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Bilateral Trade Imbalances

Alejandro Cuñat and Robert Zymek

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Bilateral Trade Imbalances
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ABSTRACT: If sectoral trade flows obey structural gravity, countries' bilateral trade imbalances are the result of macro trade imbalances, "triangular trade", or pairwise asymmetric trade barriers. Using data for 40 major economies and the Rest of the World, we show that large and pervasive asymmetries in trade barriers are required to account for most of the observed variation in bilateral imbalances. A dynamic quantitative trade model suggests that eliminating these asymmetries would significantly reduce bilateral (but not macro) imbalances and have sizeable impacts on welfare. We provide evidence that the asymmetries we measure are in part related to the policy environment: trade inside the European Single Market appears to be subject to more bilaterally symmetric frictions. Extending the same symmetry to all parts of the global economy would give a large boost to the real incomes of several non-E.U. countries.

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WORKING PAPERS

Bilateral Trade Imbalances

Prepared by Alejandro Cuñat and Robert Zymek[1]

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Contents

1 Introduction

It is a well-known fact that the U.S. trade balance has been in deficit every year since 1992. In the five years between 2010 and 2014, that deficit amounted to 3% of GDP on average. What is perhaps less well known is that the overall U.S. deficit masks significant heterogeneity of its bilateral trade balance with individual partner economies. The vertical bars in Figure 1 represent the U.S. trade balance (as a percentage of U.S. GDP) vis-à-vis 39 other economies and the "Rest of the World" (RoW) over the period 2010-2014.[2] There is significant variation in U.S. bilateral net exports around their average value, represented by the thick horizontal line.[3] The U.S. runs large bilateral deficits with China, and its NAFTA partners Mexico and Canada – but it also runs small trade surpluses with a number of other economies, including Ireland, the Netherlands and France.

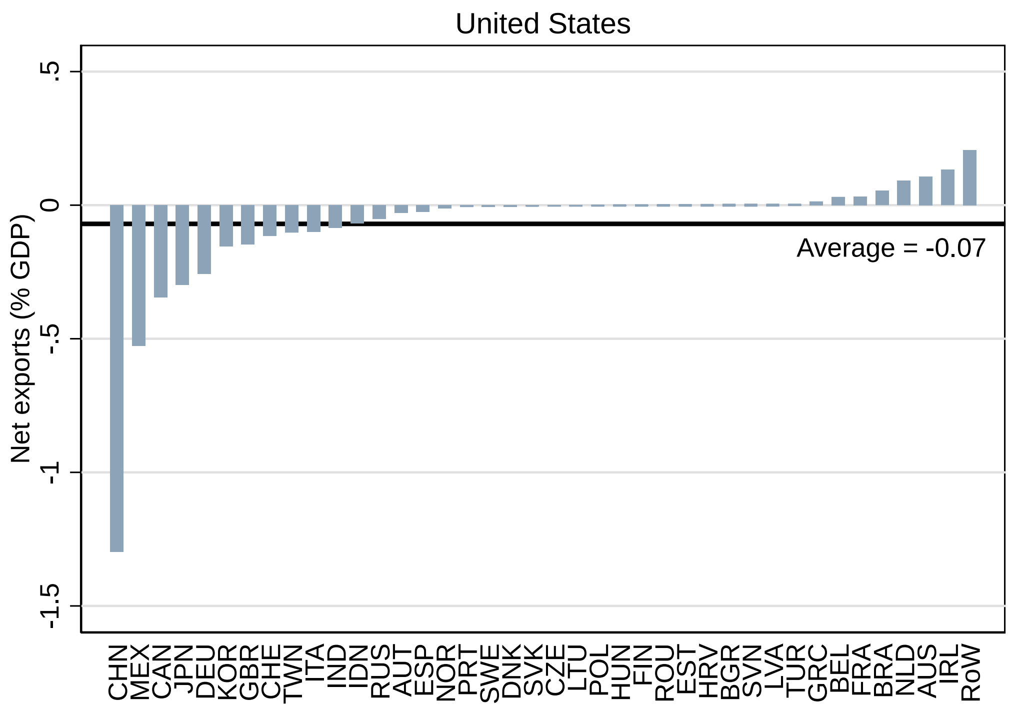
Such dispersion in a country's bilateral balances with its trade partners is not peculiar to the U.S. case. Yet so far there exists no systematic study that accounts for the large observed variation in bilateral trade balances across country pairs – despite the fact that individual examples of major imbalances between trade partners are a recurrent trigger of political controversies.[4] Our paper seeks to fill this gap in the literature. We do so by means of three specific contributions. First, we demonstrate that the drivers of bilateral trade imbalances can be understood in a simple framework underpinned by few, fairly general assumptions. Second, we take this framework to the data and document that one of these drivers – pairwise asymmetries in trade frictions – accounts for most of the variation in bilateral imbalances. Embedding our findings in a dynamic many-country, many-sector quantitative trade model, we use counterfactuals to confirm that eliminating all bilateral trade-cost asymmetries would not only cause most of the variation in bilateral imbalances to disappear, but also have sizeable effects on macroeconomic outcomes. Third, we provide some evidence of the extent to which measured pairwise asymmetries in trade frictions (and through them, bilateral imbalances) may be shaped by the trade-policy environment.

[2]The figure is based on data from the 2016 release of the World Input-Output Database (WIOD), the latest currently available. Section 2.2.1 discusses this data source in more detail.

[3]Since the data represented in Figure 1 covers the total value of all U.S. exports and imports divided across 40 economies/regions, the average bilateral trade balance equals the overall U.S. trade balance divided by 40.

[4]In the last three decades, the U.S. trade deficit vis-à-vis Japan (Janow, 1994), China (Feenstra et al., 1998; Hughes, 2005) and, most recently, Germany (Swanson, 2017; Krugman, 2017) has been in the spotlight as a possible symptom of "unfair" trade practices on the part of these countries against American producers.

Figure 1: U.S. bilateral net exports



"Net exports (% GDP)" refers to the net exports of goods and services by the United States to the horizontal-axis economy, expressed as a percentage of U.S. GDP. All data is based on WIOD (2016 release), average for the years 2010-14.

We start from the assumption that sector-level bilateral trade flows can be modelled by means of a standard structural gravity equation, as in Anderson and van Wincoop (2003). This assumption is commonly made in empirical studies of international trade and is compatible with the microfoundations of many popular quantitative trade models.[5] Aggregating across sectors, it implies that there exist *exactly three sources* of the variation in bilateral trade balances across country pairs.

Differences in (unilateral) "macro" trade balances are the first source: by definition, economies with a deficit in their macro trade balance − such as the U.S. − will have a deficit with their average trade partner; macro-surplus economies − such as China − will have a surplus. Everything else constant, we would thus expect a deficit-surplus pair to have a larger bilateral trade imbalance than two surplus or two deficit economies.

Differences in sectoral expenditure and production patterns are the second source: if a large portion of Dutch expenditure is dedicated to U.S. goods, a large portion of German expenditure to Dutch goods, and a large portion of

[5]Head and Mayer (2014) survey the use of structural gravity models in empirical studies of international trade. Costinot and Rodríguez-Clare (2014) provide an overview of the common analytical properties of "gravity class" quantitative trade models.

U.S. expenditure to German goods, the resulting "triangular trade" may give rise to *bilateral* imbalances even if trade is completely balanced at the macro level.

The third source are asymmetric obstacles to trade between two economies that penalise bilateral trade flows in one direction more than in the other. Our analytical expression for bilateral trade imbalances represents a generalisation of a formula first derived by Davis and Weinstein (2002). Taking a first-order approximation, it permits a linear decomposition of the sources of variation in *proportional bilateral imbalances* – bilateral trade balances relative to the geometric average of bilateral trade flows. We perform this variance decomposition using data on 40 economies and the Rest of the World from the World Input Output Database, and backing out unobserved (asymmetries in) bilateral trade frictions as "residuals" from a theory-consistent gravity estimation. We find that differences in macro trade balances on their own account for a small share of the variation in proportional bilateral imbalances (roughly 2%). The individual contribution of "triangular trade" is sizeable (roughly 12%), but the largest individual share is due to asymmetries in trade frictions (roughly 84%).

While this finding is suggestive, it may overstate the importance of asymmetric trade barriers in a number of ways. It relies on a linear approximation and abstracts from general equilibrium effects (such as the effect changes in trade barriers might have on expenditure patterns or macro trade balances). Moreover, even if trade imbalances are a symptom of asymmetric trade frictions, this is of interest only to the extent that such asymmetries have meaningful macroeconomic and welfare consequences. To address these issues, we set up a dynamic many-country, many-sector quantitative trade model.

Our model makes assumptions that deliver sector-level structural gravity equations. In its steady state, macro trade imbalances arise from differences in economies' technologies and rates of time preference; differences in production and spending patterns are the result of differences in countries' technologies and ideal consumption baskets; and generic "trade wedges" govern country-pair-sector variation in trade flows. We calibrate the deep parameters of the model so as to match the corresponding objects in our data perfectly and in a manner consistent with the assumptions of our variance decomposition. We then perform counterfactuals that allow us to investigate changes in the distribution of bilateral trade balances and macroeconomic outcomes in response to changes in model parameters.[6]

[6]A popular trick in quantitative trade modelling, going back to Dornbusch et al. (1977), is to introduce macro trade imbalances as exogenous international transfers into an otherwise static model. We set up a dynamic model in which macro trade imbalances are an

Our counterfactuals confirm that, in a hypothetical world economy with fully bilaterally symmetric trade wedges, 75% of the variation in proportional bilateral imbalances would disappear. By contrast, the disappearance of macro trade imbalances in counterfactual financial autarky would only reduce the variation in imbalances by 15%. Beyond its impact on trade patterns, a move to global trade-wedge symmetry would raise the median country's real GDP and consumption level by almost 11%, and it would cause a small rebalancing of international trade away from China, reducing most economies' exposure to China somewhat. This highlights that measured trade-wedge asymmetries have meaningful implications for the global macroeconomy, and makes the case for subjecting their nature and origins to further study.

Since we obtain bilateral (asymmetries in) trade wedges as a "residual", they capture all determinants of sector-level bilateral trade patterns that elude our gravity framework. These could include the pairwise asymmetric impact on trade barriers of structural factors such as preferences, technologies or geography as well as asymmetric policy barriers to trade. We investigate the properties of our measured bilateral trade-wedge asymmetries at the aggregate and sectoral levels, and show that they are sizeable but not obviously related to sector characteristics. However, we obtain some evidence that the policy environment matters: asymmetries appear to be smaller among member countries of the European Single Market, and countries that join the E.U. see their trade-wedge asymmetries vis-à-vis other members decline. We use our model to simulate the global impact of extending this bilateral trade-wedge-levelling effect of E.U. membership to all economies in our data, and find that it would significantly reduce bilateral imbalances and lead to large increases in the long-run incomes of Mexico (38%), South Korea (20%) and Turkey (19%). Each of these countries currently enjoys a close trade relationship with major markets in its respective region short of a Single Market environment. We also simulate the long-run impact of the U.S.-China trade war and illustrate that it may result in a reduction in the U.S.-China trade imbalance primarily due to a (costly) weakening of trade ties between the two economies.

Until recently, bilateral trade imbalances had received surprisingly little attention in academic research. Two notable exceptions are Feenstra et al. (1998), and Davis and Weinstein (2002). Feenstra et al. (1998) focus exclusively on the case of the U.S. trade deficit with China, whereas Davis and Weinstein (2002) analyse bilateral imbalances for a large sample of countries. Their work is most closely related with ours. The authors provide calculations

endogenous steady-state outcome that is independent of initial conditions. This allows us to derive a dynamic block of exact-hat equations which is modular to the exact-hat algebra often employed to perform counterfactuals in static trade models.

of gravity-predicted bilateral imbalances, based on a semi-structural gravity equation, and discover that actual imbalances dramatically exceed their predictions: the "mystery of excess trade balances". Our paper can be understood as embedding their analysis in a fully structural model which allows for theory-consistent variance decompositions and counterfactuals. We recover the "mystery" in a new guise: a structural gravity model requires large black-box bilateral asymmetries in trade frictions to explain why some country pairs have bigger imbalances than others.[7]

Our focus on structural gravity in the first part of the paper speaks to a large and active empirical literature, sparked by Anderson (1979) and Anderson and van Wincoop (2003), that uses this framework to quantify the drivers of the variation in bilateral trade flows across country pairs.[8] We confirm that structural gravity is also helpful in understanding the drivers of variation in *imbalances*. Expressed as part of a unified formal framework, the drivers of imbalances are theoretically and quantitatively distinct from the drivers of (average) bilateral trade flows. In taking our analysis to the data, we rely crucially on recent insights about the theory-consistent estimation of structural gravity models by Santos-Silva and Tenreyro (2006) and Fally (2015).

The second part of our paper introduces additional assumptions to cast our baseline structural gravity equation as the steady-state outcome of a dynamic quantitative trade model. This part of our work connects with a strand of research, reaching back to Eaton and Kortum (2002), that employs calibrated quantitative models of international trade to analyse the relationship between countries' sector-level productivities, bilateral trade costs and real incomes. Several papers in this literature – including Dekle et al. (2007, 2008), Eaton et al. (2016a), and Cuñat and Zymek (2018) – explore the impact of (changes in) *aggregate* trade imbalances on countries' incomes. Some analyse the impact of (changes in) trade costs on *aggregate* trade imbalances – following on from the classic paper by Obstfeld and Rogoff (2000).[9] Yet to the best of our

[7]Two recent papers re-visit the question what explains observed bilateral imbalances. The first, by Felbermayr and Yotov (2021), re-estimates the gravity model of Davis and Weinstein (2002) and suggest that the inclusion of theory-consistent multilateral resistance terms goes some way in resolving the "mystery" as originally conceived. We discuss the differences between our approach and the analyses of Davis and Weinstein (2002) and Felbermayr and Yotov (2021) in more detail in Appendix A7. The second, by Eugster et al. (2020), focuses on *changes* in bilateral imbalances over time. Consistently with our finding that bilateral trade-wedge asymmetries are fairly persistent, they find that these changes are primarily driven by macro factors (such as the macro trade balance).

[8]Carrère et al. (2020) summarise some of the main facts established and remaining open questions in this literature, including in relation to bilateral trade balances.

[9]Reyes-Heroles (2016) studies the contribution of trade globalisation to the emergence of current account imbalances. Eaton et al. (2016b) and Ravikumar et al. (2019) perform trade policy experiments in dynamic models that permit trade imbalances. Sposi (2021) shows that bilateral trade barriers influence how a shock that causes a trade and current-

knowledge, none explore the determinants of *bilateral* trade balances; and few investigate the prevalence and macroeconomic implications of asymmetric trade barriers.[10]

A notable exception is Waugh (2010), who shows that asymmetric trade barriers between rich and poor countries can help better reconcile quantitative trade models with countries' observed aggregate import shares. He demonstrates that removing them would potentially reduce international income differences significantly. Our findings are complementary with Waugh's analysis (2010), which abstracts from trade imbalances, insofar as they illustrate that trade-wedge asymmetries are also required to account for a portion of observed bilateral trade surpluses and deficits. Moreover, we find that such asymmetries appear to be influenced by the trade policy environment, shrinking among countries that opt for the deep integration of a Single Market.

The remainder of the paper is structured as follows. Section 2 shows that a structural-gravity framework can be used to understand the drivers of bilateral trade imbalances under very limited assumptions. It then uses the framework to decompose, to a first-order approximation, the observed variation in proportional bilateral imbalances. Section 3 embeds the framework from Section 2 in our fully-fledged dynamic many-country, many-sector quantitative trade model. It uses the model to perform counterfactuals that speak to the economic significance of the bilateral trade-wedge asymmetries uncovered in the variance decomposition. Section 4 investigates the nature of these trade-wedge asymmetries further, and explores the role policy through counterfactuals that simulate the effects of E.U. membership and the U.S.-China trade war. Section 5 offers a brief summary and concluding remarks.

2 Bilateral Balance Accounting with Gravity

In this section, we first show that the drivers of bilateral trade imbalances can be analysed under fairly general assumptions that are commonly employed in empirical studies of international trade patterns and compatible with many quantitative trade models. By means of a first-order approximation, we linearly decompose the drivers of bilateral imbalances in trade flows (relative to the average of bilateral flows). We take the resulting formula to the data

account imbalance in one country is reflected in the trade balances and current accounts of its trade partners.

[10] Since we restrict our analysis to a comparison of steady states, it primarily speaks to the long-run drivers of trade balances. In a recent paper, Alessandria and Choi (2021) employ a similar decomposition to the one we develop below to investigate the drivers of short-run *changes* in the U.S. trade balance in the period 1980-2015. They find that a significant role for asymmetric *movements* in trade barriers in explaining these changes.

to document that large asymmetries in "residual" trade frictions are required to explain the observed variation in bilateral trade imbalances among a large group of economies.

2.1 Structural Gravity and Bilateral Trade Imbalances

2.1.1 Bilateral Imbalances Through the Lens of Structural Gravity

Consider a set of N economies, denoted by $n = 1, ..., N$. These countries trade in S sectors, denoted by $s = 1, ..., S$.[11] We assume that sector-level trade flows obey a structural gravity equation of the form

$$M_{sn'n} = \left(\frac{\tau_{sn'n}}{O_{sn'}P_{sn}}\right)^{-\theta_s} \frac{D_{sn'}E_{sn}}{D_s}, \tag{1}$$

where $M_{sn'n}$ is the dollar value of expenditure by country n on country-n' output in sector s; $\tau_{sn'n}$ is a measure of the ad-valorem-equivalent trade frictions applying to this flow;[12] θ_s is the trade elasticity; $D_{sn'}$ is the dollar value of country-n' output in sector s; E_{sn} is the dollar value of country-n expenditure on sector-s output; D_s is an arbitrary, potentially sector-specific "normaliser"; and P_{sn} and $O_{sn'}$ are respectively the inward and outward multilateral resistance terms (MRTs), defined as follows:

$$P_{sn} \equiv \left[\sum_{n'=1}^{N}\left(\frac{\tau_{sn'n}}{O_{sn'}}\right)^{-\theta_s} \frac{D_{sn'}}{D_s}\right]^{-\frac{1}{\theta_s}}, \quad O_{sn'} \equiv \left[\sum_{n=1}^{N}\left(\frac{\tau_{sn'n}}{P_{sn}}\right)^{-\theta_s} \frac{E_{sn}}{D_s}\right]^{-\frac{1}{\theta_s}}. \tag{2}$$

The MRTs embody the key structural-gravity insight that bilateral trade flows between any two economies not only depend on the direct bilateral trade frictions between them, but also on the extent of the importer's access to all possible import sources (captured by the inward MRT, P_{sn}) and the extent of the exporter's access to all possible export destinations (captured by the outward MRT, $O_{sn'}$).

