\{\theta^j\right\}_{j=1}^{J}$, and ν, a sequential competitive equilibrium of the dynamic spatial model under a tariff structure $\left\{\tau_{in,t}^j\right\}_{i=1;n=1;j=1,t=0}^{N,N,J,\infty}$ is characterized by a sequence of factor prices $\{w_{i,t}, r_{i,t}\}_{i=1,t=0}^{N,\infty}$, value functions $\{V_{i,t}\}_{i=1,t=0}^{N,\infty}$ migration flows $\{\mu_{in,t}\}_{i=1,n=1,t=0}^{N,N,\infty}$ and labor $\{L_{i,t}\}_{i=1,t=0}^{N,\infty}$ that satisfy equilibrium conditions (19); (8); (9); (10); (11); (12); (20); (25); (26); (27) for all countries and regions i and sectors j.

3.3.1 Policy Counterfactuals in a Dynamic Spatial Trade Policy Model

The main difference between this model and the static spatial framework is that in this model, the equilibrium allocation of households across locations $L_{n,t}$ results from the households' dynamic decisions, as described by equations (25), (26), and (27). This dynamic system pins down the supply of labor across locations, and the static trade structure described in the previous section determines the labor demand. Given all the equilibrium conditions of the dynamic framework, we can see that computing the dynamic spatial model is more challenging since it requires the identification of the path of a more extended set of unobservable fundamentals; namely, $\{A_i^j, \kappa_{in}^j, m_{in}, H_i\}_{i=1,n=1,j=1}^{N,N,J}$.

Caliendo, Dvorkin, and Parro (2019) propose a method, dynamic-hat algebra (DHA), that resembles the exact-hat algebra method used in static frameworks but that is applied in the context of the dynamic discrete choice environment previously described. To facilitate the exposition of the DHA method, we first assume that the unobservable fundamentals are time-invariant, and as before, that we want to study the effects of a trade policy change, but in this case over time.

The DHA with constant fundamentals consists of expressing all the equilibrium conditions, the ones from the static trade problem and the ones from the household dynamic problem, in time differences. Here we denote by $\dot{x}$ the time difference in variable x; namely, $x_{t+1} = \dot{x}_{t+1}/x_t$. The static trade equilibrium looks analogous to the one in previous sections, with a single difference: we replace the "hat" notation with the "dot" notation. Namely, the system solves for $\dot{w}_{t+1} = w_{t+1}/w_t$ instead of $\hat{w} = w'/w$.

Therefore, we now have to express the equilibrium conditions of the household dynamic problem in time differences. The resulting equilibrium conditions of the household dynamic problem in time differences are given by

$$\dot{u}_{i,t} = \dot{\omega}_{i,t+1}\Big(\sum_{n=1}^{N} \mu_{in,t}\big(\dot{u}_{n,t+1}\big)^{\beta/\nu}\Big)^{\nu}, \tag{28}$$

$$\mu_{in,t+1} = \frac{\mu_{in,t}\big(\dot{u}_{n,t+1}\big)^{\beta/\nu}}{\sum_{k=1}^{N} \mu_{ik,t}\big(\dot{u}_{k,t+1}\big)^{\beta/\nu}}, \tag{29}$$

$$L_{i,t+1} = \sum_{n=1}^{N} \mu_{ni,t} L_{n,t}, \tag{30}$$

where $\dot{\omega}_{i,t+1} = w_{i,t+1}/P_{i,t+1}$ and $\dot{u}_{i,t} = exp(V_{i,t+1} - V_{i,t})$. Therefore, conditional on the initial gross flows $\mu_{in,0}$ and the path of real wages $\dot{\omega}_{i,t+1}$, equations (28), (29) and (30) solve for the path of the distribution of households across space and time. Note that in doing so, the time difference of the household dynamic problem with constant fundamentals differentiates out the mobility frictions m_{in}.

3.3.2 Data: Advances and Limitations

From this discussion, we can see that when computing the DHA, compared with the static spatial model, the dynamic model requires us to condition the system on the initial gross flows $\mu_{in,0}$ and estimates of the mobility elasticity ν and a value for the discount factor β. The initial gross flows across locations and sectors can be obtained from standard micro-data from the U.S. Census Bureau: the American Community Survey (ACS), the Current Population Survey (CPS), and most recently, the Jobs-to-Jobs flows (J2J). Recent work has provided alternative ways to estimate the mobility elasticity ν across sectors, occupations, and locations using the structure of the dynamic framework (e.g., Artuc, Chaudhuri, and McLaren 2010; Artuc and McLaren 2015; Caliendo, Dvorkin, and Parro 2019; Traiberman 2019).

3.3.3 Computing Counterfactuals

In order to apply the DHA to compute the effects of trade policy changes, we first solve for a baseline economy with constant fundamentals $\left\{A_i^j, \kappa_{in}^j, m_{in}, H_i\right\}_{i=1,n=1,j=1}^{N,N,J}$ and a constant path of trade policy $\tau_{in,t+1} = \tau_{in,t}$. Section C of the online appendix presents the algorithm with which to solve the baseline economy. Here we emphasize another feature of the solution method: the economy at the initial period is not necessarily in steady state, and therefore the baseline economy, even with constant fundamentals and a time-invariant trade policy, can have transitional dynamics. The intuition is that the DHA method requires us to condition on actual data at the initial period, which represents a given year of an economy that might not be in steady state. Crucially, if the initial observed gross flows $\mu_{in,0}$ do not imply zero net flows in each location, then the baseline economy will not be in steady state at the initial period. In other words, $\dot{u}_{i,t} = 1$ will not solve the system.

We then solve for a counterfactual economy under constant fundamentals and a new path of trade policy $\left\{\tau_{in,t}^j\right\}_{i=1;n=1;j=1,t=0}^{N,N,J,\infty}$. The difference in the equilibrium paths of allocations between the counterfactual economy and the baseline economy is the effect of the trade policy changes. A few other remarks are in order. First, the counterfactual economy requires taking a stand on the agent's expectations of the future path of trade policy. In the quantitative exercise that follows, we follow Caliendo, Dvorkin, and Parro (2019) and assume perfect foresight. In particular, we assume that at $t = 0$, households are not expecting a change in trade policy, and at $t = 1$, the households learn about the new path of trade policy. Under this timing assumption, the equilibrium gross flows at $t = 0$ equation (29) do not hold since the agents are surprised by the change in trade policy (see Caliendo, Dvorkin, and Parro 2019 for details).

The solution method with constant fundamentals answers the counterfactual question: starting from an initial allocation, how does the economy evolve over time and what are its long-run features after an unexpected trade policy change, given the fundamentals in the initial period? However, we might also be interested in other type of trade policy counterfactual questions like: What would the world and the United States have looked like in the absence of NAFTA? The DHA method can be extended to answer counterfactual questions with time-varying fundamentals. In this case, the baseline economy now contains the actual evolution of all fundamentals and policies; thus, the baseline economy contains the observed evolution of allocations (endogenous variables). The counterfactual economy has a counterfactual path of trade policy (e.g., constant tariffs) and assumes the actual path of fundamentals. By expressing the counterfactual economy in time differences relative to the baseline economy in time differences, all the actual time-varying fundamentals differentiate out. Caliendo, Dvorkin, and Parro (2019) show how to solve the model with time-varying fundamentals. For an extension of the method and an application to the study of the European Union's change in trade and migration policy, see Caliendo, Opromolla, Parro, and Sforza (2021b).

Following the notation in the previous section, we now denote by $\dot{x}_{t+1}$ the equilibrium allocations in time differences under the actual evolution of fundamentals and the actual path of trade policy $\{\tau_{in,t}^{j}\}_{i=1;n=1;j=1,t=0}^{N,N,J,\infty}$, by $\dot{x}'_{t+1}$ the equilibrium allocations in time differences under the actual evolution of fundamentals and the counterfactual path of trade policy $\{\tau'^{j}_{in,t}\}_{i=1;n=1;j=1,t=0}^{N,N,J,\infty}$, and by $\hat{x}_{t+1} = \dot{x}'_{t+1}/\dot{x}_{t+1}$ the changes in the equilibrium allocations between the baseline economy and the counterfactual economy. Caliendo, Dvorkin, and Parro (2019) show how to write the equilibrium conditions in dynamic-hat changes. Instead of conditioning on the initial observed allocations (i.e., $\pi_{in,0}$, $\mu_{in,0}$, etc.), solving for the equilibrium in changes requires conditioning on the observed times series of these allocations that contains all the information on the path of actual fundamentals.

3.3.4 The Aggregate, Distributional, and Dynamic Effects of the U.S.-China Trade War

As in the static spatial framework, in the present framework, we take the model to a world of 43 countries and a rest of the world, 50 U.S. states, and 22 industries.

Since the quantitative analysis is performed at the industry level, we consider transitions across both

U.S. states and industries. The industry dimension does not modify the discussion of the framework in the previous section; all the previous equilibrium conditions need to be indexed by sectors that we denote by j, k. For example, the gross flows across regions and sectors are now given by

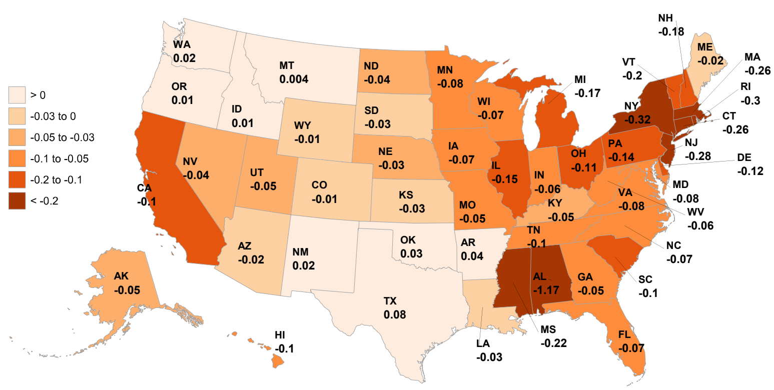
$$\mu_{ij,nk,t+1} = \frac{\mu_{ik,nk,t} \left(\dot{u}_{nk,t+1}\right)^{\beta/\nu}}{\sum_{m=1}^{N} \sum_{h=1}^{J} \mu_{ij,mh,t} \left(\dot{u}_{mh,t+1}\right)^{\beta/\nu}}.$$

In addition, we allow for these gross flows to include transitions between employment and non-employment. Following Caliendo, Dvorkin, and Parro (2019), we assume that non-employed households in each U.S. state consume home production b_n, which is assumed to be exogenous and time-invariant. To evaluate the effects of the 2018 trade war, in addition to using the data described in previous sections, we use the initial gross flows across industries and U.S. states from Caliendo, Dvorkin, and Parro (2019) at the quarterly frequencies and feed into the model the observed changes in tariffs.[27]

We now turn to the results. We first present the effects of the 2018 trade war on welfare, measured as the change in consumption equivalent of households in each region and sector. Unlike the effects on real wages discussed in Section 3.2, the change in consumption equivalent takes into account not only the changes in current real wages each period, but also the option value of moving to other locations (e.g., Artuc, Chaudhuri, and McLaren 2010; Caliendo, Dvorkin, and Parro 2019).