There structural gravity equation described by (1) and (2) has been used in a wide range of quantitative applications since its debut in Anderson and

[11] In principle, these sectors could represent very narrowly defined goods or services. In our data application, they will correspond to broad sectors at the 2-digit level of ISIC, e.g. "Transport equipment". At that level of aggregation, the output of a given sector is likely to comprise both intermediate and final goods, and expenditure flows will represent a combination of value-chain and final trade.

[12] As we illustrate in our formal model in Section 3.1, $\tau_{sn'n}$ might reflect a combination of trade barriers arising from physical and policy barriers to the delivery of sector-s output from country n' to n, and biases in sector-s spending by country n in relation to other economies' outputs (e.g. home bias). Therefore, $\tau_{sn'n}$ can be thought of more generally as an ad-valorem equivalent *trade wedge* that captures the country-pair-specific forces shaping sector-level bilateral expenditure patterns.

van Wincoop (2003).[13] Two sufficient conditions for obtaining it are:

1. The share of spending by country n on country n' output in sector s, $v_{sn'n} \equiv M_{sn'n}/E_{sn}$, can be expressed in the following multiplicatively separable form:

$$v_{sn'n} = \frac{F_{sn'}}{D_s} \left(\frac{\tau_{sn'n}}{P_{sn}} \right)^{-\theta_s}, \quad P_{sn}^{-\theta_s} D_s \equiv \sum_{n'=1}^{N} F_{sn'} \tau_{sn'n}^{-\theta_s}. \tag{3}$$

2. There is market clearing for each origin country:

$$D_{sn'} = \sum_{n=1}^{N} M_{sn'n} = F_{sn'} \sum_{n=1}^{N} \left(\frac{\tau_{sn'n}}{P_{sn}} \right)^{-\theta_s} \frac{E_{sn}}{D_s} \equiv F_{sn'} O_{sn'}^{-\theta_s}. \tag{4}$$

Equations (1) and (2) are obtained by using (4) to substitute for $F_{sn'}$ in (3).

These two conditions are sufficiently general to be compatible with many quantitative models of international trade. While condition 2. is satisfied in any general-equilibrium model, condition 1. is more restrictive. Nevertheless, Head and Mayer (2014) show that it is satisfied in the Armington (1969), Krugman (1980) and Eaton-Kortum (2002) model, as well as certain many-country incarnations of Melitz (2003).[14] This makes the structural gravity equation above a natural starting point for the analysis of bilateral trade imbalances.

The sector-s bilateral imbalance between n' and n is given by $M_{snn'} - M_{sn'n}$. This is simply the difference between the structural gravity equation describing the sector-s imports by n' from n, and the equation describing the sector-s imports by n from n'. Summing across all sectors yields an expression for the aggregate bilateral trade imbalance between n' and n:

$$M_{nn'} - M_{n'n} = D_n \left(D_{n'} - NX_{n'} \right) \sum_{s=1}^{S} \left(\frac{\tau_{snn'}}{O_{sn} P_{sn'}} \right)^{-\theta_s} \frac{d_{sn} e_{sn'}}{D_s} +$$

$$-D_{n'} \left(D_n - NX_n \right) \sum_{s=1}^{S} \left(\frac{\tau_{sn'n}}{O_{sn'} P_{sn}} \right)^{-\theta_s} \frac{d_{sn'} e_{sn}}{D_s}, \tag{5}$$

where $M_{n'n} \equiv \sum_s M_{sn'n}$; NX_n is the macro (unilateral) trade balance of country n; $d_{sn} \equiv D_{sn}/D_n$; $e_{sn} \equiv E_{sn}/E_n$; and $D_n \equiv \sum_s D_{sn}$ and $E_n \equiv \sum_s E_{sn}$ are

[13] See Anderson (2011), Costinot and Rodríguez-Clare (2014) and Head and Mayer (2014) for surveys of this literature.

[14] The compatibility of structural gravity with key assumptions of the Melitz (2003) model also implies a potential point of connection with the emerging literature on buyer-seller interactions in cross-border production networks. That literature has been using Melitz-style assumptions in combination with micro data to model cross border trade and production from the bottom up. See, for example, Antràs et al. (2017), Bernard and Moxnes (2018), and Bernard et al. (2021).

country-n aggregate output and spending, respectively. National-accounting definitions imply $D_n = E_n + NX_n$. For the remainder of the paper, we normalise D_s to equal world gross output in sector s. This is a purely presentational choice, with no material impact on any of our findings.

Equation (5), together with equation (2), can be used to describe the underlying determinants of net exports by country n to n' – that is, the trade surplus of country n with n'. Everything else constant, this bilateral trade surplus is larger...

1. ...the smaller the aggregate net exports of country n'; and the larger the aggregate net exports of country n.

2. ...the more country n' spends in sectors which account for much country-n output; and the less country n spends in sectors which account for much country-n' output.

3. ...the smaller country-n' importing frictions from country n; and the larger country-n importing frictions from country n'.

Equation (5) generalises an expression for bilateral trade imbalances first derived in Davis and Weinstein (2002).[15] There the authors abstract from intermediate inputs (setting gross output equal to GDP), and from trade barriers or home bias giving rise to trade frictions (setting $\tau_{sn'n} = 1$ for all s, n' and n). Under these assumptions they show that bilateral trade imbalances are the result of macroeconomic imbalances and "triangular trade", corresponding to points 1. and 2. above. Point 3. highlights a third potential determinant of bilateral imbalances made apparent by our generalisation: bilateral asymmetries in trade frictions.

In turn, equation (5) shows that under standard structural-gravity assumptions, macroeconomic imbalances, triangular trade and asymmetries in trade frictions are the *only* determinants of bilateral trade imbalances. If all macro trade balances were zero ($NX_n = 0$ for all n), if production and spending shares were the same across economies ($d_{sn} = e_{sn} = d_s = e_s$ for all s and n), and if trade frictions were symmetric ($\tau_{sn'n} = \tau_{snn'}$ for all s, n and n'), all trade would be balanced bilaterally.[16]

2.1.2 Proportional Bilateral Imbalances

Equation (5) provides an expression for the dollar value of the bilateral trade imbalance between n and n'. Bilateral imbalances are frequently reported

[15] See Davis and Weinstein (2002), p. 171: equation (5).

[16] Note that this follows because $P_{sn} = O_{sn}$ for all s and n in this case.

in dollar values, or as a percentage of some relevant measure of output. For example, in Figure 1 we expressed U.S. bilateral net exports as a percentage of U.S. GDP. However, for analytical purposes it is convenient to express bilateral trade imbalances as a share of the geometric average of bilateral trade flows. We will henceforth refer to $(M_{n'nt} - M_{nn't})/(M_{n'nt}^{1/2} M_{nn't}^{1/2})$ as the *proportional* bilateral imbalance. In Appendix A.1 we show that the proportional bilateral imbalance can be expressed approximately as:

$$\frac{M_{n'n} - M_{nn'}}{M_{n'n}^{\frac{1}{2}} M_{nn'}^{\frac{1}{2}}} \simeq \sum_{s=1}^{S} \left(\frac{M_{sn'n} M_{snn'}}{M_{n'n} M_{nn'}} \right)^{\frac{1}{2}} \left[\ln \left(\frac{1 - NX_n/D_n}{1 - NX_{n'}/D_{n'}} \right) + \ln \left(\frac{d_{sn'} e_{sn}}{d_{sn} e_{sn'}} \right) \right.$$

$$\left. - \theta_s \ln \left(\frac{\tau_{sn'n}}{\tau_{snn'}} \right) - \theta_s \ln \left(\frac{O_{sn} P_{sn'}}{O_{sn'} P_{sn}} \right) \right]. \tag{6}$$

The approximation decomposes the proportional bilateral trade imbalance between n and n' into four additive terms. The first three of these directly reflect the three determinants of trade imbalances described in Section 2.1.1. The first term represents differences in economies' macro trade balances; the second represents differences in production and spending patterns giving rise to triangular trade; the third represents bilateral asymmetries in trade frictions. The fourth and final term captures differences in the two economies' ratios of outward and inward MRTs. It follows from the discussion in Section 2.1.1 that the last term would be zero if the first three terms were zero for for n and n' vis-à-vis all their trading partners. Therefore, we can loosely think of the final term as arising from the "interaction" of macro trade imbalances, triangular trade and asymmetric frictions encountered by n and n' across their set of trade partners.

Note that there is a straightforward relationship between the dollar-value bilateral imbalance and the *proportional* bilateral imbalance:

$$M_{n'n} - M_{nn'} = M_{n'n}^{\frac{1}{2}} M_{nn'}^{\frac{1}{2}} \times \frac{M_{n'n} - M_{nn'}}{M_{n'n}^{\frac{1}{2}} M_{nn'}^{\frac{1}{2}}}. \tag{7}$$

Equation (7) shows that we can think of conventionally reported bilateral trade imbalances as reflecting two components. The first is the geometric average of the value of bilateral trade flows. Variation in this component across country pairs will predominantly reflect well-understood gravity factors, such as (average) bilateral trade frictions and the size of markets.[17] The second component

[17]Using equation (1), it is easy to show that

$$M_{n'n}^{\frac{1}{2}} M_{nn'}^{\frac{1}{2}} = \left[\sum_{s=1}^{S} \left(\frac{\tau_{sn'n}}{O_{sn'} P_{sn}} \right)^{-\theta_s} \frac{d_{sn'} e_{sn}}{d_s} \right]^{\frac{1}{2}} \left[\sum_{s=1}^{S} \left(\frac{\tau_{snn'}}{O_{sn} P_{sn'}} \right)^{-\theta_s} \frac{d_{sn} e_{sn'}}{d_s} \right]^{\frac{1}{2}} \times$$

is the proportional imbalance. Variation in the latter across country pairs reflects variation in the determinants of imbalances described above, described to a first-order approximation by equation (6).

By way of illustration, we decompose the U.S. bilateral trade balances from Figure 1 into the two components on the right-hand side of equation (7): the geometric average of bilateral trade flows with each corresponding trading partner, as a percentage of U.S. GDP, is shown in Panel A of Figure 2; and the proportional bilateral imbalance is shown in Panel B. The figure highlights why a focus on proportional imbalances can be insightful.

While the largest U.S. bilateral trade deficit (with China) arises from a large proportional imbalance occurring in a trade relationship also characterised by large average bilateral flows, this is not generally the case. There are also some large bilateral deficits arising from small *proportional* imbalances falling on large average bilateral flows (as in the case of Canada) and many large *proportional* imbalances masked my small average bilateral flows (as in the case for many smaller U.S. trade partners, such as Slovakia and Greece). Indeed, proportional imbalances appear to be largely uncorrelated with the economic mass of the trade partner or the average value of bilateral flows. In Figure 1, large imbalances appear to be associated with economically large U.S. trade partners. As Figure 2 makes clear, this mainly reflects large bilateral trade flows with these economies, but not necessarily large proportional imbalances.[18]

For the remainder of this section, we focus only on proportional bilateral imbalances. We do this for two reasons. First, as can be seen from equation (6), these comprehensively encapsulate the determinants of bilateral imbalances consistent with standard structural gravity. Second, the main sources of variation across country pairs in the *geometric average* of bilateral trade flows are well understood by a large empirical gravity literature reaching back to Tinbergen (1962). We therefore cast a spotlight on the less-studied drivers of *proportional imbalances*.

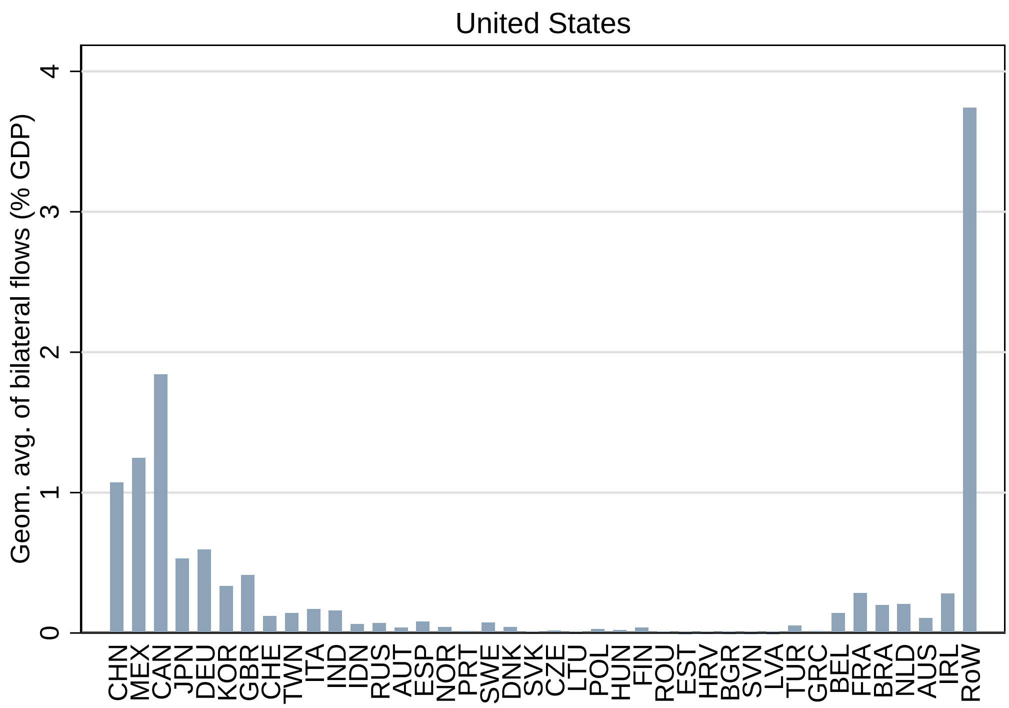
2.1.3 Estimating Trade Wedges and Multilateral Resistance Terms

Equation (6) provides a framework for assessing the approximate contribution of different drivers of imbalances to the observed variation in proportional

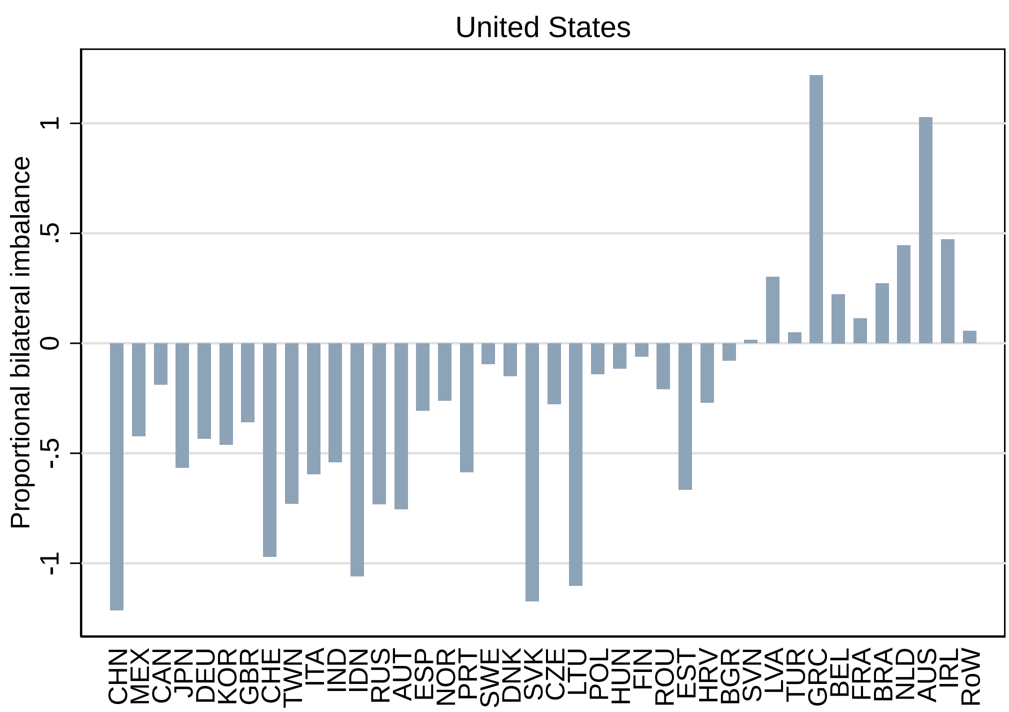
$$\times \frac{D_{n'} D_n}{D} \left(1 - \frac{NX_n}{D_n}\right)^{\frac{1}{2}} \left(1 - \frac{NX_{n'}}{D_{n'}}\right)^{\frac{1}{2}}.$$

[18]These patterns are not specific to the U.S. example. In Appendix A.7, we discuss more formally how an exclusive focus on unnormalised dollar-value bilateral net exports has led some studies to conclude that "country effects" can account for most of the variation in bilateral imbalances.

Figure 2: Proportional imbalances in U.S. bilateral net exports



Panel A: Geometric average of bilateral trade flows (as % of GDP) with given trading partner



Panel B: Proportional bilateral imbalance with given trade partner

The "geometric average of bilateral flows (% GDP)" refers to the geometric average value of U.S. imports of goods and services from the horizontal-axis economy and U.S. exports of goods and services to the horizontal-axis economy, expressed as a percentage of U.S. GDP. The "proportional bilateral imbalance" refers to U.S. net exports to the horizontal-axis economy, expressed as a share of the geometric average average of bilateral flows. All data is based on WIOD (2016 release), average for the years 2010-14.

bilateral imbalances. However, the right-hand side of equation (6) features some objects that are directly observable and others that are not. We can compute the trade weights, macro trade balances, outputs, and output and spending shares from readily available data. However, the sectoral bilateral trade frictions $\{\tau_{sn'n}\}_{s,n',n}$ and MRTs $\{P_{sn}, O_{sn}\}_{s,n}$ are unobserved.