Figure 3: Welfare effects of the 2018 trade war across space

a) Changes in households' welfare (percent)



Note: The figures present the effects of the 2018 trade war on the welfare of households, measured as the change in consumption equivalent, across U.S. states.

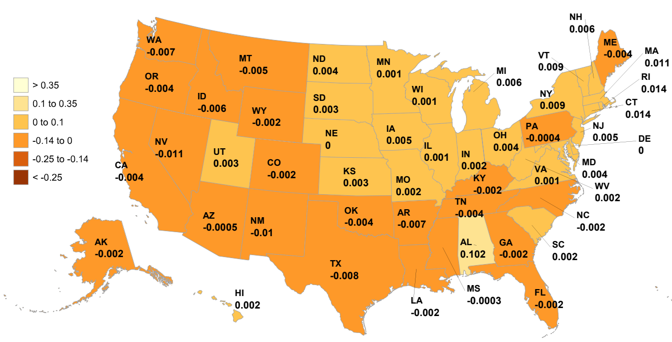
Figure 3 shows the spatial effects, and we can see that the distributional effects are much higher in

[27] We use the gross flows from Caliendo, Dvorkin, and Parro (2019) at the year 2007 and project them to the year 2014 using equation (27) under constant fundamentals. We feed into the model the observed changes in tariffs during the 2018 trade war at the quarterly frequencies, by spreading the total change in tariff over the fourth quarter of the first period in the model.

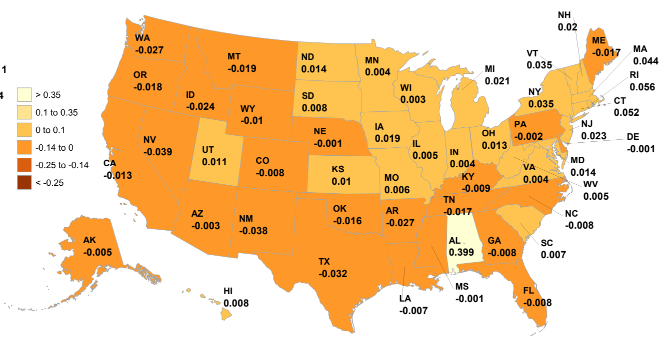
this framework than in the spatial static framework. Marking a crucial difference from the static spatial framework, here we observe that a few states in the South such as Texas, Oklahoma, Arkansas, and New Mexico, as well as Washington, Idaho, and Oregon in the Northeast, are slightly better off with the trade war. In the aggregate, we find that U.S. households' welfare declines 0.1 percent, similar but somewhat smaller than the aggregate effects on real wages found in the static framework. These results show that heterogeneity in mobility frictions and transitional dynamics cannot be ignored when quantifying the distributional effects of changes to trade policy.

Figure 4: Employment effects of the 2018 trade war across space

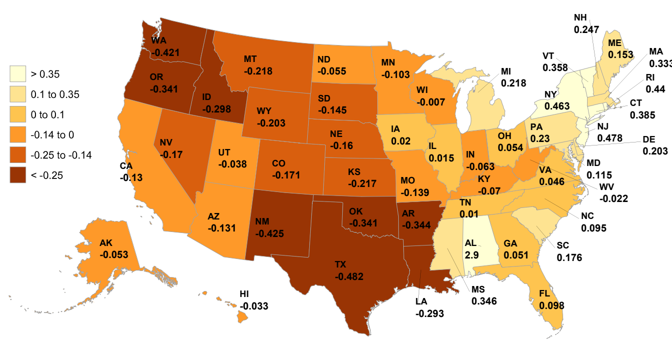
a) Changes in employment after one quarter (percent)



b) Changes in employment after one year (percent)



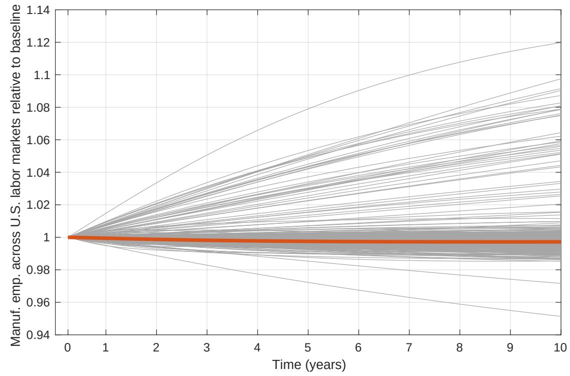
c) Changes in employment in the long run (percent)



Note: The figures present the effects of the 2018 trade war on the distribution of employment across U.S. states at different time horizons.

We highlight two other results from our analysis. First, consistent with the reduced-form evidence previously discussed, Figure 4 shows that mobility after trade policy changes takes time. Panel (a) and Panel (b) show very little employment reallocation after one quarter and one year, respectively, compared with Panel (c), which shows the long-run effects.

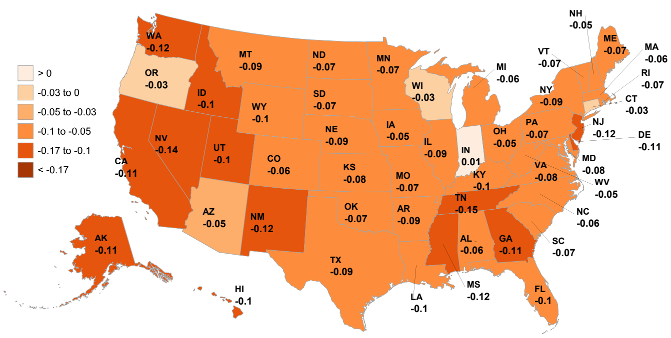
Figure 5: Trade war effects on manufacturing employment over time



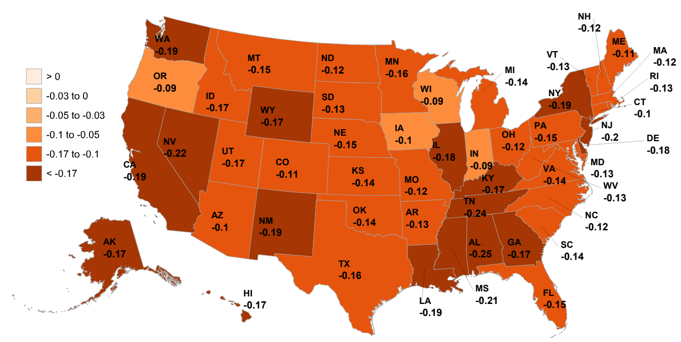
Note: The thick red line shows the U.S. aggregate manufacturing sector, and each gray thin line captures the effects across an individual U.S. manufacturing labor market.

Figure 6: Real wage effects of the 2018 trade war across space

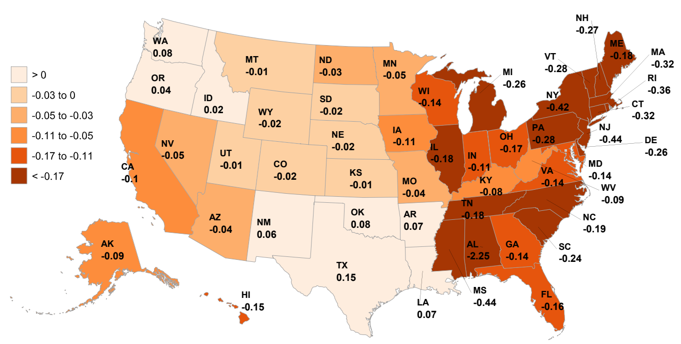
a) Changes in real wages after one quarter (percent)



b) Changes in real wages after one year (percent)



c) Changes in real wages in the long run (percent)



Note: The figures present the effects of the 2018 trade war on real wages at different time horizons.

Similarly, Figure 5 displays the dynamic employment effects of the 2018 trade war across individual U.S. labor markets in the manufacturing industries, where the effects are computed relative to the baseline economy with no changes in trade policy. Each of the thin lines represents a U.S. labor market and the thick line shows the aggregate U.S. manufacturing sector. The main takeaway from the figure is the persistent and increasing effects of trade policy on employment arising from the spatial framework with labor market dynamics, which is in line with the reduced-form evidence described earlier. Second, and also consistent with the reduced-form studies, Figure 6 shows a higher and persistent differential in real wages in the long run compared with the short run, which is different from the real wage arbitrage predicted by the static model with free mobility and reinforces the importance of the dynamics with heterogeneous mobility frictions.

3.4 Trade Policy and Exporter Dynamics

While we have focused thus far on the effects of trade policy on labor market dynamics across space, it is important to attend to another strand of the literature that has developed quantitative frameworks with exporters' dynamic decisions. These frameworks allow researchers to study the effects of trade policy on exporters' dynamics.

Das, Roberts, and Tybout (2007) and Alessandria and Choi (2007) build a sunk-cost model where exporters face the upfront sunk cost of entering foreign markets and a smaller period-by-period continuation cost. These sunk-cost frameworks successfully account for persistence in export status, low entry and exit rates, and dependence on past activities observed in the data. In what follows we lay out the sunk-cost model of exporting, following Alessandria, Arkolakis, and Ruhl (2020). Consider a firm i that already sells to the domestic market and must decide whether to export. Denote by x_{it} the export status of the firm, where x_{it}=1 if the firm exports in t and x_{it}=0 otherwise. The current profit is $\pi(x_{it}, z_{it}, d_{it})$, where z_{it} is a stochastic production efficiency and d_{it} is the demand for firm i's product in the foreign market. The demand d_{it} depends on prices, tariffs, and the stochastic iceberg cost of exporting ξ_{jt}. Exporting entails a deterministic fixed cost, $f_{it}(x_{it-1})$, which depends on the firm's past export participation. In particular, the fixed cost is f_0 for a new exporter and f_1 for a continuing exporter. The sunk-cost model assumes that $f_0 > f_1$, where the difference is the sunk entry cost. Notice that under this formulation, fixed costs depend on the last period's export status only, so that experience in exporting does not affect the firm's decision.

Denote by $V_t^0(z_{it}, \xi_{it}, f_{it})$ the value of a firm if not exporting and by $V_t^1(z_{it}, \xi_{it}, f_{it})$ the value of a firm if exporting. Firms change export status. In particular, the value of a firm is given by

$$V_t(z_{it}, \xi_{it}, f_{it}) = max\left\{V_t^0(z_{it}, \xi_{it}, f_{it}), V_t^1(z_{it}, \xi_{it}, f_{it})\right\},$$

where

$$V_t^0(z_{it},\xi_{it},f_{it}) = \pi_t(0,z_{it},\xi_{it}) + \delta_{it} \underset{z,\xi}{E} \frac{1}{1+r_{t+1}} V_{t+1}(z_{it+1},\xi_{it+1},f_{it+1}),$$

and

$$V_t^1(z_{it},\xi_{it},f_{it}) = \pi_t(1,z_{it},\xi_{it}) - f_{it}(x_{i,t-1}) + \delta_{it} \underset{z,\xi}{E} \frac{1}{1+r_{t+1}} V_{t+1}(z_{it+1},\xi_{it+1},f_{it+1}),$$

where r is the interest rate and δ is the probability that the firm survives to the next period. In this environment, there is a cutoff rule for exporting that depends on the fixed cost, which in turn depends on the export history. In particular, for each ξ there exists a $\bar{z}(\xi)$ such that a firm with variable export cost ξ and $z \geq \bar{z}(\xi)$ will choose to export. This cutoff condition is given by

$$f_s - [\pi(1,\bar{z}_s(\xi),\xi) - \pi(0,\bar{z}_s(\xi),\xi)] = \frac{\delta}{1+r} \underset{z',\xi'}{E} \left[V^1(z',\xi',f_1) - V^0(z',\xi',f_0)\right]$$

Here the subscript s denotes the export status of the firm; namely, s =0,1. The left-hand side captures the net cost of exporting, which is the fixed cost of exporting minus the extra current profit from exporting. The right-hand side captures the future benefit of exporting. In the sunk-cost model, $\bar{z}_1(\xi) < \bar{z}_0(\xi)$ since, as mentioned earlier, new exporters must pay a higher fixed cost to export. Notice the contrast between the sunk-cost model and a fixed-cost model. In a fixed-cost model $f_1 = f_0$, the right-hand side of the policy function is zero, and therefore the firm's decision is static and depends only on current profits. Moreover, there is a single productivity threshold that is independent of export status.

Two important properties arise from the sunk-cost model. First, it generates exporter hysteresis since an exporter might continue to export even after its current conditions have worsened. Second, since firms are forward-looking, the anticipation of reductions in tariffs or trade costs increases the number of exporters and the volume of exports today. The adjustment is slow; thus, another implication is that the trade elasticity with respect to trade cost shocks is larger in the long run than in the short run. In Alessandria, Choi, and Ruhl (2014), in contrast to the sunk-cost model, new exporters make a small upfront investment to export on a small scale, and they must make repeated investments in market access to expand their exports. Thus, tariffs discourage investments on two margins: the market access for new exporters and the scale of market access by all exporters. As a result, tariff reductions lead to a larger increase in trade and larger gains from tariff reductions than they do in the sunk-cost model.[28] Importantly, in both versions of the model, the response of trade and consumption to changes in trade costs are highly non-linear; thus, the welfare

[28] Mix (2020) study the effects of trade liberalization in a multi-country version of Alessandria, Choi, and Ruhl (2014).

effects are substantially different from steady state to steady state comparison. Since the firm's decision in the sunk-cost model is forward-looking, this framework is also useful for studying the effects of trade policy uncertainty, a topic that we discuss next.

3.5 Trade Policy Uncertainty

In Section 2.4 we reviewed the reduced-form effects of trade policy uncertainty. We now discuss studies that quantify the general equilibrium effects of trade policy uncertainty.

Handley and Limao (2017) study the effects of a reduction in trade policy in a model with a sunk cost of investing that generates an option value of waiting for exporters and domestic firms that face trade policy uncertainty. The study finds that trade policy uncertainty reduces firms' entry and increases the price index in the economy. Thus, trade policy uncertainty has real effects on the economy.

Building on this research, Alessandria, Khan, and Khederlarian (2019) proposes an inventory model as in Alessandria, Kaboski, and Midrigan (2010) to study the effects of reductions in the NTR gaps and finds a large increase in trade in anticipation of uncertainty regarding future tariff increases. Facing an uncertain increase in tariffs, firms shift the timing of their purchases so they have relatively large purchases and stocks of inventories in advance of the possible tariff increase.[29]

Caldara, Iacoviello, Molligo, Prestipino, and Raffo (2020) construct measures of trade policy uncertainty based on newspaper coverage, firms' earnings conference calls, and aggregate data on tariff rates, building on the methodology developed by Baker, Bloom, and Davis (2016). The authors then study the effects of trade policy uncertainty on the U.S. economy through the lens of a New-Keynesian open economy model (e.g., Gali and Monacelli 2005; Corsetti, Dedola, and Leduc 2010). Using firm-level evidence, they find that increases in trade policy uncertainty reduce investment and economic activity.

3.6 Discussion

Overall, the development of quantitative frameworks, methods, and datasets to undertake counterfactual analysis marks a significant step forward in the quantitative trade literature in at least two main aspects. First, quantitative frameworks allow researchers to evaluate the general equilibrium effects of actual or counterfactual trade policy. Importantly, these frameworks are also an important tool to understand how trade policy operates through different mechanisms, to quantify the relative importance of each mechanism,

[29] In subsequent work Graziano, Handley, and Limao (2021) apply the sunk-cost framework in Handley and Limao (2015) to study the effects of the uncertainty caused by Brexit. In contrast, Steinberg (2019) uses a dynamic general equilibrium model with heterogeneous firms and endogenous export participation to quantify the impact of the uncertainty caused by Brexit.

and to quantify the aggregate and distributional trade and welfare effects. Second, the exact-hat algebra and dynamic-hat algebra methods are advantageous in that the frameworks are conditioned on detailed trade and production data across sectors, locations, and countries, which allows researchers to match the model to disaggregated moments in the data.

Of course, the counterfactual effects of trade policy using these methods become more informative the better the estimates of the key elasticities and the more realistic the structural assumptions in the model are. For instance, Kehoe, Pujolas, and Rossbach (2017) argue that the rapid expansion of least-traded goods after trade liberalization episodes shape the trade elasticity to tariff changes. Further progress in developing tools to perform model evaluation applied to quantitative trade analysis will allow researchers to learn more about the properties of the counterfactual predictions in quantitative trade models. However, we see two important challenges. First, there are many policies and fundamentals changing at the same time; therefore, a first hurdle is distinguishing between factual and counterfactual predictions of quantitative models that compute the effects of a subset of changes in policies or fundamentals (e.g., tariff changes only). Second, even if we overcome the first hurdle and we can compellingly argue that the predictions of a model are factual, what is the right metric with which to evaluate the success of a framework? At the same time, how can we develop a metric that can be carried to a wide class of quantitative trade frameworks?

We now turn to the normative analysis of trade policy. We review the recent progress in the analysis of optimal trade policy in models with heterogeneous products/firms and global value chains. At the end of the section, we discuss the scope of further progress in the area in terms of the connection between the new results on optimal trade policy and the quantitative analysis of actual changes to trade policy discussed in the previous two sections.

4 Optimal Trade Policy with Heterogeneity

In this section we review the fast-growing literature that analyzes trade policy in the context of firm and product heterogeneity. We mostly center the discussion on optimal unilateral import tariffs. In particular, we focus on research that considers the problem of a government that from a unilateral standpoint, chooses import taxes that maximize home welfare defined as real per-capita income (we abstract, therefore, from political economy considerations in the welfare functions and international transfers). We present benchmark results in the literature under different production structures, with and without trade in intermediate goods and make the distinction between a large economy and a small open economy. We discuss to what extent new trade theory provides new answers to the question about how countries should protect the traded sector.

To organize the exposition, we first describe optimal tariffs in a neoclassical environment. By neoclassical environment, we mean an economy in which firms have no market power and there are no domestic distortions, like in a Ricardian model of trade. We then discuss optimal import tariffs in models with monopolistically competitive heterogeneous firms. We also review recent developments that use techniques borrowed from public finance literature to characterize the optimal trade policy more broadly in the context of heterogeneous products and firms, and show how this approach can be applied to study how optimal import tariffs vary across sectors. At the end of the section, we review other types of trade instruments such as export taxes and import and export subsidies; we also review studies in which non-cooperative trade policy is analyzed. We conclude by discussing possible avenues for future progress.

4.1 Optimal Unilateral Import Tariffs in Neoclassical Environments

In the neoclassical trade theory, trade protectionism can be justified by terms-of-trade manipulation, which refers to the idea that an increase in tariffs can benefit a country by allowing it to extract rents from foreign producers by forcing them to reduce prices in order to continue serving the home economy (e.g., Bickerdike 1907; de V. Graaff 1949; Johnson 1953; Kahn 1947). A direct implication of a neoclassical small open economy in which the country cannot affect world prices is that the optimal tariff is zero. In the next subsection, we revisit this and other results in neoclassical models with product heterogeneity.

4.1.1 A Two-country, One-sector Economy with a Continuum of Goods

Consider a one-sector Ricardian trade model. Denote countries by i and n. Assume that country n unilaterally chooses its import tariff and that the rest of the world (indexed by i) is not strategic. Total expenditure on goods in country n is equal to income; labor income ($w_n L_n$) plus tariff revenue under the assumption that it is lump-sum transferred to consumers. We denote the total expenditure of country n by X_n and the expenditure (inclusive of tariffs) on goods from the rest of the world i as X_{ni}. The share of the total expenditure in country n that is spent on imported goods is given by $\lambda_{ni} = X_{ni}/X_n$. Denote by τ_{ni} the one plus ad-valorem import tariff applied by country n to goods imported from country i. Then

$$X_n = w_n L_n + (\tau_{ni} - 1)\frac{\lambda_{ni} X_n}{\tau_{ni}},$$

and solving for per-capita expenditure we obtain,

$$\frac{X_n}{L_n} = w_n \frac{\tau_{ni}}{1 + (\tau_{ni} - 1)\,\lambda_{nn}}, \tag{31}$$

where $\lambda_{ni} + \lambda_{nn} = 1$.