So as to be able to recover these unobserved objects, we need to impose additional assumptions. A sufficient restriction is:

$$E\left[M_{sn'n}\middle|\, n', n\right] = \frac{D_{sn'}E_{sn}/D_s}{\left(O_{sn'}P_{sn}\right)^{-\theta_s}}, \tag{8}$$

i.e. the expected value of sectoral spending by economy n on economy-n' output reflects only "country effects" from the economic-mass variables and MRTs.

The restriction in (8) has two significant advantages. First, it treats bilateral trade frictions as a "residual" that only explains the variation in sectoral bilateral expenditures that cannot be explained by country-specific factors. This amounts to minimising the variance in unobserved bilateral trade frictions required to explain observed bilateral expenditure patterns. In turn, it works against finding an outsized role of asymmetries in such frictions in explaining proportional bilateral imbalances.

The second advantage of a restriction in the form of (8) is that we can leverage the results of Fally (2015) to obtain measures of trade frictions and the MRTs through a straightforward PPML estimation of

$$M_{sn'n} = \exp\left\{\Omega_{sn'} + \Pi_{sn}\right\}\varepsilon_{sn'n}, \tag{9}$$

where $\Omega_{sn'}$ is a economy-n'-sector-s-exporter fixed effect; Π_{sn} is a economy-n-sector-s-importer fixed effect; and $\varepsilon_{sn'n}$ is an error term.[19] Since the set of importer and exporter fixed effects is not of full rank, the restriction $\Pi_{sN} = 0$ must be imposed for a benchmark economy N.

Fally (2015) shows that, if (9) is estimated by PPML, the properties of the estimator ensure that

$$P_{sn}^{-\theta_s} = \frac{E_{sn}}{E_{sN}}\exp\left\{-\hat{\Pi}_{sn}\right\}, \quad O_{sn'}^{-\theta_s} = E_{sN}\frac{D_{sn'}}{D_s}\exp\left\{-\hat{\Omega}_{sn'}\right\}, \tag{10}$$

In turn, thus implies

$$\tau_{sn'n}^{-\theta_s} = \hat{\varepsilon}_{sn'n}. \tag{11}$$

[19]Note that a key requirement is that the estimation is performed on a full matrix of bilateral expenditures, including economies' expenditures on their *own* outputs in sector s, $\{M_{snn}\}_{s,n}$.

Equations (10) and (11) give us all the necessary information to compute bilateral trade frictions and MRTs from available data under the assumption in (8). In the next subsection we use the approach outlined here to account for the observed variation in proportional bilateral imbalances across a large number of trade-partner pairs.

2.2 Bilateral Balance Accounting

2.2.1 Data

Our analysis in this section, and the rest of the paper, relies on data from the World Input Output Database (WIOD 2016 release; Timmer et al., 2015). The utility of WIOD for the purposes of our study is that it provides a carefully integrated data set covering sector-level production, expenditure and trade that satisfies the adding-up constraints required by structural gravity models and is consistent with key macro aggregates such as nominal GDP and the trade balance for a large group of major economies.

For all data taken from this source, we calculate a simple five-year average of the reported values in our period of interest. We do this so as to average out short-run fluctuations in the values of trade balances, output and expenditure shares. Our baseline analysis uses data for the five most recent years available, 2010-14.

The 2016 release of WIOD consists of annual global input-output tables covering 43 economies and the "Rest of the World", with spending broken down into 56 sectors at the 2-digit level of ISIC (Rev. 4). Out of the 43 economies, three have populations of less than 1 million (Cyprus, Luxembourg and Malta). We merge these with the "Rest of the World" totals to focus on larger and more diversified economies. We also aggregate sectors to obtain 16 broad manufacturing sectors and 15 service sectors. We do this in order to make the data consistent with available information on sectoral trade elasticities (see below). The resulting global input-output table covers 40 economies and the "rest of the world", with spending broken down into 31 sectors. Tables A1 and A2 in the Appendix give an overview of our aggregation of regions and sectors relative to the original WIOD data.[20]

For each of the 31 sectors, the data provides us with the value of economy-n spending on economy-n' output $\{M_{sn'nt}\}_{s,n',n}$.[21] Taking the difference between

[20] For simplicity, we will refer to the 41 "economies" in our data from now on, instead of the more accurate "40 economies and one region". None of the stylised facts presented throughout the rest of the paper are sensitive to dropping the Rest of the World, and reporting statistics for only the 40 genuine economies (or the corresponding 780 trade-partner pairs) instead.

[21] For our sample of economies, and our chosen level of sectoral aggregation, zero-valued

Table 1: Bilateral trade flows and imbalances, 40 economies and Rest of the World

Variable	# obs.	mean	st. dev.	10th pctl.	med.	90th pctl.
$\lvert M_{n'n} - M_{nn'} \rvert$	820	4.2bn	13.9bn	.0bn	.6bn	10.3bn
$M_{n'n}^{1/2} M_{nn'}^{1/2}$	820	11.5bn	45.0bn	.1bn	1.5bn	22.3bn
$\frac{\lvert M_{n'n} - M_{nn'} \rvert}{M_{n'n}^{1/2} M_{nn'}^{1/2}}$	820	.645	.620	.081	.463	1.441

$M_{n'n}$ represents the total spending by economy n on output from n' (in current US$). All data is based on WIOD (2016 release), averaged for the years 2010-14. The data covers 40 individual economies and the Rest of the World.

sector-level bilateral flows and summing across sectors yields ($41 \times 40/2 =$) 820 distinct bilateral trade balances. Table 1 presents summary statistics for the absolute dollar value of these imbalances, $\lvert M_{n'nt} - M_{nn't} \rvert$, the dollar value of geometrically averaged bilateral flows, $M_{n'nt}^{1/2} M_{nn't}^{1/2}$, and the corresponding proportional imbalances: $\lvert M_{n'nt} - M_{nn't} \rvert / (M_{n'nt}^{1/2} M_{nn't}^{1/2})$. As the table shows, the median proportional imbalance is equal to .46, and there is significant variation: the smallest proportional imbalance is (nearly) 0, while the largest is 5.01.

Economy-n spending on sector s is given by $E_{sn} = \sum_{n'} M_{sn'n}$. Economy-$n$ output in sector s is given by $D_{sn} = \sum_{n'} M_{snn'}$. The macro trade balance is $NX_n = \sum_s \sum_{n' \neq n} (M_{snn'} - M_{sn'n})$. As with any input-output table, these numbers – and the corresponding shares – can easily be calculated by summing across the relevant columns and rows. Finally, sector-level bilateral trade frictions and MRTs are derived as described in Section 2.1.3. Table 2 provides summary statistics for the four component terms of the approximated proportional imbalances from equation (6) in Panel A, and pairwise correlations between these terms in Panel B.

2.2.2 Variance Decomposition for Proportional Bilateral Imbalances

Figure 3 plots the approximated proportional bilateral imbalances against their data counterparts. As the figure shows, the correlation between the two is high: the R^2 with respect to the 45-degree line is .90, and there are only a handful significant outliers. We can thus meaningfully decompose bilateral imbalances for the large majority of economy pairs using our approximation.

In Figure 4, we plot each of the four terms in (6) against our approximated proportional bilateral imbalances. In each panel, the red line represents the line of best fit. The slope of this line, also shown in red, corresponds to

flows are very uncommon. Out of a total of ($31 \times 41 \times 41 =$) 52,111 sector-country-pair flows, less than 2% are zero-valued.

Table 2: Proportional bilateral imbalances, linear decomposition terms

Term	# obs.	mean	st. dev.	10th pctl.	med.	90th pctl.
Macro NX	820	.027	.022	.004	.021	.058
Prod./spend.	820	.095	.082	.012	.073	.208
Trade frictions	820	.396	.343	.062	.302	.879
MRTs	820	.000	.000	.000	.000	.000

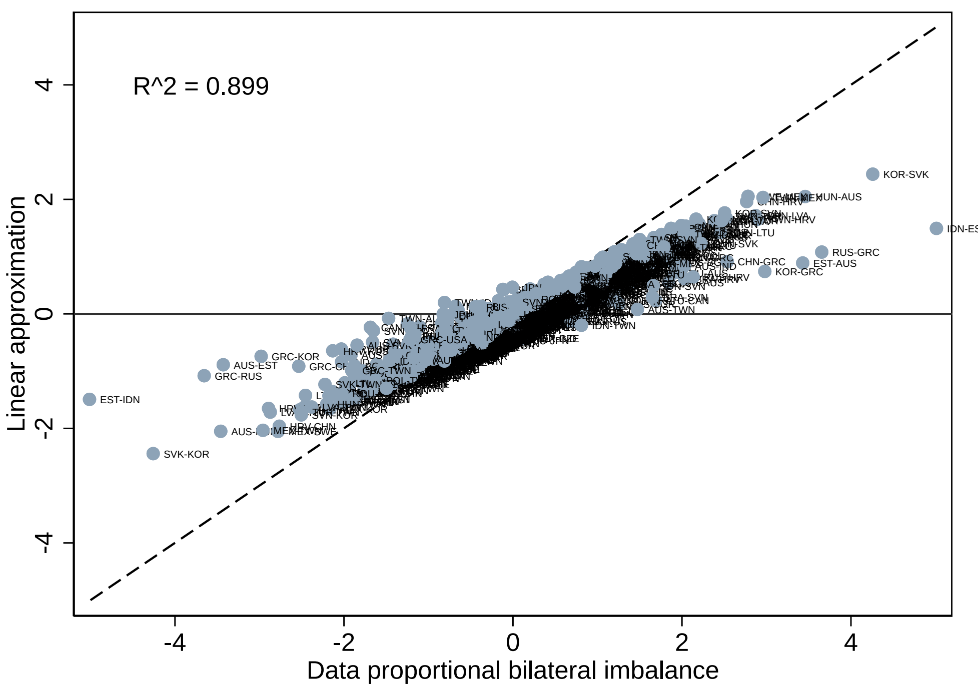
Panel A: Summary statistics

Term correlations (# obs. = 820)	Macro NX	Prod./spend.	Trade frictions	MRTs
Macro NX	1.000			
Prod./spend.	0.326	1.000		
Trade frictions	-.014	.093	1.000	
MRTs	-.076	-.250	-.041	1.000

Panel B: Pairwise correlations

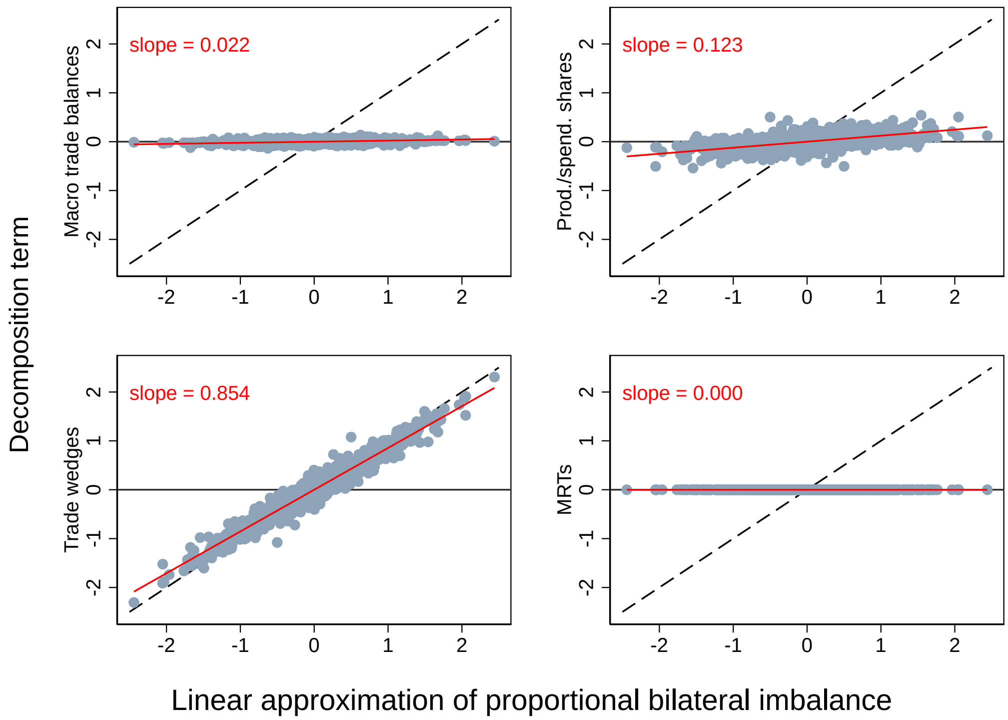
"Macro NX" refers to the first right-hand-side term in equation (6). "Prod./spend." refers to the second right-hand-side term in equation (6). "Trade frictions" refers to the third right-hand-side term in equation (6). "MRTs" refers to the fourth right-hand-side term in equation (6). Summary statistics in Panel A are based on the 820 unique absolute values of these terms. Pairwise correlations in Panel B are computed for the 820 positive-valued bilateral trade balances (equal to the 820 unique absolute values of bilateral trade balances). All data is based on WIOD (2016 release), averaged for the years 2010-14. The data covers 40 individual economies and the Rest of the World.

Figure 3: Approximated and actual trade imbalances



"Data proportional bilateral imbalance" refers to $(M_{n'n} - M_{nn'}) / (M_{n'n}M_{nn'})^{1/2}$, where $M_{n'n}$ represents the total spending by economy n on output from n'. "Linear approximation" is the first-order linear approximation of this term, described in expression (6). All data is based on WIOD (2016 release), averaged for the years 2010-14. The data covers 40 individual economies and the Rest of the World.

Figure 4: Variance decomposition



In each panel, the horizontal-axis variable is the first-order linear approximation of $(M_{n'n} - M_{nn'}) / (M_{n'n}M_{nn'})^{1/2}$ from equation (6), represents the total spending by economy n on output from n'. The vertical-axis variable is one each of the four right-hand-side terms in expression (6). The red line represents the line of best fit, whose respective slope is also printed in red. All data is based on WIOD (2016 release), averaged for the years 2010-14. The data covers 40 individual economies and the Rest of the World.

the share of the variation in trade imbalances which can be attributed to each term. By construction, the four slope coefficients add up to 1.[22] As can be seen from the figure, variation in macro trade balances accounts for the smallest share of the variation in bilateral trade imbalances – a mere 2%. Differences in production and spending patterns account for 12% of the variation, and asymmetric trade wedges account for 85%. The ratio of inward to outward MRTs, which reflects the interaction of the three imbalance drivers, displays hardly any variation and consequently accounts for a negligible share of the variation in imbalances. This makes the interpretation of the findings from our variance decomposition very straightforward.

There are three main takeaways. First, overall trade surpluses and deficits explain only a vanishingly small portion of the variation in proportional bilateral imbalances across trade-partner pairs. This is striking because macroeconomic imbalances are frequently cited as a key driver of bilateral imbalances in the public discourse. Our results suggest that this emphasis may be

[22]To see this, note that the slope of a univariate linear regression of x_i on y is $Cov(x_i, y) / Var(y)$; and that for $y \equiv \sum_i x_i$, we can write $Var(y) = \sum_i Cov(x_i, y)$.

misplaced. Second, a significantly greater share of the variation is explained by differences in production and spending patterns ("triangular trade"). Such differences are a natural determinant of trade patterns from the vantage point of trade theory, yet they are rarely acknowledged in popular discussions.

Third and finally, we recover the "mystery" uncovered by Davis and Weinstein (2002) in a different guise: large bilateral asymmetries in trade frictions are required to explain why some country pairs have bigger proportional imbalances than others. Since the restriction in (8) ensures that these frictions are recovered as an economy-pair residual, we can think of the resulting asymmetries in bilateral frictions as reflecting the portion of the variation in proportional imbalances we cannot account for through economy-specific observables, such as aggregate trade balances or production and spending shares. This portion amounts to 85%.[23]

In Appendix A2, we repeat our variance decomposition for data from the 1995-1999 period, the earliest for which WIOD data is available. The quantitative results for this earlier period are virtually the same as those described above. We also show that there is a strong correlation between 2010-2014 bilateral trade balances and their 1995-99 counterparts, even 15 years on.

The variance decomposition developed in this section suggests that asymmetries in "residual" trade wedges are required to explain the vast majority of the observed variation in proportional bilateral imbalances across pairs of economies. However, a static decomposition of this type has a number of shortcomings. First, with equation (6), it relies on a linear approximation that is liable to capture some of the larger proportional imbalances poorly. Second, changes in the world economy that significantly alter some of the determinants of bilateral imbalances would be expected to have sizeable general-equilibrium effects − not only on prices, but also on the magnitude and distribution of per-effective-worker capital stocks and macro trade balances. For example, a change in trade frictions towards greater bilateral symmetry may raise the marginal product of capital in some economies relative to others. The result would be a change in the distribution of capital across economies, in the world interest rate, and in economies' steady-state macro trade balances. In principle, such general-equilibrium effects could amplify or dampen the impact of

[23] A possible concern is that small-value bilateral trade flows may be more prone to measurement error, and that our measure of *proportional* imbalances gives the imbalances calculated from such flows an outsized weight in the variance decomposition. To address this concern, we repeat the variance decomposition for only the proportional imbalances associated with the top 50% of country pairs by the geometric-average value of their bilateral trade flows. The results we obtain are almost identical: macro trade balances account for 3% of the variation; differences in production and spending patterns account for 12%; and asymmetric trade wedges for 85%.

the initial change on bilateral trade imbalances.

Third and finally, if bilateral trade imbalances are to a significant extent a symptom of asymmetric trade frictions, this is of interest only to the extent that such asymmetries have meaningful macroeconomic and welfare consequences. Our analysis so far cannot establish this. To address these shortcomings, we embed the more limited set of assumptions made above in a fully-fledged dynamic quantitative trade model in Section 3.

3 Bilateral Imbalances in a Dynamic Quantitative Trade Model

3.1 Model Assumptions

Below we introduce a dynamic many-country, many-sector model of international trade. In the model, forward-looking agents make consumption and savings decisions. International asset trade is permitted, and differences in technology and the rate of time preference across economies give rise to aggregate trade surpluses and deficits. Final consumption and investment require tradable inputs from many sectors. Economies differ in their reliance on, and productivity in, these sectors. In addition, sectoral inputs are differentiated by their country of origin. This creates a motive for international trade between and within sectors.

We make two crucial assumptions which require some discussion. The first is that agents' lifespans are not infinite, as in the Ramsey model, but may end each period with a constant probability, as in Blanchard (1985). Agents whose life ends are replaced by a cohort of newly-borns. The appearance of new cohorts each period breaks the tight link between the growth rate of aggregate consumption and agents' individual Euler equations which characterises the Ramsey model. As a result, differences in economies' savings preferences give rise to a non-degenerate cross-country distribution of assets in steady state that is independent of initial conditions. As a consequence, economies' overall trade will not generally be balanced in the long run.[24] We exploit this property of the model to derive expressions that facilitate the analysis of counterfactual steady states as a generalisation of the exact-hat algebra often employed to compute counterfactuals in static trade models.

The second assumption is that trade within sectors can be characterised

[24] In a similar spirit, Matsuyama (1987) uses an open-economy version of the Blanchard model in order to analyse the current-account dynamics of a small open economy whose rate of time preference differs from the world interest rate.

by a standard structural gravity equation as in equation (1). We obtain this by imposing that economies trade in place-specific sectoral varieties, as in Armington (1969). However, the particular microfoundation of the gravity equation is not crucial for our purposes: in Appendix A.6 we show that we could obtain the same results by microfounding our gravity equation using the assumptions of Eaton and Kortum (2002).[25]

3.1.1 Preferences and Endowments

There are many economies, denoted by $n = 1, ..., N$. Time lasts forever, and there is no aggregate uncertainty. However, individual agents face a constant probability of death, ξ, each period. There is a unit mass of agents in each economy, and each period an exogenous mass ξ of agents is born in n, so that net population growth is zero in all economies.[26] Agents in n discount the future at rate ρ_n and are endowed with H_{nt} units of human capital, which they supply inelastically in domestic labour markets at wage w_{nt}. H_{nt} grows exogenously at gross rate γ for all economies: $H_{nt+1} = \gamma H_{nt}$. Agents are born without wealth, but can accumulate it through savings. Actuarially fair life insurance is available: agents in n choose to pay their wealth to the life insurance company if they die, and in return have $1 + \xi / (1 - \xi) = 1 / (1 - \xi)$ times their wealth if they live. There is no bequest motive, and negative bequests are prohibited.

Agents' period utility is logarithmic in final consumption each period, and we denote by $C_{nt}(t')$ the final consumption in period t of an agent in economy n who was born in period t'. The optimal-savings problem of an agent born in period t' can be expressed as

$$\max_{\{C_{nt}(t')\}_{t=t'}^{\infty}} \sum_{t=t'}^{\infty} \left(\frac{1-\xi}{1+\rho_n} \right)^{t-t'} \ln C_{nt}(t') \tag{12}$$

subject to

$$P_{nt} C_{nt}(t') + A_{nt+1}(t') = w_{nt} H_{nt} + \frac{R_t}{1-\xi} A_{nt}(t') \tag{13}$$

$$A_{nt'}(t') = 0, \tag{14}$$

where P_{nt} denotes the price of final consumption in economy n and period t; R_t is the return to wealth, which is equal across economies (as we discuss below);

[25] Increasing-returns models such as Krugman (1980) and Chaney (2008) would also deliver the same structural gravity equation. However, the presence of market-size effects makes an analysis of model dynamics more intricate. The extent of the isomorphisms between all these models is discussed in detail in Costinot and Rodríguez-Clare (2014).

[26] However, note that we allow for exogenous human capital growth below which could be re-interpreted as reflecting combined population and productivity growth.

and $A_{nt}(t')$ is the wealth that a cohort-t' member has at the beginning of period t, before the uncertainty about her death has been resolved.[27] We describe the solution to this problem in Appendix A.3. Aggregate final consumption in n is a weighted average of the final consumption of cohorts alive in n in period t:

$$C_{nt} = \sum_{t'=-\infty}^{t} \xi (1-\xi)^{t-t'} C_{nt}(t'). \tag{15}$$

3.1.2 Technologies

In each n firms assemble a non-traded aggregate "all-purpose" good by using inputs from many sectors, $s = 1, ..., S$:

$$X_{nt} = \prod_{s=1} \left(\frac{X_{snt}}{\sigma_{sn}} \right)^{\sigma_{sn}}, \tag{16}$$

where $\sigma_{sn} \in (0,1)$; $\sum_s \sigma_{sn} = 1$; X_{nt} is the output of the good; and X_{snt} is the quantity of sector-s inputs used. The sector-s input is also non-tradable, but firms assemble it from tradable, place-specific varieties:

$$X_{snt} = \left(\sum_{n'=1}^{N} \omega_{sn'n}^{\frac{1}{1+\theta_s}} x_{sn'nt}^{\frac{\theta_s}{1+\theta_s}} \right)^{\frac{1+\theta_s}{\theta_s}}, \tag{17}$$

where $\theta_s \geq 0$; $\omega_{sn'n} \geq 0$; and $x_{sn'nt}$ represents the use of the economy-n' variety in the production of the sector-s input by economy n. The economy-n variety in sector s is produced with the Cobb-Douglas technology

$$Q_{snt} = z_{sn} \left(\frac{K_{snt}^{\alpha_n} H_{snt}^{1-\alpha_n}}{1-\mu_{sn}} \right)^{1-\mu_{sn}} \left(\frac{J_{snt}}{\mu_{sn}} \right)^{\mu_{sn}}, \tag{18}$$

where $\alpha_n, \mu_{sn} \in (0,1)$. K_{snt} and H_{snt} respectively represent the capital and efficiency units of labour used; J_{snt} denotes the use of the economy-n final good as intermediate input in s; and shifter z_{sn} describes the economy-sector-specific efficiency of production.

The non-traded aggregate good in n can be used to provide one unit of final consumption, one unit of intermediate input for one of the economy-sector-specific varieties, J_{snt}, or $1/\eta_n > 0$ units of investment, I_{nt}: $X_{nt} = C_{nt} + \eta_n I_{nt} + \sum_s J_{snt}$. The parameter η_n thus captures (inversely) the investment efficiency of economy n. Investment in n adds to the economy's capital stock

[27] After this uncertainty is resolved, the wealth of a surviving cohort-t' member in period t is $A_{nt}(t') / (1-\xi)$.

according to:

$$K_{nt+1} = I_{nt} + (1-\delta) K_{nt}, \tag{19}$$

where $\delta \in (0,1)$; K_{nt} is the capital stock of n in period t.

3.1.3 Market Structure

Goods and factor markets are perfectly competitive. International trade is subject to iceberg transport costs: $\kappa_{sn'n} \geq 1$ units of the economy-n', sector-s variety must be shipped for one unit to arrive in country n. Production factors can move freely between activities within economies, but cannot move across borders.

Agents in all economies can trade in a one-period international riskless bond (which is in zero net supply) in a competitive global bond market. One unit of bond holdings at the end of period t pays a nominal return of R_t. The wealth that a cohort-t' member has at the beginning of period t is $A_{nt}(t') \equiv \eta_n P_{nt-1} K_{nt}(t') + B_{nt}(t')$.

3.1.4 Steady State

Throughout the remainder of the paper, we will focus exclusively on steady states of the model described above. For a given set of parameters, the model has a unique steady state in which all aggregate variables – C_{nt}, I_{nt}, K_{nt}, B_{nt} and Y_{nt} – grow at the constant rate γ. Consequently all prices are constant, as are the ratios $C_{nt}/H_{nt} \equiv c_n$, $I_{nt}/H_{nt} \equiv i_n$, $K_{nt}/H_{nt} \equiv k_n$, $B_{nt}/H_{nt} \equiv b_n$ and $Y_{nt}/H_{nt} \equiv y_n$.

As per the discussion in Section 2.1.1, the assumption that the world economy is in steady state is not necessary for trade flows in a given period to obey a gravity equation of the form given in (1). However, it *is* key when exploring changes in prices, capital stocks and macro trade balances in response to changes in model parameters. We are content to rely on this assumption in for two reasons. First, it allows us to perform illustrative counterfactuals about the long-run impact of parameter changes that are in the spirit of typical static trade counterfactuals – but do not require us to assume that capital stocks and trade balances are exogenously given (as in, for example, Deckle et al., 2007; 2008). Second, the calibrated steady state of our model turns out to be consistent with two widely acknowledged observations about aggregate trade balances: i) high-savings economies are more likely to run trade surpluses; and ii) overall trade surpluses and deficits are fairly persistent over time.[28]

[28] Ravikumar et al. (2019) develop a framework for the analysis of the macroeconomic impact of trade-cost changes in a world of financially integrated economies in steady state as well as along the transition path.

Steady-state prices are given by

$$P_n^C = P_n^J = \frac{P_n^I}{\eta_n} = \prod_{s=1}^{S}\left[\sum_{n'=1}^{N}\left(\tau_{sn'n}p_{sn'}\right)^{-\theta_s}\right]^{-\frac{\sigma_{sn}}{\theta_s}} \equiv P_n, \tag{20}$$

where P_{nt}^C, P_{nt}^I and P_{nt}^I respectively denote the final-consumption price, the intermediates price, and the investment price; and

$$p_{sn} = \frac{1}{z_{sn}} f_n^{1-\mu_{sn}} P_n^{\mu_{sn}}, \quad f_n \equiv \left(\frac{r_n}{\alpha_n}\right)^{\alpha_n}\left(\frac{w_n}{1-\alpha_n}\right)^{1-\alpha_n} \tag{21}$$

where f_n is the factor cost in economy n, and $\tau_{sn'n} \equiv \omega_{sn'n}^{-1/\theta_s}\kappa_{sn'n}$. We can thus think of $\tau_{sn'n}$ as the ad-valorem tax equivalent of all factors − trade costs and possible home biases in preferences or technologies − which may impede sectoral trade between pairs of economies. For this reason, we will refer to $\tau_{sn'n}$ as a "trade wedge" from now on.

Equalisation of the returns to physical capital and the riskless bond yields

$$R = \frac{\alpha_n}{\eta_n}\frac{f_n}{P_n}k_n^{\alpha_n - 1} + 1 - \delta. \tag{22}$$

The steady-state ratio of aggregate net exports to GDP of n is

$$\frac{NX_{nt}}{f_n k_n^{\alpha_n} H_{nt}} = 1 - \frac{\alpha_n\left(1 - \frac{1-\delta}{\gamma}\right)}{\frac{R}{\gamma} - \frac{1-\delta}{\gamma}} - \frac{\xi\left(\rho_n + \xi\right)\frac{R}{\gamma}\left(1-\alpha_n\right)}{\left[1 + \rho_n - \frac{R}{\gamma}\left(1-\xi\right)\right]\left[\frac{R}{\gamma} - \left(1-\xi\right)\right]}. \tag{23}$$

This ratio depends negatively on the capital share of n (α_n). An economy with a large capital share will have a higher share of investment expenditure and a lower share of next exports in GDP, everything else constant. If $\gamma > R$, it also depends negatively on the discount rate of n (ρ_n). An economy with a high discount rate will have negative holdings of the international bond; if $\gamma > R$, the value of new international liabilities it incurs each period outstrips the interest payments it must make on past liabilities in steady state. As a result, its steady-state expenditure exceeds its steady-state GDP, causing a trade deficit. Conversely, an economy with a low discount rate will run a trade surplus in steady state.[29]

Applying Shephard's Lemma in equation (20) yields the value of sector-s

[29] In our calibration below, $\gamma > R$ turns out to be the relevant case. If $\gamma < R$, the interest payments an impatient country makes in steady state outstrip its new international liabilities. In this case, the country's steady-state GDP exceeds expenditure, causing a trade surplus. Conversely, a patient country will run a trade deficit in steady state.

imports by n from n':

$$M_{sn'nt} = \frac{\left(\tau_{sn'n} p_{sn'}\right)^{-\theta_s}}{\sum_{n''=1}^{N} \left(\tau_{sn''n} p_{sn''}\right)^{-\theta_s}} \sigma_{sn} \left(\sum_{s=1}^{S} p_{sn} Q_{snt} - NX_{nt} \right). \tag{24}$$

Market clearing implies

$$p_{sn} Q_{snt} = \sum_{n'=1}^{N} M_{snn't}; \quad f_n k_n^{\alpha_n} H_{nt} = \sum_{s=1}^{S} (1-\mu_{sn})\, p_{sn} Q_{snt}; \quad \sum_{n=1}^{N} NX_{nt} = 0. \tag{25}$$

Equations (25) and (24) respectively ensure that conditions 1. and 2. from Section 2.1.1 are satisfied in any period of the model and, therefore, spending by economy n on economy-n' output in sector s in steady state can be characterised by means of a gravity equation of the form shown in (9):

$$M_{sn'nt} = \left(\frac{\tau_{sn'n}}{O_{sn'} P_{sn}} \right)^{-\theta_s} \frac{D_{sn't} E_{snt}}{D_{st}}, \tag{26}$$

$$P_{sn} \equiv \left[\sum_{n'=1}^{N} \left(\frac{\tau_{sn'n}}{O_{sn'}} \right)^{-\theta_s} \frac{D_{sn't}}{D_{st}} \right]^{-\frac{1}{\theta_s}}, \quad O_{sn'} \equiv \left[\sum_{n=1}^{N} \left(\frac{\tau_{sn'n}}{P_{sn}} \right)^{-\theta_s} \frac{E_{snt}}{D_{st}} \right]^{-\frac{1}{\theta_s}}, \tag{27}$$

where $D_{snt} \equiv p_{sn} Q_{snt}$; $E_{snt} = \sigma_{sn} \left(\sum_s p_{sn} Q_{snt} - NX_{nt} \right)$; and $D_{st} = \sum_n D_{snt}$.

For given model parameters, there is a unique vector of equilibrium factor costs, $\{f_n\}_n$, up to a normalisation, which satisfies pricing conditions (20) and (21) and market-clearing conditions (24) and (25). Finally, we can express the steady-state real GDP per effective worker of n as

$$y_{nt} \equiv \frac{Y_{nt}}{H_{nt}} \equiv \frac{f_n}{P_n} k_n^{\alpha_n} = Z_n k_n^{\alpha_n} \times \prod_{s=1}^{S} \left(\frac{M_{snnt}}{\sum_{n'=1}^{N} M_{sn'nt}} \right)^{-\frac{1}{\theta_s} \frac{\sigma_{sn}}{1-\sum_s \sigma_{sn}\mu_{sn}}}, \tag{28}$$

where $Z_n \equiv \prod_{s=1}^{S} \left(z_{sn} / \tau_{snn} \right)^{\sigma_{sn} / \left(1-\sum_s \sigma_{sn}\mu_{sn}\right)}$. Equation (28) shows that steady-state real GDP per effective worker can be written as a function of an aggregate productivity term, the per-effective-worker capital stock, and an aggregator of sectoral "own spending" shares in line with familiar results from gravity-class trade models by Arkolakis et al. (2012) and Ossa (2015).

3.2 Calibration and Counterfactual Parameter Changes

Below we explain how we calibrate the full set of parameters of our model. We also describe the nature of the counterfactual parameter *changes* we will explore in the rest of the paper. We make use of exact-hat algebra to compute

Table 3: Calibration overview

Object	Data
ξ	= .13 (life expectancy: 60 years)
δ	= .06
γ	= 1.044 (PWT: 1985-2014)
R	= 1.030 (King and Low, 2014: 1985-2014)
$\{\rho_n\}_n$	match $\{NX_{nt}/f_n k_n^{\alpha_n} H_{nt}\}_n$ (WIOD)
$\{\alpha_n\}_n$	match 1− economy-n labour share (PWT)
$\{\eta_n\}_n$	match $\{k_n\}_n$ (PWT)
$\{\sigma_{sn}\}_{s,n}$	match economy-n, sector-s spending share (WIOD)
$\{\mu_{sn}\}_{s,n}$	match economy-n, sector-s input share (WIOD)
$\{\theta_s\}_s$	match trade elasticities (Caliendo and Parro, 2015; Costinot and Rodríguez-Clare, 2014): Table A.2
$\{\tau_{sn'n}\}_{s,n',n}$	match $\{\hat{\varepsilon}_{sn'n}\}_{s,n',n}$ from PPML estimation: Section 2.1.3
$\{z_{sn}/z_{sN}\}_{s,n}$	match $\left\{\hat{\Omega}_{sn} - \hat{\Omega}_{sN}\right\}_{s,n}$ from PPML estimation: Section 2.1.3
$\{Z_n\}_n$	match $\{y_n\}_n$ (PWT)

For parameter definitions, see Section 3.1. The data sources and calibration strategy are described in detail in Sections 2.2.1 and 3.21.

the effect of these changes on key outcomes. As it turns out, the system of equations that characterises the exact-hat algebra only requires a more limited set of parameters to be specified. We nevertheless sketch the full calibration of the model to show that it has sufficient parameters to match, for our baseline period of interest, all endogenous outcomes of interest in the global economy in a manner that is consistent with the assumptions underlying our variance decomposition in Section 2.

3.2.1 Calibration

As our baseline, we calibrate the model to match sectoral trade patterns, trade imbalances, real incomes and capital stocks to their average during the 2010-14 period, the five most recent years for which WIOD data is available. The WIOD data already described in Section 2.2.1 and the Penn World Tables (PWT, edition 9.0) are the two main sources of data for the calibration. Unless otherwise specified, all data moments used to pin down model parameters are simple five-year averages for the years 2010-14. Table 3 presents an overview of how the model parameters are calibrated.

Sectoral spending shares and intermediate input shares, $\{\sigma_{sn}, \mu_{sn}\}_{s,n}$, are set to match their empirical counterparts which can be computed straightforwardly from WIOD data. Capital shares and human capital stocks, $\{\alpha_n, H_{nt}\}_n$, are obtained from PWT.[30] Trade elasticities are taken from Caliendo and Parro (2015) and Costinot and Rodríguez-Clare (2014), as listed in Appendix Table A3. The probability of death for an individual agent is put at $\xi = .13$, yielding an expected lifespan of 60 years for an agent in our model. The capital depreciation rate is calibrated to be $\delta = .06$.