We assume that trade is balanced,

$$\frac{\lambda_{ni}}{\tau_{ni}} X_n = \frac{\lambda_{in}}{\tau_{in}} X_i, \tag{32}$$

where the tariff that the rest of the world applies to goods from n is τ_{in}.

The gravity structure follows Eaton and Kortum (2002) where

$$\lambda_{nn} = A_n \left[\frac{w_n}{P_n}\right]^{-1/\theta} = \frac{A_n\,[w_n]^{-1/\theta}}{A_n\,[w_n]^{-1/\theta} + A_i\,[w_i \tau_{ni} \kappa_{ni}]^{-1/\theta}}, \tag{33}$$

where P_n is the ideal price index at n, κ_{ni} are the iceberg-type trade costs incurred when shipping a good across countries, and A_n is the technology fundamental (absolute advantage) in country n. In this section, we define the parameter θ as the dispersion of individual productivities as in Alvarez and Lucas (2007), and therefore the trade elasticity is given by $1/\theta$.

Finally, welfare in country n is given by

$$W_n = \frac{X_n}{L_n P_n}.$$

Fully differentiating welfare, we obtain

$$\hat{W}_n = \widehat{\left(\frac{w_n}{P_n}\right)} + \frac{1 - \lambda_{nn}}{\lambda_{nn}\,(\tau_{ni} - 1) + 1}\hat{\tau}_{ni} - \frac{\lambda_{nn}\,(\tau_{ni} - 1)}{\lambda_{nn}\,(\tau_{ni} - 1) + 1}\hat{\lambda}_{nn}, \tag{34}$$

where $\hat{x} = dln\,(x)$. We now can use (33) to obtain $\hat{\lambda}_{nn} = -\,(1/\theta)\widehat{\left(\frac{w_n}{P_n}\right)}$. In addition, combining trade balance (32) with gravity (33) and per-capita income (31), we obtain

$$\varpi L_n \left(\frac{A_i \tau_{in}}{A_n\,[\varpi \tau_{in} d_{in}]^{-1/\theta}} + 1\right) = L_i \left(\frac{A_n\,[\varpi]^{-1/\theta}\,\tau_{ni}}{A_i\,[\kappa_{ni}\tau_{ni}]^{-1/\theta}} + 1\right)$$

where $\varpi = w_n/w_i$. Now, fully differentiating this expression, and assuming that $\hat{\tau}_{in} = 0$ (the rest of the world does not change tariffs), we obtain

$$\hat{\varpi} = \frac{(1+\theta)\,\tilde{\lambda}_{nn}}{\left(\theta + \tilde{\lambda}_{ii} + \tilde{\lambda}_{nn}\right)}\hat{\tau}_{ni}, \tag{35}$$

where $\tilde{\lambda}_{ii} = \frac{\lambda_{ii}\tau_{in}}{\lambda_{ii}\tau_{in}+1-\lambda_{ii}}$, and $\tilde{\lambda}_{nn} = \frac{\lambda_{nn}\tau_{ni}}{\lambda_{nn}\tau_{ni}+1-\lambda_{nn}}$ are the share of production sold to domestic firms at each country, or the domestic production shares. Solving for $\hat{\lambda}_{nn}$ as a function of $\hat{\varpi}$ using (33) and substituting for $\hat{\varpi}$ using (35), we obtain

$$\hat{\tau}_{ni} = \frac{\theta}{(1-\lambda_{nn})} \frac{\theta + \tilde{\lambda}_{ii} + \tilde{\lambda}_{nn}}{\theta\left(1-\tilde{\lambda}_{nn}\right) + \tilde{\lambda}_{ii}} \hat{\lambda}_{nn}.$$

Finally, substituting all these expressions into welfare, we obtain

$$\hat{W}_n = \left(-\theta + \frac{\theta}{\lambda_{nn}(\tau_{ni}-1)+1}\left(\frac{\theta + \tilde{\lambda}_{ii} + \tilde{\lambda}_{nn}}{\theta\left(1-\tilde{\lambda}_{nn}\right) + \tilde{\lambda}_{ii}}\right) - \frac{\lambda_{nn}(\tau_{ni}-1)}{(\lambda_{nn}(\tau_{ni}-1)+1)}\right)\hat{\lambda}_{nn},$$

where the optimal unilateral import tariff solves

$$-\theta + \left(\frac{\theta}{\lambda_{nn}(\tau^*_{ni}-1)+1}\right)\frac{\theta + \tilde{\lambda}_{ii} + \tilde{\lambda}_{nn}}{\theta\left(1-\tilde{\lambda}_{nn}\right) + \tilde{\lambda}_{ii}} - \frac{\lambda_{nn}(\tau^*_{ni}-1)}{\lambda_{nn}(\tau^*_{ni}-1)+1} = 0$$

and then we obtain

$$\tau^*_{ni} = 1 + \frac{\theta}{\tilde{\lambda}_{ii}}. \tag{36}$$

The optimal tariff responds to terms of trade considerations, and depends on the trade elasticity $1/\theta$ and on the size of the foreign country captured by $\tilde{\lambda}_{ii}$.

4.1.2 Small Open Economy

We now turn to analyze the optimal tariff in a small open neoclassical economy with product differentiation. We follow Gros (1987), Alvarez and Lucas (2007), and Demidova and Rodríguez-Clare (2009), and define country n to be a small open economy as the limiting economy such that $L_n/L_i \to 0$. Accordingly, in the limiting economy, we have that $\lambda_{ii} = 1$ and $\lambda_{nn} = 0$.[30] As we will see later on, with product heterogeneity even a small economy can manipulate its terms of trade. This result contrasts with the case of homogeneous goods in which a small economy is not able to manipulate its terms of trade.

To obtain the optimal tariff in the limiting economy, we proceed to take the limit after solving for the optimal tariff of a large economy. Namely, set $\tilde{\lambda}_{ii} \to 1$ and $\tilde{\lambda}_{nn} \to 0$ in the optimal tariff formula for the large economy (36).[31]

[30] It can be shown that in the limiting economy $\tilde{\lambda}_{ii} = 1$ and $\tilde{\lambda}_{nn} = 0$ (see Alvarez and Lucas 2007).

[31] As mentioned in Footnote 27 in Costinot and Rodríguez-Clare (2014), one expects that in a small country, welfare must change with import tariffs due to deadweight losses and tariff revenues. However, with linear technology we can see in equation (34) that the welfare function is invariant to tariffs, thus the optimal tariff is undetermined. An optimal tariff can be found by taking the limit of a small open economy after computing the optimal tariff for the large economy (see also Gros 1987). Alternatively, in Section E.2 of the online appendix, we arrive at the same formula by computing the optimal tariff in a limiting economy with intermediate goods and then taking the limit when the share of intermediate goods in output approaches to zero.

The optimal import tariff is given by

$$\tau_{ni}^* = 1 + \theta. \tag{37}$$

A small economy cannot affect factor prices abroad; still, it would want to manipulate its terms of trade. As emphasized in Alvarez and Lucas (2007), in a Ricardian economy with heterogeneous goods as in Eaton and Kortum (2002), any economy, no matter how small, has some goods that it is extremely efficient at producing. This "market power" cannot be exploited by individual sellers because others in the same economy have free access to the efficient constant-returns technology. However, it can be exploited by the government if the government imposes import tariffs to maximize real income.[32] For smaller values of θ, goods produced across countries are more similar, and therefore there is less room for the government to manipulate its terms-of-trade. The parameter θ plays a role analogous to the elasticities of substitution in Armington models that assume that goods produced in different countries appear as imperfect substitutes in the utility function. Too see this, in an Armington model $\lambda_{nn} = \frac{a_{nn}[w_n]^{1-\sigma}}{a_{nn}[w_n]^{1-\sigma}+a_{ni}[w_i\tau_{ni}\kappa_{ni}]^{1-\sigma}}$, where a_{nn} has the interpretation of preference weights on domestic goods, and σ is the elasticity of substitution across goods. In this case, we obtain that the optimal tariff for a large economy is given by $\tau_{ni}^* = 1+1/\left((\sigma-1)\,\tilde{\lambda}_{ii}\right)$, and for the small open economy is given by $\tau_{ni}^* = 1 + 1/(\sigma - 1)$, both increasing in the degree of production differentiation.

Note that the optimal import tariff in the case of a small open economy is smaller than in the case of a large economy. This is because the terms of trade elasticity with respect to exports (or imports) is larger for a large economy since the foreign country's domestic expenditure share is lower, leading to a higher optimal tariff. The importance of the relative country size is captured by the degree of trade openness of the country $\tilde{\lambda}_{ii}$ and is absent in the case of a small open economy. To summarize, the main results are that in a one-sector Ricardian economy, the optimal unilateral uniform import tariff is positive and given by (36); for a small open economy in a one-sector Ricardian economy, the optimal unilateral uniform import tariff is positive and given by (37); and for a small open economy with no product heterogeneity, the optimal unilateral tariff is zero.

4.1.3 Trade Policy Across Goods

Should governments take into account heterogeneity when designing trade policy? Namely, should taxes vary at the product level according to comparative advantage? Costinot, Donaldson, Vogel, and Werning

[32] Unlike the analysis in this section, Alvarez and Lucas (2007) present numerical simulations to show that the optimal tariff in a small open economy is positive and increasing in θ. They assume a Ricardian model in which final goods are produced with labor and intermediate goods, and under this assumption, the optimal import tariff does not have a closed-form solution. The optimal tariff in Alvarez and Lucas (2007) can be mapped into (37) by making the share of labor in final goods approach zero.

(2015) explore the welfare-maximizing structure of trade taxes in the context of a canonical Ricardian model of comparative advantage. The study investigates whether optimal trade taxes should vary according to the comparative advantage at the variety level (which could be thought of as product-level trade taxes).

Costinot, Donaldson, Vogel, and Werning (2015) show that in a canonical two-country Ricardian model with CES utility, the overall level of trade taxes is indeterminated, but optimal trade policy depends on the extent of heterogeneity at the micro level. In particular, optimal trade taxes have the following structure: import tariffs that are uniform across goods, and export taxes that vary with comparative advantage. Examples of optimal trade taxes are zero uniform import tariffs and export taxes that are increasing with respect to comparative advantage, or uniform and positive import tariffs and export subsidies that are decreasing with respect to comparative advantage. This latter result intuitively follows from the observation that countries can better manipulate prices in their comparative advantage sectors than they can in their less productive sectors. One should not think of this result as suggesting that governments have incentives to subsidize less productive firms in order to expand the production and export of these varieties. Rather, the home country is constrained in its ability to exploit monopoly power in all goods due to the threat of entry of foreign goods. That is, the home country at most can have constant monopoly markups for exported goods in its strongest comparative advantage varieties, while the threat of entry of foreign firms leads markups to decline with comparative advantage. Optimal policy restricts overall trade on net and export subsidies are optimal provided import tariffs are high enough. Interestingly, the optimal allocation with export subsidies results in an equilibrium in which all goods are traded. This result relates to Itoh and Kiyono (1987) who show that non-uniform export subsidies are welfare-maximizing in a Ricardian model and that such subsidies allow for the expansion of the set of goods traded.