We set the steady-state growth rate to $\gamma = 1.044$ to match the average annual growth rate of world GDP during the 1985-2014 period from PWT. We then target a world interest rate of $R = 1.030$ based on estimates by King and Low (2014) of the real world interest rate during the same period, and use $\{\eta_n\}_n$ to match per-effective-worker capital stocks from PWT using equation (22). Note that this calibration implies $\gamma > R$. The empirical analogue of the real risk-free world interest rate in our model is not obvious. However, it is reassuring that our model calibration implies that η_n is approximately equal to 1 for countries like Germany and Switzerland, so the calibrated risk-free world rate is approximately equal to the real marginal product of capital in countries that generally attract some of the lowest risk premia in real-world bond markets.[31] Given R, we use the discount rates, $\{\rho_n\}_n$, to match macro trade balances from WIOD using equation (23). The resulting correlation between discount rates and aggregate trade balances is -.75: more impatient economies tend to have trade deficits, while patient economies tend to have surpluses.

Finally, we impose

$$\tau_{sn'n}^{-\theta_s} = \hat{\varepsilon}_{sn'n}, \tag{29}$$

$$\left(\frac{z_{sN}}{z_{sn}} \frac{f_n^{1-\mu_{sn}} P_n^{\mu_{sn}}}{f_N^{1-\mu_{sN}} P_N^{\mu_{sN}}} \right)^{-\theta_s} = \exp\left\{ \hat{\Omega}_{sn} - \hat{\Omega}_{sN} \right\}, \tag{30}$$

where $\hat{\varepsilon}_{sn'n}$ and $\hat{\Omega}_{sn}$ are derived from the PPML estimation discussed in Section 2.1.3; and N is the arbitrary benchmark economy in that estimation. This ensures that the model perfectly matches sector-level bilateral trade patterns and is consistent with the restriction in (8). Moreover, it lends a new interpretation to that restriction in terms of our model parameters. For given $\{E_{snt}/D_{st}\}_{s,n}$ pinned down to a first order by $\{\sigma_{sn}\}_{s,n}$, the restriction amounts to explaining as much variation in sectoral bilateral expenditures as possible as the result of technological comparative advantages, $\{z_{sn}/z_{sN}\}_{s,n\neq N}$. This

[30] Note that the labour share in PWT is computed as the share of labour income in GDP, which corresponds to $1 - \alpha_n$ in our model.

[31] Note from equations (22) and (28) that $\eta_n > 1$ implies $\alpha_n y_n / k_n > R - 1 + \delta$, so despite the assumption of fully integrated international asset markets, our model is consistent with the observed differences in the marginal product of capital across economies. One interpretation of a "low investment efficiency" ($\eta_n > 1$) is that it captures frictions in the flow of capital to certain economies in a black-box fashion.

still leaves enough free parameters to set $\{Z_n\}_n$ so as to match economies' expenditure-side real GDPs from PWT for given steady-state prices and capital stocks.

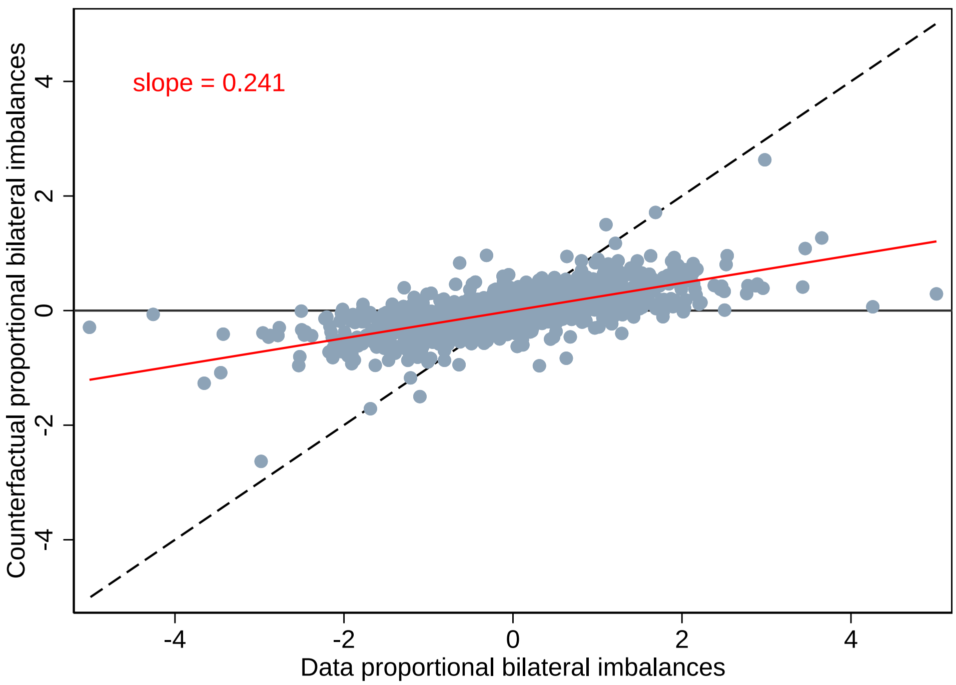
3.2.2 Exact-hat Algebra

In the following, we explore three types of counterfactual parameter changes by means of exact hat algebra. The first relates to changes in inter-economy trade wedges, $\{\tau_{sn'n}\}_{s,n'\neq n}$ which can be thought to result from changes in the iceberg trade costs, $\{\kappa_{sn'n}\}_{s,n'\neq n}$. The second relates to changes in the productivity parameters, $\{z_{sn}\}_{s,n}$, that are *proportionally uniform* across sectors within economies and thus equivalent to economy-specific productivity shocks. The system of equations needed to analyse these two types of changes are provided in Appendix A.4.2. They share the same basic structure of the exact-hat algebra that can be performed to explore counterfactuals in static gravity-class quantitative trade models (see Costinot and Rodríguez-Clare, 2014). However, this basic structure is complemented by three new equations that reflect the impact of parameter changes via international asset markets and capital accumulation on the steady-state world interest rate and macro trade balances.

The third type counterfactual we explore relates to changes in an implicit parameter: the barriers to international asset trade. In our model setup, we have assumed that such barriers are negligible. In Appendix A.4.3, we derive exact-hat algebra for the specific case in which these barriers go from negligible to prohibitive for *all* economies ("financial autarky"). One consequence of this change is that all macro trade balances are zero in the new steady state, which allows us to explore the consequences of balanced trade at the economy level for pairwise trade imbalances.

The exact-hat algebra introduced in Appendix A.4 extends results from Dekle et al. (2007; 2008). Their papers explore trade counterfactuals in the presence of unbalanced trade by treating macro trade balances as exogenous parameters in an otherwise static model. The model we have derived above makes it possible to perform counterfactuals in which macro trade balances are steady-state outcomes that change endogenously in response to changes in underlying structural parameters.

Figure 5: Proportional bilateral imbalances under global trade-wedge symmetry



"Data proportional bilateral imbalance" refers to $(M_{n'nt} - M_{nn't}) / (M_{n'nt} M_{nn't})^{1/2}$, where $M_{n'nt}$ represents the total spending by economy n on output from n'. "Counterfactual imbalances" refers to the corresponding term in the counterfactual steady state in which all bilateral trade wedges are made symmetric, as described in Section 3.3. The red line represents the line of best fit, whose respective slope is also printed in red. All data is based on WIOD (2016 release), average for the years 2010-14. The data covers 40 economies and the Rest of the World.

3.3 Global Trade-Wedge Symmetry

3.3.1 Assumptions

Our variance decomposition in Section 2.2.2 suggested that most of the cross-pair variation in proportional bilateral imbalances must be attributed to pair-wise asymmetric trade frictions. We now use our fully fledged quantitative model to re-visit this finding. Specifically, we set model trade wedges from a calibration that is consistent with the variance decomposition to a state of bilateral symmetry and investigate i) the effect on proportional bilateral imbalances and ii) the broader impacts on macroeconomic outcomes and international integration.

Starting from the calibration of the model described in Section 3.2.1, we impose proportional changes in inter-economy trade wedges, $\{\hat{\tau}_{sn'n}\}_{s,n'\neq n}$, such that

$$\hat{\tau}_{sn'n} = \min\left\{1, \frac{\tau_{snn'}}{\tau_{sn'n}}\right\} \quad \text{for all } s, n' \neq n, \tag{31}$$

i.e. for any sector s and pair n' and n, we set the higher of the two bilateral trade wedges to equal the lower wedge. This counterfactual scenario of complete global bilateral trade-wedge symmetry is admittedly extreme, but it serves to illustrate the extent to which bilateral asymmetries in frictions may shape outcomes in the global economy.[32] In Section 4.2.4, we explore counterfactual changes in bilateral trade barriers that trade policy could more realistically effect.

3.3.2 Impact of Trade Patterns

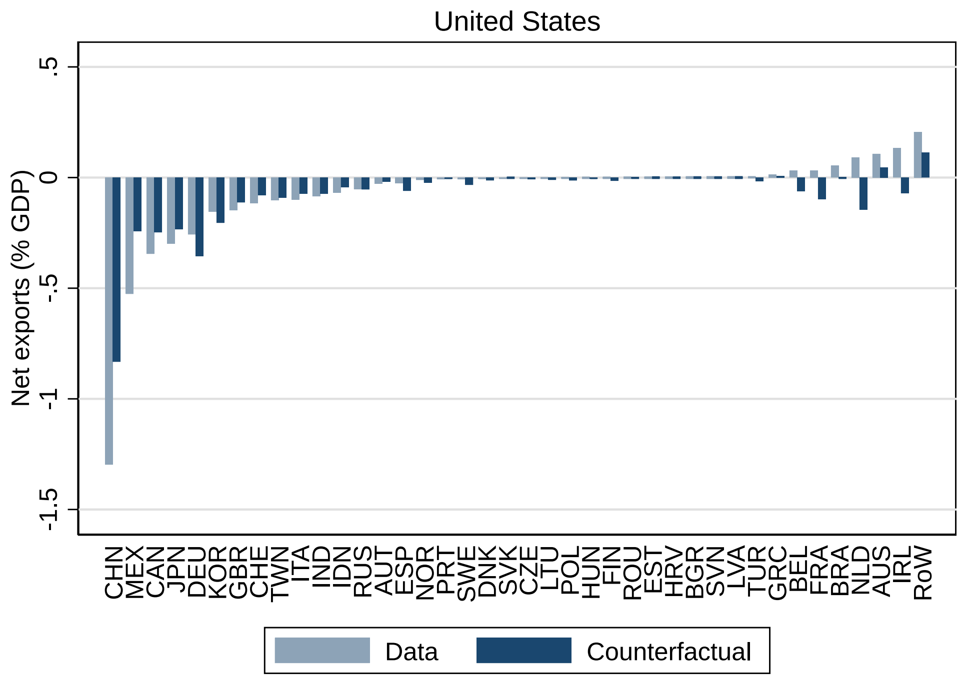
Figure 5 plots the remaining proportional bilateral imbalances in the counterfactual new steady state of the world economy against the original (actual) proportional imbalances. In the counterfactual steady state, there is a lot less variation in bilateral imbalances: the slope of the line of best fit between the new and the original imbalances is only .24. In line with the discussion in

[32] Alternatively, we could impose proportional changes in inter-economy trade wedges, $\{\hat{\tau}_{sn'n}\}_{s,n'\neq n}$, such that

$$\hat{\tau}_{sn'n} = \left(\frac{\tau_{snn'}}{\tau_{sn'n}}\right)^{\frac{1}{2}} \quad \text{for all } s, n' \neq n,$$

i.e. for any sector s and pair n' and n, we set bilateral trade wedges to equal their geometric average. The main results presented below are also obtained in this alternative global trade-wedge symmetry counterfactual. In particular, i) most proportional bilateral imbalances vanish; ii) macro trade balances remain almost unchanged; and iii) per-worker real income and consumption changes primarily reflects the changes in import wedges that economies experience. However, in this scenario import wedges rise for some countries (causing real income and consumption losses), while they fall for others (bringing real-income and consumption gains).

Figure 6: U.S. bilateral net exports under global trade-wedge symmetry



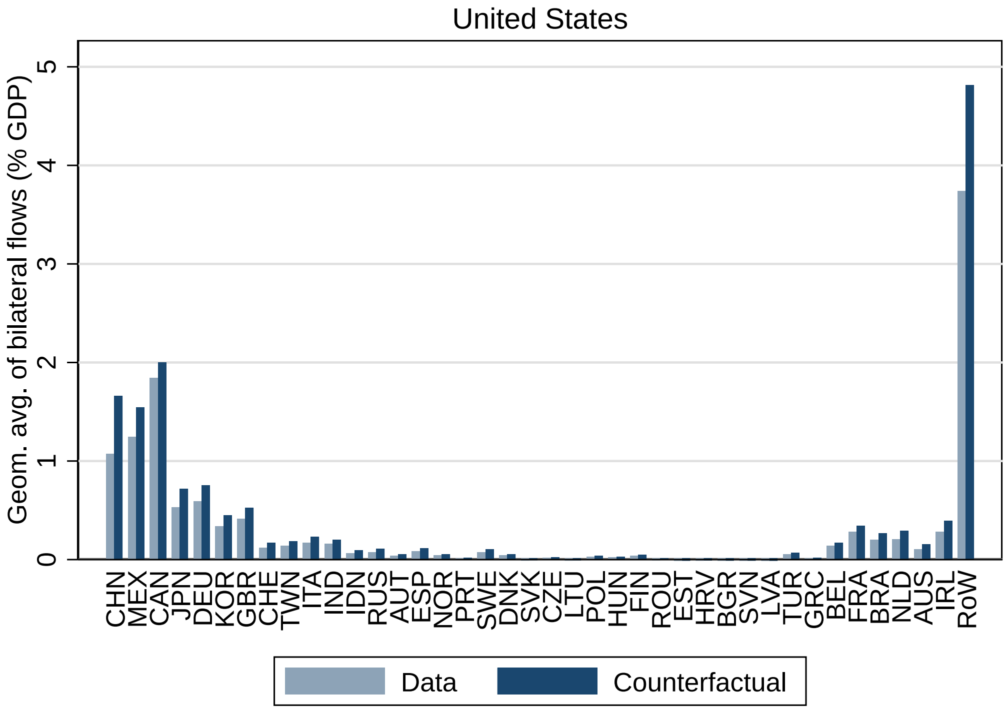
"Net exports (% GDP)" refers to the net exports of goods and services by the United States to the horizontal-axis economy, expressed as a percentage of U.S. GDP. "Data" refers to actual bilateral net exports. "Counterfactual" refers to bilateral net exports in the counterfactual steady state in which all bilateral trade wedges are made symmetric, as described in Section 3.3. Calibration on data from PWT (edition 9.0) and WIOD (2016 release), average for the years 2010-14.

Section 4.1, it suggests that asymmetric trade wedges account for by far the greatest share of variation in proportional bilateral imbalances. Yet Figure 5 also shows that, once non-linearities and general-equilibrium effects are taken into account, the remaining variation in proportional imbalances in a world of trade-wedge symmetry is somewhat larger than what the simple variance decomposition in Section 2.2.2 would suggest.

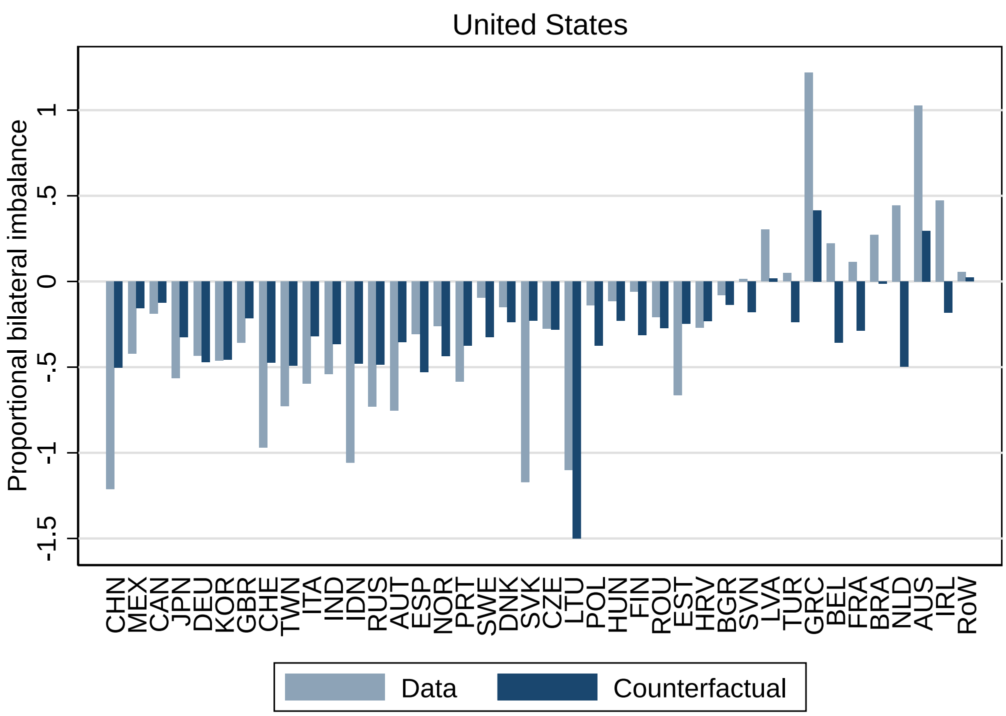
As can be seen in column 5 of Table 4 below, the move towards trade-wedge symmetry has almost no impact on macro trade balances. This is because the new set of trade barriers leaves the world interest rate almost unchanged, and without significant changes in the world interest rate there are no changes in macro trade balances via equation (23).

Returning to our motivating example, Figure 6 shows the effect of global trade-wedge symmetry on U.S. bilateral net exports. The large majority of bilateral net export positions shrinks in absolute value, leaving their distribution more "compressed". Figure 7 decomposes the change in U.S. bilateral net exports into the change in geometric average bilateral trade flows (Panel A) and proportional bilateral imbalances (Panel B). It highlights that the changes visible in Figure 6 reflect two distinct underlying effects. First, as seen in Panel

Figure 7: Decomposing changes in U.S. bilateral net exports under trade-wedge symmetry



Panel A: Changes in in the geometric average of trade flows (as % of GDP) with given trading partner



Panel B: Changes in proportional bilateral imbalance with given trade partner

The "geometric average of bilateral flows (% GDP)" refers to the geometric average value of U.S. imports of goods and services from the horizontal-axis economy and U.S. exports of goods and services to the horizontal-axis economy, expressed as a percentage of U.S. GDP. The "proportional bilateral imbalance" refers to U.S. net exports to the horizontal-axis economy, expressed as a share of the geometric average average of bilateral flows. "Data" refers to actual components of bilateral net exports. "Counterfactual" refers to components of bilateral net exports in the counterfactual steady state in which all bilateral trade wedges are made symmetric, as described in Section 3.3. Calibration on data from PWT (edition 9.0) and WIOD (2016 release), average for the years 2010-14.