Suppose we are interested in knowing the optimal trade taxes when the government is constrained to use only one instrument; import tariffs. Opp (2010) and Costinot, Donaldson, Vogel, and Werning (2015) show that the optimal import tariff is uniform across goods. The intuition builds on the Lerner symmetry in a multiple-good environment. Import tariffs, at most, can be used to obtain the same average domestic relative price between imported and exported goods as in the unconstrained environment. However, since the relative world price of any pair of imported goods is not manipulable (it is equal to the relative unit labor requirements in the rest of the world), there is no reason for the home country to impose heterogeneous import tariffs, even if export taxes are ruled out.

To perform the analysis, Costinot, Donaldson, Vogel, and Werning (2015) use techniques borrowed from public finance literature. The authors follow the primal approach as in Baldwin (1948) and Dixit (1985) and show how Lagrange multiplier methods can be used to characterize the structure of optimal trade taxes even without knowing the aggregate variables and foreign wages. While Dixit (1985) presents general formulas for the optimal trade taxes in terms of various elasticities, Costinot, Donaldson, Vogel, and Werning (2015) relate those elasticities to primitives, such as patterns of comparative advantage between countries. In a nutshell, the primal approach is as follows: first, assume that the government can directly choose output and consumption and solve for the optimal allocation; second, show that the optimal allocation can be implemented using trade taxes. Of course, the first best can be implemented if enough instruments are available.

The techniques applied in the study exploit the additive separability property of the Lagrangian, which is a common property in many types of economic environments used in the field. The methodological contribution entails solving for the planning problem in two steps. First, consider the problem of solving for the micro-allocations (consumption and production) that maximize home welfare as a function of the aggregate variables and foreign wages. This is what Costinot, Donaldson, Vogel, and Werning (2015) refer to as the inner problem. Solving the inner problem provides a value function that is a function of the foreign wage. With this function, one can solve for the outer problem; namely, the foreign wages that maximize the value of the inner problem. Costinot, Donaldson, Vogel, and Werning (2015) show that the solution to the inner problem is concave, which allows to compute the solution to the inner problem using Lagrange multiplier methods. In addition, if the objective function and the constraints from the inner problem are additively separable in the control variables, one can solve the inner problem cell by cell; namely, market by market. They show that the optimization problem of the inner problem becomes a "cell-problem" and can be solved cell by cell (see Everett 1963 for a description of more general types of ''cell problems''). Importantly, note that after solving the inner problem, one can characterize the structure of trade taxes even without knowing the foreign wage. Similar techniques have been applied by Amador, Werning, and Angeletos (2006) and Amador and Bagwell (2013). More recently, Kortum and Weisbach (2020) apply this method to characterize optimal trade, production, and carbon taxes in a two-country Ricardian model (akin to Dornbusch, Fischer, and Samuelson 1977) with elements from Markusen (1975).

The techniques in Costinot, Donaldson, Vogel, and Werning (2015) can be applied to many other setups. For example, to characterize optimal trade taxes across sectors. We now move to a multi-sector environment and present and example of the primal method.

4.1.4 Trade Taxes Across Sectors

In the context of a Ricardian model, one can interpret goods as sectors, and given this, the structure of optimal trade taxes across goods described above apply to a multi-sector environment. In fact, in a two-country neoclassical model, Costinot, Donaldson, Vogel, and Werning (2015) show that optimal trade taxes vary by sector, but that in order for the decentralized equilibrium to match the planners' solution, one should use uniform import tariffs and non-uniform export subsidies.

Beshkar and Lashkaripour (2020) present similar results and derive the optimal trade tax formulas for a class of general equilibrium trade models with multiple sectors and input-output linkages that have become the workhorse models for quantitative work. Within that class of models, Beshkar and Lashkaripour (2020) show that optimal import tariffs are uniform even under the presence of input-output linkages as far as export taxes are available. The authors then use estimates for 35 industries and 40 countries to quantify the gains from optimal trade policy. Beshkar and Shourideh (2020) show in a dynamic Ricardian model with endogenous trade imbalances that if the government has access to time-varying import and export taxes, optimal import tariffs are also uniform across sectors, and countercyclical over time.

It is important to stress again that the results in Costinot, Donaldson, Vogel, and Werning (2015), Beshkar and Lashkaripour (2020), and Beshkar and Shourideh (2020) apply only to two country frameworks. Intuitively, as discussed before, in a two-country Ricardian world, the relative price of imported goods is not manipulable since they are pinned down by the relative labor requirements in the foreign country. With more than two countries, the government can manipulate the relative price of its imports by manipulating the relative wage of the foreign countries it sources from.

Example of the Primal Approach with Multiple Sectors

We now show how to apply the primal approach to characterize trade policy at the sector level. We consider a two-country, multi-sector Armington model and solve for the inner problem to characterize the optimal import and export tariffs. We continue denoting countries by i and n and sectors by j. Consider country $i's$ planning problem, in which the planner directly chooses consumption at home and abroad and foreign wages in order to maximize home welfare. Consider first a relaxed planner problem of choosing consumption taking as given foreign wages w_n. Namely,

$$V_i\left(w_n\right) \equiv \max_{c_{ii}^j, c_{in}^j, c_{ni}^j} \sum_j \alpha^j \ln\left[\left[c_{ii}^j\right]^{1-1/\sigma^j} + \left[c_{in}^j\right]^{1-1/\sigma^j}\right]^{\frac{\sigma^j}{\sigma^j-1}}, \tag{38}$$

where α^j is the expenditure share of goods from sector j, c_{in}^j denotes country $i's$ consumption of goods produced in n, and σ^j is the sectoral elasticity of substitution. The home solves this problem subject to the resource constraints at home and foreign, and trade balance. We now describe each of these constraints.

The resource constraint at home is given by

$$\sum_j a_i^j \left[c_{ii}^j + c_{ni}^j\right] \leq L_i, \tag{39}$$

where a_i^j is the unit labor requirement to produce sector j goods in country i, and L_i is the labor endowment in country i. Home also chooses the consumption of goods from abroad that is feasible, taking into account that trade has to be balanced. The trade balance condition is given by

$$\sum_J \left[a_n^j w_n c_{in}^j - p_{ni}^j(c_{ni}^j, w_n) c_{ni}^j\right] \leq 0, \tag{40}$$

where $a_n^j w_n$ is the price of foreign goods and $p_{ni}^j\left(c_{ni}^j, w_n\right)$ is the world price of domestic goods, which is a function of foreign wages and the foreign consumption of domestic goods. In particular, this price function is implicitly defined using the optimal consumption of domestic goods from foreign; namely,

$$c_{ni}^j = \frac{\left[p_{ni}^j(c_{ni}^j, w_n)\right]^{-\sigma^j}}{\left[a_n^j w_n\right]^{1-\sigma^j} + \left[p_{ni}^j(c_{ni}^j, w_n)\right]^{1-\sigma^j}} \alpha^j w_n L_n.$$

Finally, home also takes into account the resource constraint of foreign,

$$\sum_j a_n^j \left[c_{in}^j + \frac{\left[a_n^j w_n\right]^{-\sigma^j}}{\left[a_n^j w_n\right]^{1-\sigma^j} + \left[p_{ni}^j(c_{ni}^j, w_n)\right]^{1-\sigma^j}} \alpha^j w_n L_n\right] \leq L_n, \tag{41}$$

where home internalizes that foreign is optimally choosing the consumption of its domestic goods.

To solve this optimization problem, one would usually write the Lagrangian for the entire problem. Let $\mathcal{L}\left(c_{ii}^j, c_{in}^j, c_{ni}^j, \lambda, \lambda^*, \mu, w_n\right)$ be the Lagrangian from the optimization problem (38) subject to the following constraints: (39) with corresponding multiplier λ, (41) with corresponding multiplier λ^*, and (40) with corresponding multiplier μ. Formally,

$$\begin{aligned}
\mathcal{L}\left(c_{ii}^j, c_{in}^j, c_{ni}^j, \lambda, \lambda^*, \mu, w_n\right) \equiv & \sum_j \alpha^j \ln\left[\left[c_{ii}^j\right]^{1-1/\sigma^j} + \left[c_{in}^j\right]^{1-1/\sigma^j}\right]^{\frac{\sigma^j}{\sigma^j - 1}} - \lambda\Big[\sum_j a_i^j \left[c_{ii}^j + c_{ni}^j\right] - L_i\Big] \\
& - \lambda^* \Big[\sum_j a_n^j \Big[c_{in}^j + \frac{\alpha^j w_n L_n \left[a_n^j w_n\right]^{-\sigma^j}}{\left[a_n^j w_n\right]^{1-\sigma^j} + \left[p_{ni}^j(c_{ni}^j, w_n)\right]^{1-\sigma^j}}\Big] - L_n\Big] \\
& - \mu \sum_J \left[a_n^j w_n c_{in}^j - p_{ni}^j(c_{ni}^j, w_n) c_{ni}^j\right],
\end{aligned}$$

As we can see, the Lagrangian is separable across sectors. Namely,

$$\mathcal{L}(c_{ii}^j, c_{in}^j, c_{ni}^j, \lambda, \lambda^*, \mu, w_n) = \sum_j \left[F^j\left(c_{ii}^j, c_{in}^j, \lambda, \lambda^*, \mu, w_n\right) + g^j\left(c_{ni}^j, \lambda, \lambda^*, \mu, w_n\right)\right]$$

where

$$F^j\left(c_{ii}^j, c_{in}^j, \lambda, \lambda^*, \mu, w_n\right) \equiv \alpha^j \ln\Big[\left[c_{ii}^j\right]^{1-1/\sigma^j} + \left[c_{in}^j\right]^{1-1/\sigma^j}\Big]^{\frac{\sigma^j}{\sigma^j-1}} - \lambda a_i^j c_{ii}^j - \lambda^* a_n^j c_{in}^j - \mu a_n^j w_n c_{in}^j$$

and

$$g^j\left(c_{ni}^j, \lambda, \lambda^*, \mu, w_n\right) \equiv \mu p_{ni}^j(c_{ni}^j, w_n) c_{ni}^j - \lambda a_i^j c_{ni}^j - \lambda^* \frac{\alpha^j w_n L_n \left[a_n^j w_n\right]^{-\sigma^j}}{\left[a_n^j w_n\right]^{1-\sigma^j} + \left[p_{ni}^j(c_{ni}^j, w_n)\right]^{1-\sigma^j}}.$$

As a result, one can maximize the Lagrangian sector by sector (cell by cell). From the solution to this problem, one can determine the optimal allocations sector by sector. The next step is to show that the allocations can be implemented using trade taxes. Let τ_{in}^j be the wedge between the domestic price and the world price of a foreign-sector j good. Note that this wedge represents one plus the optimal import tariff on foreign goods in the decentralized equilibrium. From the first-order conditions of the sector j Lagrangian, we obtain

$$\tau_{in}^j = \left(\mu + \frac{\lambda^*}{w_n}\right).$$

As becomes apparent in this expression, the right-hand side of τ_{in}^j does not vary across sectors j; therefore, having uniform import tariffs across sectors is optimal. Following similar logic, let τ_{in}^{Xj} be the wedge between the domestic price and the world price of a domestic good from sector j. Then this wedge represents one plus the optimal export subsidy on domestic goods in the decentralized equilibrium. To see this, from the first-order conditions of the sector j Lagrangian, we obtain that export subsidies are implicitly defined as

$$\tau_{in}^{Xj} = \frac{\left(\mu + \frac{\lambda^*}{w_n}\right)}{\left(\frac{1}{\sigma^j-1}\left(\frac{a_n^j w_n \tau_{in}^{Xj}}{\lambda a_i^j}\right)^{\sigma^j-1} + \frac{\sigma^j}{\sigma^j-1}\right)},$$

where one can see that τ_{in}^{Xj} are increasing with comparative advantage, a_i^j/a_n^j. Namely, sectors with weaker comparative advantage should be subsidized more.

4.2 Monopolistic Competitive Firms

We now move to environments that feature monopolistic competition and firm heterogeneity. We start by describing the results of optimal import tariffs when we restrict policies to be uniform across firms. We discuss how the results differ in large economy and small open economy settings and how the presence of selection might change the results. We then shift to review results on firm-level trade taxes.

4.2.1 A Two-Country, One-sector Economy with a Continuum of Firms

Gros (1987) shows that in a Krugman (1980) model of trade with product differentiation and monopolistic competition, the optimal unilateral import tariff is positive even for a small economy. The intuition comes from the fact that product differentiation allows the home country to manipulate its terms of trade. This result has been reassessed by Demidova and Rodríguez-Clare (2009) for a small open economy and by Felbermayr, Jung, and Larch (2013) with two large countries in the context of heterogeneous firm models a la Melitz (2003) with Pareto productivity distribution as in Chaney (2008). We now follow these papers and describe the main findings. We direct the reader to Demidova and Rodríguez-Clare (2009), Haaland and Venables (2016), and Felbermayr, Jung, and Larch (2013) for a complete characterization of the problem of choosing the optimal tariff.

Compared to the previous section (neoclassical), there are two new key equilibrium relationships: the free entry condition and selection. The free entry condition implies that

$$\frac{\sigma-1}{\alpha-\sigma+1}\left[f_{nn}\left(\varphi_{nn}^{*}\right)^{-\theta}+f_{ni}\left(\varphi_{ni}^{*}\right)^{-\theta}\right] \quad = \quad f^{E};$$

namely, that expected profits from selling domestically and from exporting are equal to the fixed cost of entry. The parameters f_{nn} and f_{ni} represent the fixed cost of production and f^E represents the entry cost, all in units of labor. Selection dictates that only the most productive firms operate domestically and an even more selective group of firms are the only ones able to export. The productivity of the firms is denoted by φ, where φ_{nn}^* refers to the cut-off level of productivity that determines the productivity of the marginal firm that is indifferent about entering the domestic market and φ_{ni}^* is the cut-off level of productivity for exporting. The parameter α represents the shape parameter of the Pareto distribution and σ represents the demand elasticity. We assume that $\alpha > \sigma - 1$, which is the standard regularity condition imposed to solve the model.

Combining the free entry condition with the labor market clearing condition, one can solve for the mass of operating firms in the market; namely,

$$M_n = \frac{\left(\lambda_{nn} + \frac{1-\lambda_{nn}}{\tau_{ni}}\right) X_n}{w_n\, f^E \left(\frac{\alpha\,\sigma}{\sigma-1}\right)}$$

where X_n is given by (31). Combining this expression with (31) we obtain

$$M_n = \left(\frac{\sigma - 1}{\alpha\,\sigma}\right)\frac{L_n}{f^E},$$

where we can immediately see that trade policy does not affect the entry margin in this model. This is quite an interesting result that follows from having a CES demand system, a Pareto productivity distribution, and a single sector. Several papers that we subsequently discuss have shown that this result does not hold if we depart from the model in particular ways, such as by adding intermediate goods, multiple sectors, or non-CES preferences.

It turns out that the domestic expenditure share in this model can be expressed as

$$\lambda_{nn} = \frac{M_n\left[\frac{\sigma}{\sigma-1}w_n\right]^{1-\sigma}}{M_n\left[\frac{\sigma}{\sigma-1}w_n\right]^{1-\sigma} + M_i\left[\frac{\sigma}{\sigma-1}w_i\tau_{ni}\kappa_{ni}\right]^{1-\sigma}}.$$

This expression needs to be compared with its neoclassical counterpart, equation (33). Using (33), we can solve for the elasticity of trade flows with respect to tariffs ($dlnX_{ni}/dln\tau_{ni}$) in the Ricardian model, which is given by $-1/\theta$. In the monopolistic competitive model, the elasticity of trade flows with respect to tariffs is given by $1 - \frac{\sigma\alpha}{\sigma-1}$. Felbermayr, Jung, and Larch (2013) show that the optimal unilateral import tariff is given by

$$\tau^*_{ni} = 1 + \frac{1}{(\frac{\sigma\alpha}{\sigma-1} - 1)\tilde{\lambda}_{ii}}, \tag{42}$$

where $\tilde{\lambda}_{ii}$ is the foreign domestic production share.

In order to understand the intuition of this formula, let us consider the case of a small open economy ($\tilde{\lambda}_{ii}{\to}1$). First note that when $\alpha{\to}\sigma{-}1$, we obtain the optimal import tariff formula derived by Gros (1987); namely,

$$\tau^*_{ni} = \frac{\sigma}{\sigma - 1}.$$

Now let us consider the case with selection and a small open economy, as in Demidova and Rodríguez-Clare (2009). In this case, the optimal import tariff formula is

$$\tau^*_{ni} = \frac{\sigma}{\sigma - 1}\frac{\alpha}{(\frac{\sigma\alpha}{\sigma-1} - 1)}, \tag{43}$$

where now the optimal tariff formula is the product of the instrument for handling the markup distortion and the "entry distortion." This second distortion is due to selection and arises because consumers at home do not internalize the effect that their spending on imports has on the number of imported varieties available for domestic consumption. In consequence, consumers spend less than is optimal and the number of foreign varieties available to domestic consumers is below the optimal level. Note that since $\alpha > \sigma - 1$, then $\frac{\alpha}{(\frac{\sigma\alpha}{\sigma-1}-1)} < 1$, which indicates that the optimal policy to address this distortion is subsidizing the entry of foreign varieties (Demidova and Rodríguez-Clare 2009 show alternative instruments to address this distortion, including a tax on the consumption of domestic varieties, an import subsidy, or an export subsidy). We now summarize the main findings. In a one-sector monopolistic competitive economy with heterogeneous firms, CES utility, and Pareto distribution of productivity, the optimal unilateral uniform import tariff is positive and given by (42). In the case of a small open economy, the optimal uniform import tariff is given by (43) and it is lower than the one for the large economy; in this same case, the optimal uniform import tariff in a model without selection is larger than that of a model with selection.

Recent work has been able to generalize this result to environments with arbitrary distributions of productivity (beyond Pareto). Costinot, Rodríguez-Clare, and Werning (2020) present a more general optimal unilateral import tariff formula:

$$\tau_{ni}^{*} = 1 + \frac{1 + \sigma/\psi_i}{(\sigma-1)\tilde{\lambda}_{ii}}. \tag{44}$$

As we can see, the generalized formula contains a new term, ψ_i, which denotes the elasticity of the transformation curve of the foreign country. In a model with a general distribution of productivity, the elasticity may be positive or negative; namely, there can be non-convexities in the production possibility frontier and the sign determines whether the tariff is higher or lower than it is in a model without firm heterogeneity. It turns out that with a Pareto distribution, Feenstra (2010) shows that the aggregate production possibility frontier has a constant elasticity of transformation. Following our notation, it is given by $\psi_i = -\frac{\alpha\sigma-(\sigma-1)}{\alpha-(\sigma-1)} < 0$. One can see that after substituting this expression into (44), we obtain (42). This result is a generalization of the formulas in Gros (1987), Demidova and Rodríguez-Clare (2009), and Felbermayr, Jung, and Larch (2013) and it provides further insight into the role that firm heterogeneity and selection play in optimal unilateral trade tariffs. Note that the sign of ψ_i crucially determines whether the optimal tariff is larger or smaller compared to the tariff in a model without selection. As we saw before, with a Pareto distribution we know that it is smaller, but beyond Pareto, this might not be the case.

A set of studies considers economic environments with non-CES utility functions and endogenous markups. Demidova (2017) studies trade policy in the context of the Melitz (2003) model with a linear demand system and horizontal product differentiation following Ottaviano, Tabuchi, and Thisse (2002). This model is a single-sector version of the Melitz and Ottaviano (2008) model. The study finds that from the unilateral perspective of the home country, a strictly positive import tariff is optimal. In addition, the paper finds that import tariffs are optimal even if home is a small open economy, but the optimal tariff is smaller compared to the large economy case. The paper also shows that with variable markups, the optimal level of protection is higher than it is in an economy with constant markups, as in Melitz (2003). This is because import tariffs can shift resources away from the high-markup firms to the low-markup firms and in this way partially address the misallocation distortion generated by the variable markups. Imposing an import tariff leads to the survival of the least productive domestic firms (the ones with lower markups) that otherwise would have exited.