A of Figure 7, our counterfactual reduction in trade barriers increases average bilateral trade flows with all U.S. trade partners, albeit to different extents. For given proportional imbalances, this would *increase* the magnitude of conventionally reported trade imbalances. However, as seen in Panel B, most U.S. proportional bilateral imbalances decrease as a result of our symmetry counterfactual. This decline in proportional imbalances trumps the increase in average trade flows, and leads to less variation overall in conventionally reported as well proportional imbalances.

3.3.3 Impact on Macro Outcomes and the Global Economy

The move to bilaterally symmetric trade wedges, by lowering the higher of the two bilateral wedges, has very sizeable effects on real incomes. For the median economy in column 1 of Table 4 per-worker real GDP increases by almost 11%. This effect arises from two channels. First, lower trade barriers raise the purchasing power of domestic income. This enters equation (28) via smaller shares of spending on domestically produced output, as described in Arkolakis et al. (2012) and Ossa (2014). Second, the presence of international capital mobility in our dynamic model amplifies this effect through equation (22): lower trade barriers raise an economy's marginal product of capital and, for a given world interest rate, this results in a higher steady-state per-worker capital stock. Columns 2 and 3 of Table 4 report the changes in these two components of real GPD from equation (28). Unsurprisingly, they are highly correlated: economies whose reliance on domestic output declines more also experience a greater increases in their capital stocks.

In principle, an economy could increase its reliance on foreign output either as a result of lower trade barriers or due to general-equilibrium changes in relative prices. Column 4 of Table 4 shows the weighted average decline in import trade wedges for each economy. The correlation with changes in economies' own-spending terms in column 2 is .91. Therefore, to a first order, we can think of the magnitude of economies' gains from our counterfactual exercise as deriving from the decline in import trade wedges they experience. In turn, this reflects the extent to which their imports were exposed to higher bilateral wedges than their exports. Our counterfactual leaves the world interest rate, and with it macro trade balances, virtually unchanged. Consequently, the changes in real GDP are accompanied by almost one-for-one changes in real aggregate consumption – which is a more meaningful measure of aggregate welfare in our model.

Finally, we document in Appendix A.5.1 that global trade-wedge symmetry would reduce economies' exposure to China. We define exposure of economy

Table 4: Macroeconomic impacts of global trade-wedge symmetry

	(1)	(2)	(3)	(4)	(5)	(6)
Economy	$\hat{y}_n$ %	$\hat{v}_{nn}$ %	$\hat{k}_n$ %	$\hat{\tau}_n$ %	$\tilde{nx}_n - nx_n$ ppt.	$\hat{c}_n$ %
AUS	2.4	-1.2	2.7	-.1	.0	2.1
AUT	12.6	-6.6	12.9	-1.6	.0	12.3
BEL	10.2	-5.8	10.5	-1.3	.0	9.8
BGR	11.1	-5.1	11.5	-.9	-.1	11.1
BRA	2.4	-1.2	2.7	-.2	-.1	2.3
CAN	4.0	-2.2	4.3	-.4	.0	3.8
CHE	7.0	-4.2	7.3	-.7	.1	6.5
CHN	6.0	-3.1	6.3	-.2	.0	5.7
CZE	30.1	-12.6	30.4	-2.5	.0	29.4
DEU	12.6	-7.0	13.0	-1.3	.1	12.2
DNK	6.9	-4.1	7.2	-.8	.1	6.5
ESP	6.7	-3.7	7.1	-.9	-.1	6.6
EST	15.6	-8.1	16.0	-1.7	0.0	15.4
FIN	6.8	-3.8	7.1	-.6	0.0	6.6
FRA	6.0	-3.5	6.3	-.6	-.1	5.9
GBR	6.5	-3.7	6.8	-.7	-.1	6.4
GRC	3.5	-1.6	3.8	-.2	-.2	3.6
HRV	8.4	-5.1	8.7	-.9	-.1	8.3
HUN	19.6	-10.1	20.0	-2.3	.0	19.2
IDN	4.1	-1.6	4.4	-.3	-.1	3.7
IND	4.7	-2.1	5.0	-.3	-.1	4.5
IRL	19.0	-8.0	19.4	-1.9	.0	17.8
ITA	6.3	-3.1	6.7	-.6	.0	6.1
JPN	7.8	-4.3	8.1	-.5	-.1	7.6
KOR	21.2	-9.2	21.6	-.7	.0	20.6
LTU	14.8	-6.2	15.2	-.9	.0	14.4
LVA	9.2	-4.8	9.5	-.9	-.1	9.1
MEX	16.1	-5.5	16.4	-1.2	-.1	15.6
NLD	9.7	-5.2	10.0	-1.2	.1	9.1
NOR	5.2	-2.5	5.5	-.4	.1	4.5
POL	11.7	-6.0	12.1	-1.5	.0	11.5
PRT	8.1	-4.4	8.4	-.7	-.1	8.1
ROU	14.9	-6.1	15.2	-1.1	-.1	14.7
RUS	2.3	-1.5	2.6	-.3	-.2	4.6
RoW	4.5	-2.2	4.8	-.3	-.2	4.6
SVK	44.3	-18.0	44.7	-2.5	.0	43.8
SVN	19.6	-11.2	19.9	-2.1	.0	19.4
SWE	10.9	-5.5	11.2	-1.0	.0	10.4
TUR	11.8	-4.6	12.1	-.8	-.1	11.4
TWN	12.8	-5.5	13.2	-.9	.0	12.0
USA	2.4	-1.3	2.7	-.2	-.1	2.3

For each steady-state outcome x, define $\tilde{x}$ as the new outcome after the counterfactual parameter change, and $\hat{x} \equiv \tilde{x}/x$. y_n is real GDP per effective worker; k_n is real capital stock per effective worker; $nx_n \equiv NX_n/(f_n k_n^{\alpha_n} H_{nt})$; c_n is real aggregate consumption per effective worker; all as formally defined in Section 3.1. $v_{nn} \equiv \prod_s \left(M_{snnt}/\sum_{n'} M_{sn'nt}\right)^{\sigma_{sn}/\theta_s/(1-\sum_s \sigma_{sn}\mu_{sn})}$; and $\hat{\tau}_n \equiv \sum_s \sum_{n'} M_{sn'n}\hat{\tau}_{sn'n}/\sum_s \sum_{n'} M_{sn'n}$.

n to economy n' as the percent change in economy-n steady-state real GDP in response to a permanent 1 percent increase in the aggregate productivity of economy n'. Under this definition, all economies naturally face significant exposure to China as a large economy that is also highly integrated into global value chains. However, our analysis also shows that most economies' trade wedges in importing from China are lower than China's wedges in importing from them. As a result, for most economies our counterfactual implies a trade liberalisation vis-à-vis trade partners *other than China*. This somewhat rebalances their exposure towards the rest of the world.

In sum, our counterfactual confirms not only that trade-wedge asymmetries could explain most of the variation in economies' bilateral imbalances but also that the existence of such asymmetries might have substantive implications for macro outcomes and global interconnectedness. This makes the case for subjecting the nature and origins of bilateral trade-wedge asymmetries to further study. In Section 4, we report some further stylised facts about the bilateral trade-wedge asymmetries implied by our analysis, and we explore some ways in which they might be shaped by the trade-policy environment.

3.4 Financial Autarky

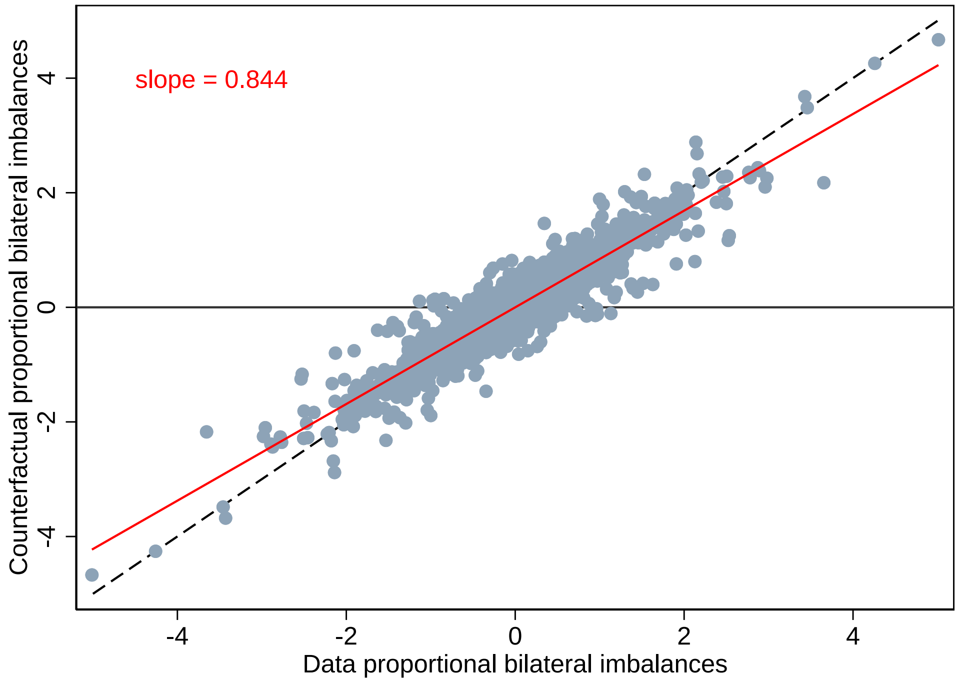
3.4.1 Assumptions

Before we turn to a more detailed analysis of bilateral trade-wedge asymmetries, we briefly explore another counterfactual that speaks to the drivers of the observed variation in (proportional) bilateral imbalances. Starting from the baseline steady state of the model in which agents can freely trade a riskless bond in international financial markets, we let the barriers to international asset trade become prohibitive so that economies exist in financial autarky in the new steady state. The exact-hat algebra for this counterfactual is described in Appendix A.4.3. All macro trade balances are zero in the financial-autarky steady state, which allows us to investigate the impact on bilateral trade imbalances of the disappearance of macroeconomic imbalances.

3.4.2 Impact on Trade Patterns

Figure 8 plots the remaining proportional bilateral imbalances in the counterfactual financial-autarky steady state against the actual proportional imbalances. The slope of the line of best fit between the new and the original imbalances is .84: there is somewhat less variation in proportional imbalances, but the bulk remains. The reduction in the variation in proportional imbalances in a world of counterfactual financial autarky is moderately larger than

Figure 8: Proportional bilateral imbalances under financial autarky



"Data proportional bilateral imbalance" refers to $(M_{n'nt} - M_{nn't}) / (M_{n'nt}M_{nn't})^{1/2}$, where $M_{n'nt}$ represents the total spending by economy n on output from n'. "Counterfactual imbalances" refers to the corresponding term in the counterfactual steady state in which economies exist in financial autarky, as described in Section 3.4. The red line represents the line of best fit, whose respective slope is also printed in red. All data is based on WIOD (2016 release), average for the years 2010-14. The data covers 40 economies and the Rest of the World.

the variance decomposition in Section 2.2.2 suggests.

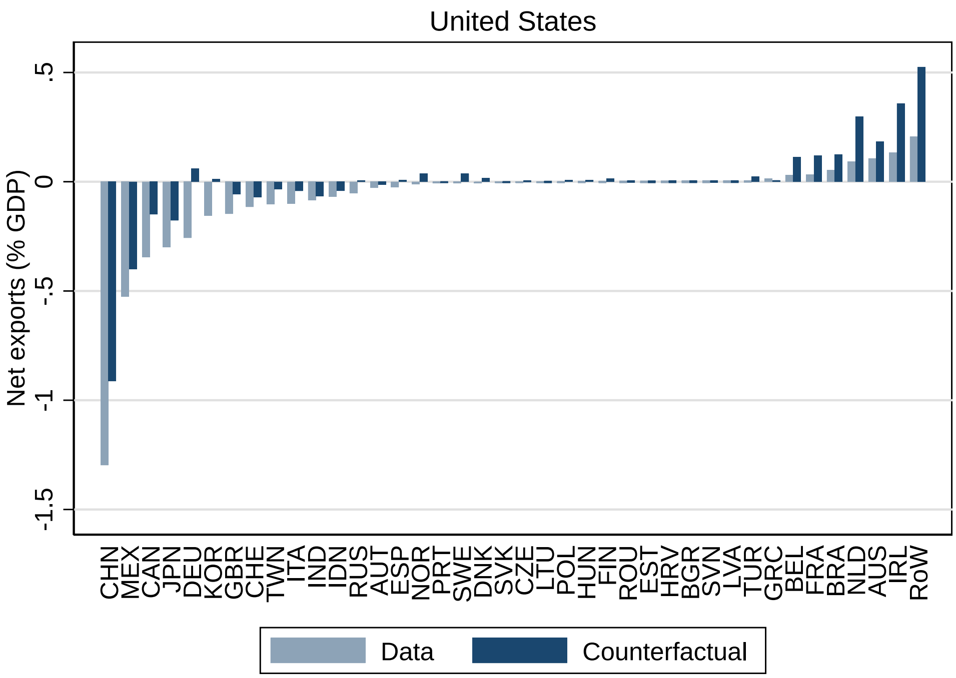
Figure 9 shows the effect on U.S. bilateral net exports. As would be expected, the closing of the U.S. macro trade deficit shifts all U.S. bilateral net exports towards surplus. However, it has almost no impact on the *range* of U.S. bilateral net export positions, or the ranking of U.S. trade partners in terms of the size and direction of the imbalance.

In addition to the effect of counterfactual financial autarky on trade patterns, it has a major impact on economies' real incomes, capital stocks and real aggregate consumption levels. For completeness, these impacts are described in Appendix A.5.2.

4 Properties of Trade-Wedge Asymmetries and the Impact of Trade Policy

Having shown that trade-wedge asymmetries are required to account for a large share of the variation in bilateral trade imbalances, and that these asymmetries may be shaping outcomes in the global macroeconomy substantively,

Figure 9: U.S. bilateral net exports under financial autarky



"Net exports (% GDP)" refers to the net exports of goods and services by the United States to the horizontal-axis economy, expressed as a percentage of U.S. GDP. "Data" refers to actual bilateral net exports. "Counterfactual" refers to bilateral net exports in the counterfactual steady state in which economies exist in financial autarky, as described in Section 3.4. Calibration on data from PWT (edition 9.0) and WIOD (2016 release), average for the years 2010-14.

we now investigate their properties further. We first use different measures to document their magnitude and incidence at the aggregate and sectoral levels. We then provide evidence that the E.U. Single Market appears to reduce trade-wedge asymmetries between member countries. Using our calibrated model to extend the trade-wedge-levelling effects of the Single Market to all economies meaningfully reduces the global variation in proportional bilateral imbalances. Finally, our model suggests that the U.S.-China trade war may succeed in reducing the U.S.-China deficit in the long run, but that this is primarily due to a (costly) weakening of trade ties between the two economies.

4.1 Properties of Aggregate and Sectoral Asymmetries

4.1.1 Aggregate Trade-Wedge Asymmetries

Define the log difference between "aggregate" trade wedge from n' to n and "aggregate" wedge from n to n' as

$$\ln\left(\frac{\tau_{n'n}}{\tau_{nn'}}\right) \equiv \sum_{s=1}^{S}\left(\frac{M_{sn'nt}M_{snn't}}{M_{n'nt}M_{nn't}}\right)^{\frac{1}{2}}\frac{\theta_s}{\theta}\ln\left(\frac{\tau_{sn'n}}{\tau_{snn'}}\right) =$$

Table 5: Aggregate asymmetries in trade wedges

Variable	# obs.	mean	st. dev.	10th pctl.	median	90th pctl.
$\left\|\ln\left(\tau_{n'n}/\tau_{nn'}\right)\right\|$	820	.099	.086	.015	.076	.220

$\tau_{n'n}$ represents the ad-valorem equivalent of the aggregate trade wedge applying to imports by economy n from n', as defined in equation (32). Calibrations are based on data from PWT (edition 9.0) and WIOD (2016 release), averaged for the years 2010-14. The data covers 40 individual economies and the Rest of the World.

$$= \frac{1}{\theta} \sum_{s=1}^{S} \left(\frac{M_{sn'nt} M_{snn't}}{M_{n'nt} M_{nn't}} \right)^{\frac{1}{2}} \ln \left(\frac{\hat{\varepsilon}_{snn'}}{\hat{\varepsilon}_{sn'n}} \right), \tag{32}$$

where θ is the aggregate trade elasticity; and $\{\hat{\varepsilon}_{sn'n}\}_{s,n',n}$ are the residuals from the estimation described in Section 2.1.3. The larger is $\ln\left(\tau_{n'n}/\tau_{nn'}\right)$, the more difficult it is to sell goods and services from n' in n relative to selling goods and services from n in n'.