Beyond these single-sector results, optimal unilateral trade policy has been characterized in a variety of economic environments in recent literature. For example, Caliendo, Feenstra, Romalis, and Taylor (2015) analyze import tariffs in the context of a multi-sector Melitz (2003) model with Pareto distribution of productivity and trade in intermediate goods. They show in a symmetric two-sector, two-country model starting at free trade, that under certain conditions related to the importance of roundabout production and the size of the non-tradable sector, a country may gain from the unilateral introduction of a small import subsidy. Bagwell and Lee (2020) analyze optimal trade policy in a symmetric two-country and two-sector heterogeneous firm model with quadratic preferences, as in Melitz and Ottaviano (2008). The authors highlight three forces that shape optimal trade policy in their model. First, there is a selection effect by which an increase in the import tariff by home lowers the cut-off cost level for domestic sales in home and increases the cut-off cost level for domestic sales in the foreign country. Second, there is a firm delocation effect by which an increase in the import tariff by home increases the number of entrants (varieties) in home and decreases the number of entrants (varieties) in the foreign country. This second effect generates a Metzler paradox wherein an import tariff reduces the domestic price index and increases the foreign price index. Third, the difference in markups between the differentiated and the competitive outside sectors generates a distortion that tariffs may be able to correct.[33] The authors show that a country can gain by imposing a small import tariff; they also identify conditions under which a country can gain by introducing a small export subsidy. An export subsidy has two opposite effects. It facilitates entry and lowers the average price while expanding varieties in the intervening country, but it also gives rise to a subsidy expense. Given this, the country gains from the introduction of a small export subsidy if selection effects are strong enough. In a subsequent paper, Bagwell and Lee (2018) replace quadratic preferences with quasi-linear preferences in the Bagwell and Lee (2020) framework and show that in this case, the home country always gains from imposing a small export subsidy.

Beyond the terms of trade manipulation, in the context of imperfect competition models, several papers have focused on a firm delocation motive to trade policy introduced by Venables (1985, 1987) and Helpman

[33] This entry distortion is not present in a single-sector CES model; see Dhingra and Morrow (2019).

and Krugman (1989).[34] In this context, Grossman, McCalman, and Staiger (2021) study the unilateral incentives to invoke regulatory protectionism to induce firm delocation. Other recent studies characterizing optimal policy in this setup with delocation motives include Ossa (2011), Bagwell and Staiger (2012a), Campolmi, Fadinger, and Forlati (2014), and Bagwell and Staiger (2015). There is another strand of the literature that studies a profit-shifting motive to trade policy. Namely, governments use trade policy to shift profits from foreign to domestic firms (see Brander and Spencer 1985). More recent studies investigating trade policy under these motives include Mrazova (2011), Bagwell and Staiger (2012b), and Ossa (2012). Finally, in an economic environment where prices are determined by bilateral bargaining, Antràs and Staiger (2012b) and Antràs and Staiger (2012a) show that it generates a trade-volume externality due to the fact that prices are not determined by market clearing. The government policies can then affect the terms of trade and the volume of trade separately, which is not the case in a model where prices are determined by supply and demand. These studies are explained and reviewed in great detail in Maggi (2014).

Trade policy uncertainty may also generate an additional reason to reconsider optimal trade policy. Governments might want to use policies to manage the uncertainty generated by unexpected changes in the economic or political environment, which in turn affect trade policies. Limao and Maggi (2015) consider an "uncertainty managing" motive for trade policy. In the study, they characterize conditions under which the degree of uncertainty might require governments to consider policies that regulate the degree of policy uncertainty. They find gains from reducing trade policy uncertainty, conditional on the degree of risk aversion, when economies are more open, export supply elasticities are lower, and economies are more specialized. Importantly, as countries become more open, the gains from decreasing tariff uncertainty are larger relative to those from decreasing the overall level of tariffs.

4.2.2 Trade Policy Across Firms

We now revisit the question of how governments should take into account firm heterogeneity when designing trade policy. Costinot, Rodríguez-Clare, and Werning (2020) study optimal unilateral trade taxes in the context of monopolistic competitive environments with heterogeneous firms. The authors separate the problem of finding the optimal trade taxes into a series of micro sub-problems where the planner chooses micro-allocations conditional on aggregate quantities (domestic and foreign). Then the authors write down the macro problem that allows them to solve for the optimal aggregate quantities. The solution to the micro problem allows them to characterize the optimal micro structure of trade taxes, while the solution

[34] While not justified theoretically or empirically, policymakers have explicitly mentioned this argument for trade protectionism (see Baldwin, Forslid, Martin, Ottaviano, and Robert-Nicoud 2003).

to the macro problem allows them to characterize the level of such taxes. Directly solving the government problem requires addressing an optimization problem that is infinite-dimensional and non-convex. By invoking the Lagrangian necessity theorem, the paper shows that the micro problem can be reduced to a simple one-dimensional Lagrangian problem.

Several new important results follow from this research. The study shows that at the micro-firm level, unilaterally optimal policies are as follows: domestic taxes that are uniform across all domestic producers, export taxes that are uniform across all exporters, and import taxes that are uniform across the most profitable foreign exporters and strictly increasing with profitability across the least profitable ones (import subsidies). As we can see, these results contrast with the findings in a neoclassical economy whose optimal trade taxes consist of uniform import tariffs and non-uniform export subsidies.

The paper shows that one way to implement these policies is by imposing uniform export taxes and import subsidies to foreign varieties sold at home that are decreasing in profitability and setting the overall level of other taxes to zero. This follows from Lerner symmetry, which Costinot and Werning (2019) show still holds in the context of monopolistic competition. As explained in the paper, this result is driven by the selection of firms and the fact that consumers and firms do not internalize the effect of their import decisions on import prices. As a result, the self-selection of heterogeneous firms into exporting motivates the imposition of import subsidies on the least profitable foreign firms. Costinot, Rodríguez-Clare, and Werning (2020) also analyze optimal uniform tariffs on final differentiated goods with general separable preferences.

4.3 Trade in Intermediate Goods - Global Value Chains

Beyond the research we presented earlier in this chapter, several studies have found evidence of the impact of trade policy along supply chains. For example, Yi (2003), Costinot and Rodríguez-Clare (2014) and Caliendo and Parro (2015) show that quantitatively, the trade and welfare effects of import tariffs are affected by the presence of intermediate goods. Accordingly, one might ask to what extent optimal trade policy is affected by the presence of intermediate goods. Surprisingly, there are not many studies that characterize this problem.

In order to make progress in addressing this question, one needs to extend the economic framework to accommodate trade in intermediate goods. For a recent review on how the literature has modeled intermediate goods with roundabout production and global value chains, see Johnson (2018), Antràs and Chor (2018), and Antràs (2020). We now review papers that show how optimal import tariffs differ with and without intermediate goods.[35]

[35] Grubel and Johnson (1971) provide an early review of the effective rate of protections. Ruffin (1969), Casas (1973), Suzuki (1978), and Das (1983) are examples of pioneering studies looking at optimal tariffs on intermediate and final goods.

We start with Blanchard, Bown, and Johnson (2017), who introduce global value chains into a specific-factors model with quasi-linear preferences and an outside sector, as in Grossman and Helpman (2005), Broda, Limao, and Weinstein (2008), and Ludema and Mayda (2013).[36] Global value chains are modeled assuming that final output is produced using both home and foreign factors of production. In order to accommodate the high degree of input specificity in value chains, the model features factor specificity. While the paper does not specify the production structure by which factors are transformed into final goods, one can interpret the model as an economy in which intermediate inputs produced are traded and combined with foreign intermediate inputs and assembled into final goods. The paper then characterizes the optimal bilateral import tariffs on final goods. The key findings are that when domestic content in foreign final goods is high, governments have less incentive to manipulate the terms of trade on final goods. In addition, when foreign content in domestic final goods is high, then part of the benefits of protection are passed back up the value chain to foreign suppliers. Both mechanisms imply lower optimal tariffs, and the paper finds empirical evidence of these mechanisms at play in the data.

As we described before, Beshkar and Lashkaripour (2020) characterize and quantify the effects of optimal import tariffs in multi-sector Ricardian models with input-output linkages. Building on their result, and in order to gain more insight into the way intermediate goods affect optimal policy, we now extend the analysis from the previous subsection and show how the optimal uniform import tariff is lower in a one sector neoclassical Ricardian environment due to the presence of intermediate goods. Suppose that in order to produce, firms use labor and materials. In particular, let the unit cost of a firm in country n be given by $x_n = w_n^{\beta} P_n^{1-\beta}$, where β is the value added share in production. Materials are produced as a bundle of domestic and imported varieties that for simplicity are aggregated with the same CES aggregator as that used to produce final goods. Following the same steps as in Section 4.1.1, we obtain that the per-capita expenditure of goods is given by

$$\frac{X_n}{L_n} = \frac{\tau_{ni}}{\tau_{ni}\lambda_{nn} + 1 - \lambda_{nn}} \frac{w_n}{\beta}.$$

Then, solving for the optimal import tariff, we obtain that the welfare-maximizing import tariff is given by (see Section E of the online appendix for the derivation)

$$\tau_{ni}^* = 1 + \frac{\theta}{\tilde{\lambda}_{ii}} \left(\frac{1 + \frac{\theta(1-\beta)}{(\theta+\beta)\tilde{\lambda}_{nn} - \theta(1-\beta)\lambda_{nn}} \left(\frac{1-\lambda_{nn}}{1+\lambda_{nn}(\tau_{ni}^*-1)} \right)}{1 + \frac{\theta(1-\beta)}{(\theta+\beta)\tilde{\lambda}_{nn} - \theta(1-\beta)\lambda_{nn}} \left(\frac{1+\lambda_{nn}}{1+\lambda_{nn}(\tau_{ni}^*-1)} \right)} \right).$$

Note that this is an implicit function of the optimal tariff. However, we can still characterize the structure of the tariff. It is easy to see that, conditional on the domestic expenditure shares λ_{nn} and λ_{ii}, the term

[36] For a related study, see Cadot, de Melo, and Olarreaga (2003).

inside the parentheses is smaller than one; as a result, this tariff is lower than it would be if there were no intermediates, ($\beta = 1$). Of course, quantitatively, the magnitude of the optimal tariff in economies with and without intermediate goods also depends on the level of trade openness, (λ_{nn} and λ_{ii}). Second, in the case of a small open economy, ($\tilde{\lambda}_{ii} = 1$ and $\tilde{\lambda}_{nn} = 0$), we can see that the optimal tariff formula becomes $\tau^*_{ni} = 1 + \theta$, and therefore the optimal tariff in a small open economy is the same as it is in an economy with no intermediate goods.

Beshkar and Lashkaripour (2020), in a large economy setup with multiple industries, show that industry-level tariffs are imperfect substitutes for industry-level export taxes. As a result, if export taxes are restricted, they find that import tariffs can be used as a second-best instrument to manipulate export market power via the input-output network. Similarly, Lashkaripour (2021), in the context of a competitive model (e.g., Armington, Ricardian), analyzes the second-best use of import tariffs in an economy with input-output linkages. The author finds that the welfare impact of tariffs depends on their ability to raise wages in the importing country and that input-output linkages reduce the calculated optimal tariffs.

In monopolistic competitive multi-sector economies in the presence of markup distortions and without access to targeted subsidies, it has been shown that it is optimal to raise (lower) tariffs on high-markup (low markup) sectors relative to the first-best benchmark (e.g., Flam and Helpman 1987; Haaland and Venables 2016; Lashkaripour and Lugovskyy 2021). Existing second-best results, however, overlook input-output linkages. Caliendo, Feenstra, Romalis, and Taylor (2021a) show that accounting for "double marginalization" (due to sectoral linkages) implies a lower optimal tariff than the one implied by models without sectoral linkages. This is an important point that speaks directly to prevalent trade policy practices.

Global supply chains are created when generic intermediate goods are traded across economies, but in many cases, intermediate goods are customized for particular final good producers. This is particularly true when a firm outsources the production of a specific intermediate good to a foreign firm. As a result, hold-up problems might arise under the presence of relationship-specific investments and incomplete contracts. Trade policy in the presence of a hold-up problem can look very different in this situation compared to the ones we described before. Recent papers that study the effect of import tariffs in a model with customized intermediate goods and incomplete contracts are Ornelas and Turner (2008), Ornelas and Turner (2012), Antràs and Staiger (2012a), and Ornelas, Turner, and Bickwit (2021).[37]

Ornelas and Turner (2008) present a model where a firm can purchase either a standardized version of the input from the home country at a competitive price or a specialized version from the foreign country supplier with an incomplete contract. The foreign supplier has to make a relationship-specific investment

[37] In a related strand of the literature, Grant (2020) develops a model with political economy aspects to rationalize the existence of special economic zones in which tariffs depend on the identity of the importer of intermediate goods.

to produce the input. The paper shows that import tariffs on intermediate inputs aggravate the hold-up problem. Ornelas and Turner (2012) builds on this framework but considers the reverse case in which the standardized input is produced abroad and the customized input may be domestic or foreign. They find that an import tariff mitigates the hold-up problem faced by domestic firms. Yet the tariff may result in inefficient organizational choices. Ornelas, Turner, and Bickwit (2021) extend Ornelas and Turner (2012) to a setup where buyers can match with heterogeneous suppliers and focus on the welfare effects of a preferential trade agreement. A key finding is that a preferential trade agreement may generate welfare gains even without trade creation.

Antràs and Staiger (2012a) consider an economic environment with two small countries in which there is an homogeneous good sold at an exogenous world price. The final good producers are located at home, and the input suppliers are foreign. Inputs are customized with no value apart from the relationship, and the terms of exchange are negotiated after the inputs have been produced. Incomplete contracting results in a hold-up problem. The study shows that the constrained-efficient trade policy (the policy that maximizes aggregate world welfare subject to the contractual frictions) has free trade in the final good and an import subsidy on inputs with the aim of solving the hold-up problem and reaching an efficient volume of input trade.

More recently, Grossman and Helpman (2020b) show that global supply chains that involve firm-to-firm supply relationships are formed in anticipation of free trade. The model builds on Venables (1987) and extends the economic environment to allow for firms that produce differentiated products to undertake costly searches for input suppliers. In particular, firms negotiate bilateral prices with suppliers who are above a certain cut-off level of match productivity. The authors then study how the structure of the supply chain is affected after the home government unexpectedly introduces a tariff on imports of intermediate goods. The paper finds that tariffs disrupt the supply chain, leading to renegotiation with the initial suppliers or even the initiation of a new search for a replacement. They provide the conditions under which the renegotiation can generate improvements or deterioration in the terms of trade. Yet the calibrated model shows that these unanticipated changes generate welfare losses that increase with import tariffs.

4.4 Industrial, Political and Social Considerations

We finalize this section on optimal trade policy by briefly mentioning other strands of the literature that take into account the interaction between trade and industrial policy, and incorporate political and social aspects in the analysis of trade policy.

Recent research has studied the interaction between optimal trade policy and optimal industrial policy. For example, in the context of a small open Ricardian economy with sector-level external economies of scale Bartelme, Costinot, Donaldson, and Rodríguez-Clare (2019) estimate the sectoral variation in external economies of scale, and find that sector-level economies of scale differ considerably across sectors. The authors then quantify the gains from industrial and trade policy and find larger welfare gains from optimal trade policy than from optimal industrial policy. Finally, the study shows that the gains from optimal industrial policy are larger in the presence of intermediate goods and input-output linkages. Lashkaripour and Lugovskyy (2021) study the optimal industrial and trade policy for a large economy in a monopolistically competitive environment. The paper finds that trade policy is ineffective at correcting misallocation in domestic industries and that coordinated optimal industrial policies across countries result in welfare gains that exceed those of non-cooperative alternatives.

Changes in the economic environment can cause increased income inequality or heightened racial and ethnic tensions that may lead to changes in social identification patterns. These changes in identification patterns might result in pronounced changes in trade policy. In fact, Atkin, Colson-Sihra, and Shayo (2021) provide evidence of how social identities may change as a consequence of shifts in the economic environment. Motivated by the recent reversal of trade attitudes and trade policies in some countries, Grossman and Helpman (2020a) incorporate aspects of social identity in models of the political economy of trade policy (like Lindbeck and Weibull 1987, Dixit and Londregan 1996, and Grossman and Helpman 1996). They show that in the two-goods and two-factor model, identity politics can result in positive import tariffs when individuals (regardless of their skill) identify with an expansive group in society. Inequality aversion in their political behavior may result on protectionism as a way to make these individuals similar to the expansive group. Motivated by the empirical evidence on the distributional consequences of trade and technological change, Costinot and Werning (2018) study the optimal taxes on technology (robots) and trade in a second best world. The authors show that more robots or more trade may concur with more inequality and lower taxes, despite robots or trade being responsible for the rise in inequality, and governments having extreme preferences for redistribution.

4.5 Discussion

Our review of the recent literature on optimal trade policy shows that one main advance in this area is the study of optimal trade policy in different environments that involve heterogeneous goods and/or heterogeneous firms, as well as new insight into how optimal trade policy is altered in the presence of global value chains. We end this section summarizing some main takeaways from recent literature in this area.

Dixit (1985) shows that in general economic environments the optimal unilateral uniform import tariff is inversely proportional to the foreign export supply elasticity; which in turn is shaped by the elasticity of trade flows with respect to tariffs. We have presented results for small open economies in which the optimal tariff in a wide class of two-country models (one sector neoclassical models with or without product heterogeneity, and in monopolistic competitive models with or without firm heterogeneity) is given by

$$\tau_{ni}^{*} = 1 + \frac{1}{dlnX_{ni}/dln\tau_{ni}},$$

where $dlnX_{ni}/dln\tau_{ni}$ is the elasticity of trade flows with respect to tariffs. Different models have different microstructure and as a result the elasticity might depend on different parameters reflecting preferences, technology or both (as we saw, for instance, in the case of Armington, Eaton and Kortum, and Melitz). However, at the aggregate, optimal import tariffs in all these models can be mapped to the same elasticity.

Micro-level considerations lead to different policy recommendations regarding the optimal structure of trade taxes when one considers trade taxes that vary across firms (or goods). For example, in a neoclassical Ricardian model it is optimal to set export taxes that are heterogeneous across goods and optimal import tariffs that are uniform, while in a monopolistic competitive model (as Melitz 2003) optimal export taxes are uniform across exporters, and import taxes that are uniform across the most efficient foreign exporters and strictly increasing with profitability across the least efficient foreign exporters (import subsidies). As we can see, while for a wide class of heterogeneous goods and firms trade models there is an equivalent welfare gain from trade openness (Arkolakis, Costinot, and Rodríguez-Clare 2012), such equivalence result does not hold for the case of optimal trade policy.

Characterizing optimal trade policy in these environments has been challenging, and the studies described in this section have brought new methods and intuition to this strand of the literature. We believe that a promising avenue for future work in this area involves a more thorough investigation of the actual changes in trade policy. The recent trade war between the United States and its trading partners seems to indicate that terms of trade manipulation is not the main reason behind these trade policy changes.[38] Similarly, some of the results described in this chapter are hard to reconcile with the actual policy changes during this period (for instance, the theoretical result on uniform import tariffs across goods versus the observed wide range of tariff changes across products during the recent trade war). While some strands of the literature have provided new theoretical insights to rationalize episodes like these, with the exception of the work by Ossa (2014), this literature remains highly disconnected from the quantitative frameworks that are used for trade policy evaluation. Recent work by Bagwell, Staiger, and Yurukoglu (2018) showcases a promising approach

[38] In fact, it looks like policymakers have ignored more than 100 years of trade policy research.

to closing this gap. In this work, a model of tariff negotiations is embedded into a workhorse quantitative trade framework to capture the design of the institutional rules of the GATT/WTO.

5 Conclusion

There has been substantial progress on trade policy analysis in the last decade. Recent reduced-form studies have provided robust evidence of how trade policy affects global value chains and the importance of the input-output structure. The revival of shift-share analysis likewise has been a useful tool to analyze the distributional effects of trade policy across local labor markets. In addition, the recent trade war between the United States and its trading partners and the availability of detailed trade and tariff data have encouraged researchers to evaluate the economic consequences of trade protectionism and trade policy uncertainty. The findings of reduced-form studies have guided researchers in developing quantitative trade models to study the aggregate and distributional effects of trade policy changes in general equilibrium. New rich datasets across and within countries and the development of new methods to undertake counterfactuals have also contributed to progress in the evaluation of the effects of trade policy using frameworks that take into account global value chains, local labor markets, and different sources of dynamics. There has also been progress in researchers' understanding of optimal trade policy in a variety of neoclassical and monopolistic competition environments that involve goods or firm heterogeneity, in large and small open economies, and with global value chains. Looking ahead, the recent trade war between the United States and its trading partners raises the question of the reasons behind these trade policy changes. Some strands of the literature have provided new theoretical insights to rationalize episodes like this, and we believe that a stronger connection between them and the rich quantitative frameworks that are used for trade policy evaluation would provide fresh views on the analysis of trade policy.

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