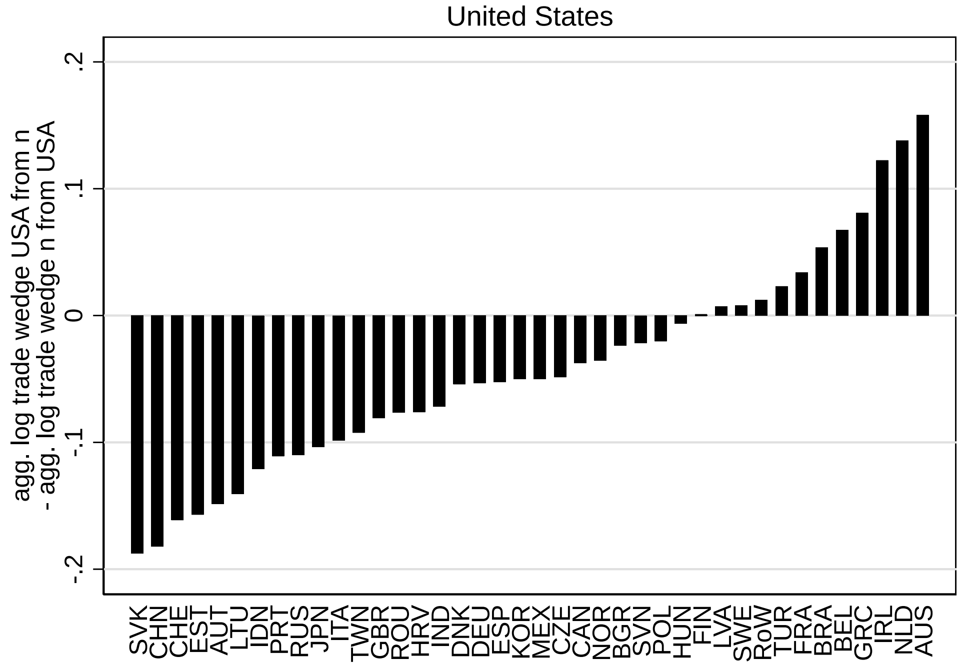
Equation (32) is a natural measure of aggregate trade-wedge asymmetries in the context of our analysis because – up to the value of θ – it corresponds to the contribution of these asymmetries in our approximate decomposition of bilateral imbalances in (6). We choose $\theta = 4$ in this section, in keeping with Simonovska and Waugh's (2014) estimate of the aggregate trade elasticity, and because it is close to the median of our sectoral trade elasticities in Appendix Table A3 (which is 5). Given this parameter choice, Table 5 reports summary statistics for the 820 distinct absolute values of $\left|\ln\left(\tau_{n'n}/\tau_{nn'}\right)\right|$ from our data for the 2010-14 period.[33]

The table highlights the size of trade-wedge asymmetries required for a structural-gravity framework to fit sectoral trade flows perfectly. For the median pair of economies, the average import wedge in one direction is .08 log points (roughly 8%) higher than in the other direction. For 10% of pairs, this gap is larger than .20 log points (roughly 22%). By way of illustration, Figure 10 displays the log difference between the U.S. average import wedge from each of its trading partners and the corresponding partner's average import wedge from the U.S. The U.S. has lower aggregate import than export wedges for roughly two thirds of its trade partners. Some of these asymmetries are sizeable: the U.S. import wedge from China is .18 log points (roughly 16%) smaller than the Chinese import wedge from the U.S. By contrast, China stands out as a country whose import wedges from trade partners are generally high compared to its partners' import wedges from China.[34]

[33]Note that we only need to choose a value of the parameter θ for expositional reasons, so as to be able to interpret the numbers in Table 5 and Figure 9 in terms of ad-valorem trade costs.

[34]China has a lower aggregate import than export wedge for only one fifth of its trade partners.

Figure 10: Model-implied trade-wedge asymmetries in U.S. bilateral trade



Each bar represents $\ln \tau_{nUSA} - \ln \tau_{USAn}$, where $\tau_{n'n}$ is the ad-valorem equivalent of the calibrated weighted average trade wedge applying to imports by economy n from n', as defined in equation (32), and n is the horizontal-axis economy. Calibrations are based on data from PWT (edition 9.0) and WIOD (2016 release), average for the years 2010-14.

The distribution of aggregate trade-wedge asymmetries for the 1995-99 period is characterised by summary statistics that are very similar to those for the 2010-14 period in Table 5. Moreover, the *persistence* of these measured asymmetries mirrors almost exactly the persistence of proportional bilateral imbalances documented in Appendix A.2.

4.1.2 Sectoral Trade-Wedge Asymmetries

In Table 6, we dig deeper to assess the role of different sectors in the aggregate trade-wedge asymmetries described above. The table reports a measure of the contribution of each of the 31 sectors in our baseline 2010-14 data to the cross-pair variation in aggregate trade-wedge asymmetries as defined in equation (32).

Five out of the 31 sectors in Table 3 ("Electrical and optical equipment", "Chemicals and chemical products", "Basic metals and fabricated metal", "Transport equipment", "Machinery, nec") on their own account for 70% of the aggregate variation. For each sector, the table also lists the median weight of each sector in a pairs' bilateral trade flows, $M_{sn'n}^{1/2} M_{snn'}^{1/2} / M_{n'n}^{1/2} M_{nn'}^{1/2}$, and the magnitude of the sector's median estimated bilateral asymmetry, $|\ln (\hat{\varepsilon}_{sn'n}/\hat{\varepsilon}_{snn'})|$. These numbers suggest that the sectors that contribute most of the variation

Table 6: Sectoral bilateral trade-wedge asymmetries and their contribution to aggregate asymmetries

Sector code	Sector name	Contribution to agg. asymmetries	Median $\frac{M^{1/2}_{sn'nt}M^{1/2}_{snn't}}{M^{1/2}_{n'nt}M^{1/2}_{nn't}}$	Median $\left\vert\ln\left(\frac{\hat{\varepsilon}_{sn'n}}{\hat{\varepsilon}_{snn'}}\right)\right\vert$
12	Electrical and optical equipment	.307	.073	.778
8	Chemicals and chemical products	.112	.070	.683
11	Basic metals and fabricated metal	.110	.059	.654
14	Transport equipment	.084	.040	.903
15	Machinery, nec	.082	.040	.790
3	Food, beverages and tobacco	.042	.034	1.015
18	Wholesale trade,...	.040	.024	1.407
4	Textiles and textile products;...	.039	.015	1.091
9	Rubber and plastics	.039	.020	.777
15	Manufacturing, nec; recycling	.029	.020	.778
28	Other business activities	.027	.037	.640
6	Pulp, paper; paper, printing...	.019	.015	1.123
7	Coke, refined petroleum and nuclear fuel	.016	.006	1.397
10	Other non-metallic, mineral	.013	.007	.982
19	Retail trade, except of motor vehicles...	.009	.003	1.663
17	Construction	.009	.002	1.545
26	Financial intermediation	.008	.002	1.279
1	Agriculture, hunting, forestry and fishing	.007	.011	1.356
5	Wood and products of wood and cork	.006	.004	1.328
23	Air transport	.005	.006	.837
16	Electricity, gas and water supply	.003	.006	1.031
24	Other supporting transport activities;...	.003	.005	1.094
21	Inland transport	.003	.009	1.302
31	Public admin,...	.002	.003	1.167
30	Health and social work	.001	.000	1.555
25	Post and telecommunications	.000	.003	.908
27	Real estate activities	.000	.000	1.983
22	Water transport	.000	.001	1.102
29	Education	-.000	.000	1.527
20	Hotels and restaurants	-.001	.000	1.193
2	Mining and quarrying	-.006	.005	1.711

The contribution of sector s to aggregate trade-wedge asymmetries is defined as $Cov\left[\ln\left(\tau_{sn'n}/\tau_{snn'}\right)\theta_s M^{1/2}_{sn'nt}M^{1/2}_{snn't}/\left(\theta M_{n'nt}M_{nn't}\right), \ln\left(\tau_{n'n}/\tau_{nn'}\right)\right]/Var\left[\ln\left(\tau_{n'n}/\tau_{nn'}\right)\right]$. All variables and parameters are as defined in Sections 3.1 and 3.2. The data source is WIOD (2016 release), averaged for the years 2010-14. The data covers 40 individual economies and the Rest of the World.

in aggregate trade-wedge asymmetries do so because they make up a relatively large share of bilateral trade flows, not because they are characterised by especially large sectoral trade-wedge asymmetries.[35]

As a check on the above, we turn to an alternative, useful measure of sectoral symmetries in bilateral trade barriers, first employed by Caliendo and Parro (2015). This measure has the benefit of imposing very little structure on trade wedges. In particular, it does not rely on our restriction (8) and only requires that sectoral trade flows are governed by structural gravity as described by equations (1) and (2). Suppose we can generically write

$$\ln \tau_{sn'n} = \ln \tau^{E}_{sn'} + \ln \tau^{I}_{sn} + \ln \bar{\tau}_{sn'n} + \ln \vec{\tau}_{sn'n}, \tag{33}$$

where $\tau^{E}_{sn'}$ captures trade-wedge determinants in sector s that are specific to n' as exporter; τ^{I}_{sn} captures determinants that are specific to n as importer; $\bar{\tau}_{sn'n}$ represents the pairwise symmetric component of trade costs (so that $\bar{\tau}_{sn'n} = \bar{\tau}_{snn'}$ for all s, n' and n); and $\vec{\tau}_{sn'n}$ is the component that is pairwise asymmetric (so that $\vec{\tau}_{sn'n} \neq \vec{\tau}_{snn'}$ for all s, n' and n). Then Caliendo and Parro (2015) show that, given (1) and (2),

$$\left| \ln \frac{M_{sn''n'} M_{sn'n} M_{snn''}}{M_{sn''n} M_{snn'} M_{sn'n''}} \right| = \left| -\theta_s \ln \left(\frac{\vec{\tau}_{sn''n'} \vec{\tau}_{sn'n} \vec{\tau}_{snn''}}{\vec{\tau}_{sn''n} \vec{\tau}_{snn'} \vec{\tau}_{sn'n''}} \right) \right| \tag{34}$$

for any s, n'', n' and n.

Equation (34) provides a measure of the extent of *pairwise* asymmetries in trade wedges.[36] The further away from zero the measure, the larger the extent of such asymmetries. Table 7 lists summary statistics for it based on the 10,660 unique cross-border trade-flow triplets in our 2010-14 data. It does so by sector, focusing on the 15 goods-producing sectors that make 90% of the variation in aggregate trade-wedge asymmetries according to Table 6.[37]

[35] In line with these findings, if we return to our global symmetry counterfactual from Section 3.3.1, but only apply (31) in the top five sectors from Table 6, about half of the variation in proportional bilateral imbalances disappears. This is equivalent to roughly two thirds of the effect of full global trade-wedge symmetry. The distribution of macroeconomic impacts across economies is qualitatively similar to that described in Section 3.3.3, but the magnitude of impacts is commensurately smaller.

[36] Allen and Arkolakis (2016) define trade wedges of the form

$$\tau_{sn'n} = \tau^{E}_{sn'} \tau^{I}_{sn} \bar{\tau}_{sn'n}$$

as "quasi-symmetric". Note that quasi-symmetric wedges would still give rise to bilateral asymmetries of the form

$$\ln \tau_{sn'n} - \ln \tau_{snn'} = \left(\ln \tau^{E}_{sn'} - \ln \tau^{E}_{sn} + \ln \tau^{I}_{sn} - \ln \tau^{I}_{sn'} \right).$$

However, such asymmetries, which derive purely from *country* – not *pair* – effects cancel in the triple ratio of trade flows in (34).

[37] Three manufacturing sectors have fewer than 10,660 triplets as a result of zero-valued

Table 7: Caliendo and Parro (2015) measure of sectoral trade-cost asymmetries

$\lvert \ln [(M_{sn''n'} M_{sn'n} M_{snn''}) / (M_{sn''n} M_{snn'} M_{sn'n''})] \rvert$					
Sector code	Sector name	Obs.	$p(10)$	$p(50)$	$p(90)$
1	Agriculture, hunting, forestry and fishing	10,660	.275	**1.491**	4.130
2	Mining and quarrying	10,583	.383	**2.017**	5.365
3	Food, beverages and tobacco	10,660	.188	**1.018**	2.869
4	Textiles and textile products;...	10,660	.173	**.993**	2.594
5	Wood and products of wood and cork	10,621	.222	**1.196**	3.207
6	Pulp, paper; paper, printing and publishing	10,660	.215	**1.212**	3.605
7	Coke, refined petroleum and nuclear fuel	10,224	.362	**1.946**	5.655
8	Chemicals and chemical products	10,660	.174	**.973**	2.696
9	Rubber and plastics	10,660	.147	**.845**	2.380
10	Other non-metallic, mineral products	10,660	.188	**1.027**	2.734
11	Basic metals and fabricated metal	10,660	.179	**1.064**	3.105
12	Electrical and optical equipment	10,660	.143	**.813**	2.283
13	Machinery, nec	10,660	.162	**.905**	2.456
14	Transport equipment	10,660	.208	**1.155**	3.137
15	Manufacturing, nec; recycling	10,660	.169	**.952**	2.654

$M_{sn'nt}$ represents spending by economy n on sector-s output from n' during period t. All data is based on WIOD (2016 release), averaged for the years 2010-14. The data covers 40 individual economies and the Rest of the World.

The sectoral median of the Caliendo-Parro measure is highly correlated with the median sectoral trade-wedge asymmetry reported for the 15 goods sectors in Table 6, with a correlation coefficient of .86. Both measures thus appear to capture largely the same "residual" pairwise asymmetries in sectoral trade flows.

4.2 Trade-Cost Asymmetries in a Single Market

4.2.1 Trade Policy and Trade-Cost Asymmetries

For illustrative purposes, our counterfactual in Section 3.3 analysed the global impact of the elimination of *all* trade-wedge asymmetries. However, at least some of these asymmetries likely arise from the (asymmetric) impact on trade barriers of deep structural factors such as geography, technologies and preferences. This would explain the high persistence in our measure of aggregate bilateral trade-wedge asymmetries highlighted in Section 4.1.1, and render the complete global trade-wedge symmetry of Section 3.3 a somewhat misleading benchmark. In the remainder of this section, we instead assemble some evidence on the extent to which the trade-policy environment might realistically impact bilateral trade-cost asymmetries and, through them, bilateral trade flows.

imbalances.

One straightforward way in which trade policy could give rise to pliable trade-cost asymmetries is through pairwise asymmetries in bilateral import tariffs. However, the sample of economies in our data is heavily biased towards economies with low or zero tariff barriers to trade. Out of 40 individual sample economies, 24 were E.U. members in the 2010-14 period.[38] Therefore, out of the 820 trade-partner pairs in our data, about a third are not subject to tariffs at all. Based on WDI data (2021 edition), the E.U.'s weighted average external tariff rate was 1.7% in the 2010-14 period, and the weighted average tariff rate for the median non-E.U. economy in our sample was 2.6%. This means that pairwise asymmetries in tariffs can at best account for a small fraction of the magnitude of trade-wedge asymmetries implied by our calculations above.

We thus take a broader view and ask to what extent membership in a single market that eliminates both tariff *and* non-tariff barriers to trade appears to reduce trade-cost asymmetries. Focusing on this question has two advantages. First, it allows us to exploit the overrepresentation of E.U. member countries in our baseline data for the 2010-14 period, as well as the fact that 11 countries that are both in our 1995-99 and 2010-14 datasets joined the European Single Market between these two periods. Second, it casts a spotlight on the experience of an economic union created with express purpose of eliminating trade barriers so as to level the playing field between suppliers from different member countries within its boundaries.[39]

4.2.2 Cross-Sectional Evidence on the Single Market Effect

Table 8 is once again based on the economy-triplet measure of the extent of pairwise bilateral trade-wedge asymmetries introduced in (34). Starting from the same data for which summary statistics by goods sector are reported in Table 7, it now divides these triplets into three groups. The first group contains only triplets involving at most one E.U. member country, so *none* of the 6 bilateral trade flows constitute intra-E.U. flows. The second group is made up of triplets with *exactly two* E.U. countries, so 2 out of 6 bilateral trade flows are intra-E.U. The third group is made up of triplets comprising *exactly three* E.U. countries. To describe the distribution of the asymmetry measure from (34) by sector and triplet group, the table reports the 10th percentile,

[38] Note that Croatia only joined the E.U. in 2013, and that we group Cyprus, Luxembourg and Malta with the "rest of the world" as discussed in Section 2.2.1.

[39] For example, Zuleeg (2020) notes that "the E.U.'s Single Market (SM) has been built around the concept of a level playing field, going further than the rules which exist to govern global interactions. There is an extensive body of law that ensures that European companies face the same conditions no matter which member state's markets they enter, with EU institutions executing supranational implementation, arbitration and enforcement."

Table 8: Trade-cost asymmetries and E.U. membership

$\|\ln[(M_{sn''n'}M_{sn'n}M_{snn''})/(M_{sn''n}M_{snn'}M_{sn'n''})]\|$												
Sector code	< 2 E.U. members				2 E.U. members				3 E.U. members			
	Obs.	$p(10)$	$p(50)$	$p(90)$	Obs.	$p(10)$	$p(50)$	$p(90)$	Obs.	$p(10)$	$p(50)$	$p(90)$
1	3,944	.321	**1.723**	4.708	4,692	.302	**1.517**	4.049	2,024	.190	**1.081**	.2966
2	3,912	.438	**2.224**	5.873	4,647	.368	**2.018**	5.286	2,024	.334	**1.701**	4.680
3	3,944	.227	**1.241**	3.321	4,692	.199	**1.068**	2.873	2,024	.123	**.641**	1.735
4	3,944	.195	**1.190**	3.064	4,692	.167	**.959**	2.371	2,024	.144	**.797**	2.064
5	3,928	.260	**1.402**	3.665	4,669	.212	**1.184**	3.150	2,024	.176	**.905**	2.322
6	3,944	.295	**1.584**	4.154	4,692	.216	**1.186**	3.561	2,024	.154	**.793**	2.319
7	3,754	.427	**2.327**	6.585	4,468	.370	**1.954**	5.512	2,002	.261	**1.496**	4.021
8	3,944	.212	**1.171**	3.030	4,692	.188	**1.003**	2.676	2,024	.110	**.636**	1.857
9	3,944	.194	**1.041**	2.718	4,692	.150	**.867**	2.368	2,024	.095	**.565**	1.602
10	3,944	.218	**1.162**	2.881	4,692	.203	**1.050**	2.790	2,024	.134	**.770**	2.158
11	3,944	.244	**1.350**	3.748	4,692	.192	**1.103**	2.982	2,024	.112	**.624**	1.919
12	3,944	.171	**.978**	1.753	4,692	.147	**.821**	2.204	2,024	.101	**.581**	1.625
13	3,944	.197	**1.064**	2.680	4,692	.171	**.929**	2.526	2,024	.111	**.648**	1.723
14	3,944	.252	**1.366**	3.487	4,692	.220	**1.182**	3.167	2,024	.143	**.822**	2.181
15	3,944	.221	**1.226**	3.129	4,692	.165	**.922**	2.484	2,024	.114	**.647**	1.769

$M_{sn'nt}$ represents spending by economy n on sector-s output from n' during period t. All data is based on WIOD (2016 release), averaged for the years 2010-14. The data covers 40 individual economies and the Rest of the World.

median and 90th percentile value of the measure in each bin.

As these statistics show, relative to the group with at most one E.U. country per triplet, the distribution of the measure is shifted towards zero in the group with exactly two E.U. countries per triplet. This is true for all sectors. It is shifted further towards zero still in the group with exactly three E.U. countries per triplet, again with remarkable consistency across all sectors. Note that, by virtue of the properties of the Caliendo-Parro measure of asymmetries, differences in economies' attributes or symmetric elements of geography between these groups are effectively "controlled for" in Table 8. Therefore, the table offers simple yet compelling evidence that trade wedges in intra-E.U. trade are characterised by greater pairwise symmetry.

4.2.3 Evidence on the Single-Market Effect from E.U. Accessions

Given the findings in the previous section, we now ask whether trade-wedge asymmetries appear to *decline* when countries join the E.U. Single Market. To answer the question, we use the fact that 11 countries that are both in our 1995-99 and 2010-14 datasets (Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, Bulgaria, Romania) became E.U. members between these two periods. We run a regression of the form

$$\triangle\left(\ln\tau_{sn'n}-\ln\tau_{snn'}\right)=\Psi_s+\psi_s\triangle EU_{n'n}+\upsilon_{n'n}, \tag{35}$$

where $(\ln\tau_{sn'n}-\ln\tau_{snn'})$ is the change in measured trade-wedge asymmetries between 1995-99 and 2010-14 computed as,

$$\triangle\left(\ln\tau_{sn'n}-\ln\tau_{snn'}\right)\equiv$$

$$=\left[\ln\left(\frac{\hat{\varepsilon}_{sn'n10-14}}{\hat{\varepsilon}_{snn'10-14}}\right)^{-\frac{1}{\theta_s}}-\ln\left(\frac{\hat{\varepsilon}_{sn'n95-99}}{\hat{\varepsilon}_{snn'95-99}}\right)^{-\frac{1}{\theta_s}}\middle|\left(\frac{\hat{\varepsilon}_{sn'n95-99}}{\hat{\varepsilon}_{snn'95-99}}\right)^{-\frac{1}{\theta_s}}>1\right]; \tag{36}$$

$\hat{\varepsilon}_{sn'nt}$ is derived from the PPML estimation in Section 2.1.3 performed for period $t\in\{1995-99;2010-14\}$; θ_s is our calibrated sector-s trade elasticity; $\triangle EU_{n'n}$ is a dummy variable taking value 1 if n' and n are both E.U. members in period 2010-14 but at least one of them was not in 1995-1999; and $\upsilon_{n'n}$ is the error term.[40]

We are testing if $\psi_s<0$, i.e. if joining the E.U. between the two periods was associated with a decline in new members' trade-wedge asymmetries vis-à-vis other members in sector s. Our estimates of ψ_s for each of the 15 goods-producing sectors, along with standard errors and the regression fit are shown in Table 9. As can be seen there, we do find a statistically significant negative association across all goods sectors. In a handful of these sectors, the "Single Market effect" on its own accounts for more than 10% of the over-time change in trade-wedge asymmetries.

The above suggests that intra-E.U. trade is not only characterised by smaller bilateral trade-wedge asymmetries, but that countries that join the E.U. see their trade-wedge asymmetries with other E.U. members decline. To the best of our knowledge, this effect of E.U. Single Market membership has not been documented before. It is separate from, and additional to, the well documented reduction in the average level (rather than pairwise asymmetries) of bilateral trade barriers from E.U. membership.[41] We now assess whether the trade-wedge-levelling effect of E.U. membership is economically meaningful, by exploring a counterfactual that extends it to all non-E.U. sample economies.

[40] We exclude the "Rest of the World" from these regressions because its definition differs between the two datasets. See Appendix A.2 for a description of the properties of the 1995-99 data. After excluding the "Rest of the World", we have 40 individual economies in our 2010-14 data, but only 38 of these are also in our 1995-99 data. This leaves $(38\times 37/2=)$ 666 unique pairs on which to perform the regression in (35). In line with (36) we define unique pairs such that their 1995-99 trade-wedge gap is positive, and we can thus assess by means of (35) if E.U. membership shrinks this gap.

[41] See Mayer et al. (2019) for a discussion of the literature on the trade-promoting effects of E.U. membership as well as updated estimates.

Table 9: Estimated impact of E.U. accession on sectoral trade-wedge asymmetries

Sector code	Sector name	$\hat{\psi}_s$	R^2	Obs.
1	Agriculture, hunting, forestry and fishing	-.108*** (.012)	.06	664
2	Mining and quarrying	-.100*** (.012)	.08	604
3	Food, beverages and tobacco	-.351*** (.040)	.08	663
4	Textiles and textile products;...	-.097*** (.017)	.04	664
5	Wood and products of wood and cork	-.039*** (.009)	.02	661
6	Pulp, paper; paper, printing and publishing	-.091*** (.011)	.06	664
7	Coke, refined petroleum and nuclear fuel	-.025*** (.003)	.05	619
8	Chemicals and chemical products	-.154*** (.018)	.08	666
9	Rubber and plastics	-.642*** (.055)	.13	664
10	Other non-metallic, mineral products	-.320*** (.038)	.10	665
11	Basic metals and fabricated metal	-.096*** (.009)	.07	666
12	Electrical and optical equipment	-.505*** (.042)	.09	664
13	Machinery, nec	-.113*** (.008)	.19	628
14	Transport equipment	-3.749*** (.307)	.11	664
15	Manufacturing, nec; recycling	-.175*** (.020)	.08	664

Estimates from the regression described in Section 4.2.3 for 15 goods-producing sectors. All data is based on WIOD (2013 and 2016 releases), taking 5-year averages to compare the 1995-99 and 2010-14 periods. The data used for the regressions covers 38 individual economies, including 11 countries (Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, Bulgaria, Romania) that joined the E.U. between 1995-99 and 2010-14.

4.2.4 Extending the Single Market Effect to Non-E.U. Countries

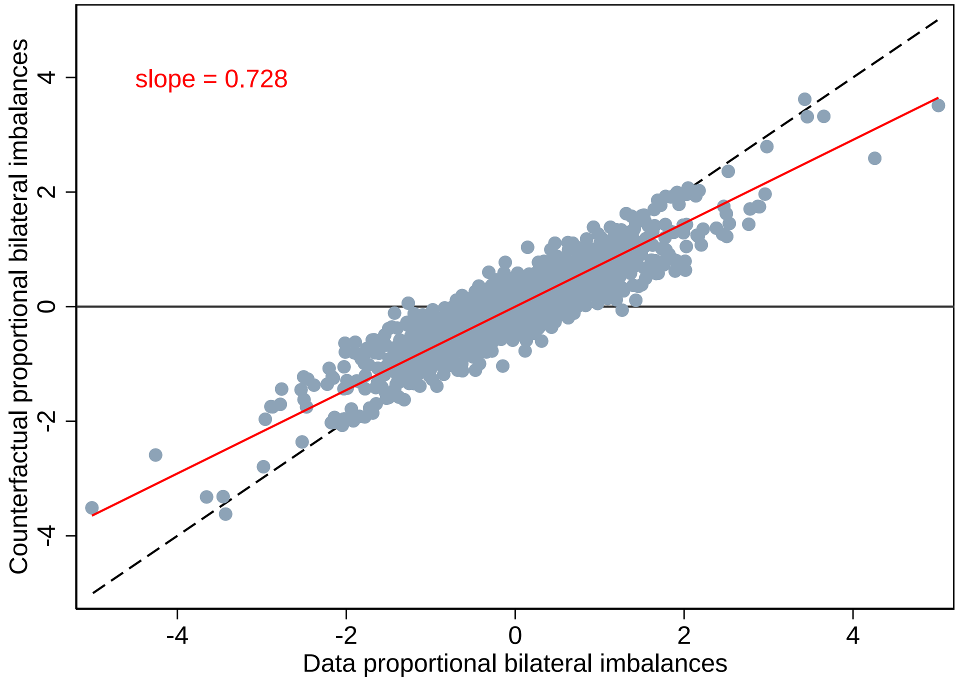
Starting from the model and calibration described in Sections 3.1 and 3.2, we impose proportional changes in inter-economy trade wedges for the period 2010-14, $\{\hat{\tau}_{sn'n}\}_{s,n'\neq n}$, such that

$$\hat{\tau}_{sn'n} = \begin{cases} \exp\left\{\hat{\psi}_s\right\} & \text{if } \tau_{sn'n} > \tau_{snn'} \\ 1 & \text{otherwise} \end{cases}, \tag{37}$$

for any goods-producing sector s, and any pair in which at least one of n' and n is *not* an E.U. member. That is, for all non-E.U. economies, we keep the lower of each bilateral goods trade wedge unchanged, and change the higher wedge in line with our estimate of the Single Market symmetry effect estimated in Section 4.2.3. All intra-E.U. and all service-sector trade wedges remain as they are.

This counterfactual only captures the trade-wedge-levelling effect of E.U. membership we documented above, *not* the reduction in average bilateral trade barriers E.U. accession has been shown to bring about. It is also clearly more limited than the global trade-wedge symmetry experiment from Section 3.3.

Figure 11: Proportional imbalances with E.U. trade-wedge symmetry in non-EU economies



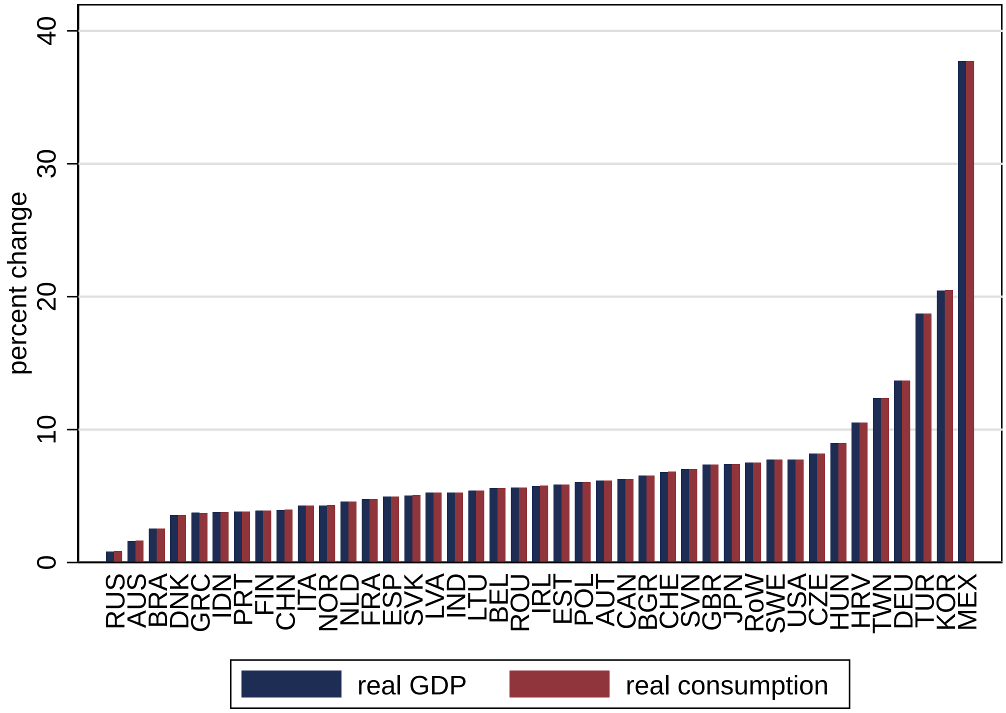
"Data proportional bilateral imbalance" refers to $(M_{n'nt} - M_{nn't}) / (M_{n'nt}M_{nn't})^{1/2}$, where $M_{n'nt}$ represents the total spending by economy n on output from n'. "Counterfactual imbalances" refers to the corresponding term in the counterfactual steady state in which non-E.U. economies' trade-wedge asymmetry declines in line with the estimated EU accession effect, as described in Section 4.2. The red line represents the line of best fit, whose respective slope is also printed in red. All data is based on WIOD (2016 release), average for the years 2010-14. The data covers 40 economies and the Rest of the World.

Only extra-E.U. goods trade wedges are affected, and these only move towards symmetry in line with our estimates from Table 9, instead of becoming fully symmetric.

Once again, Figure 11 plots the resulting counterfactual proportional bilateral imbalances against actual 2010-14 imbalances. As can be seen from the figure, the variation in proportional bilateral imbalances declines noticeably, equivalent to roughly one third of the effect of full global trade-wedge symmetry. Given the more limited scope of the Single Market effect, and that it is imposed for the bilateral trade flows of the 17 non-E.U. economies in out data, this demonstrates that a Single Market-like trade policy environment could have substantive effects on bilateral imbalances.

Figure 12 gives a graphical overview of the impact of this counterfactual experiment on economies' real per-capita GDP and consumption levels. While these effects are smaller than under full global trade-wedge symmetry, they are still sizeable: the median economy experiences a real GDP increase of more than 5%. One noteworthy aspect of these results is that the three biggest winners from in this counterfactual scenario are Mexico (38%), South Korea

Figure 12: Macroeconomic impacts of E.U. trade-wedge symmetry in non-E.U. economies



Percent change in real per-capita GDP and consumption relative to data in a counterfactual steady in which non-E.U. economies' trade-wedge asymmetry declines in line with the estimated E.U. accession effect, as described in Section 4.2. Calibrations are based on data from PWT (edition 9.0) and WIOD (2016 release), average for the years 2010-14.

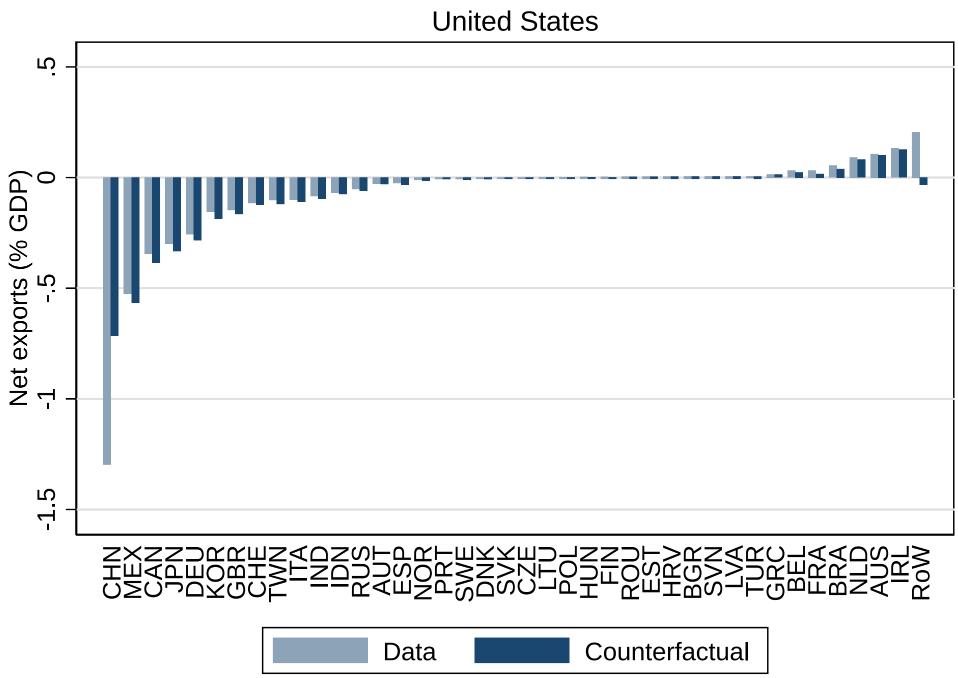
(20%) and Turkey (19%). Each of these countries currently enjoys a close trade relationship with major markets in its respective region short of a Single Market environment. As a result of the real-GDP gains in these middle-to-high-income countries, the top end of the international income distribution in our data narrows, even though the overall extent of international income differences remains broadly unchanged.

4.3 U.S.-China Trade War

4.3.1 Assumptions

In our final counterfactual, we let U.S.-China trade wedges rise to simulate the effect of the tariffs imposed by the U.S. on China between January 2018 and June 2019, and the retaliatory tariffs imposed by China during this period. We study this episode because the U.S.-China trade war arose as a real-world policy outcome in the wake of a stated ambition by a U.S. Administration to shrink the U.S.-China trade deficit. Our counterfactual sheds some light on the likely effectiveness of higher bilateral trade barriers as a means of reducing bilateral imbalances.

Figure 13: U.S. bilateral net exports in the wake of U.S.-China trade war



"Net exports (% GDP)" refers to the net exports of goods and services by the United States to the horizontal-axis economy, expressed as a percentage of U.S. GDP. "Data" refers to actual bilateral net exports. "Counterfactual" refers to bilateral net exports in the steady state of the U.S.-China trade-war counterfactual, as described in Section 4.3 and Appendix A.5.3. Calibration on data from PWT (edition 9.0) and WIOD (2016 release), average for the years 2010-14.

Between January 2018 and June 2019, the U.S. increased average tariffs on Chinese imports under Section 301 of the U.S. Trade Act by 14.4 percentage points. In retaliation, China increased average tariffs on U.S. imports by 13.5 percentage points.[42] In Appendix A.5.3, we describe how we compute sectoral-level tariff changes on U.S.-China trade consistent with our sectoral aggregation, and we show how these tariffs affect U.S.-China trade wedges in Table A4. Our counterfactual should be interpreted as describing the new long-run steady state of the world economy, relative to 2010-14, if the new tariffs imposed between the U.S. and China up until June 2019 remain in place permanently, and everything else is constant.

4.3.2 Impact on Trade Patterns and Macro Outcomes

As in our other counterfactuals, the rise in trade barriers has a very limited effect on the world interest rate. Therefore, as before, macro trade balances remain virtually unchanged. Figure 13 gives an overview of the long-run impact of the tariffs on U.S. bilateral net exports. Most significantly, the U.S.-China deficit is halved in the new steady state.

[42]See Bown (2019) and Bown et al. (2019).

The halving of the U.S.-China imbalance is the result of two effects. Figure 14 decomposes the changes in U.S. bilateral net exports into the changes in the geometric average value of trade trade flows with each U.S. trade partner (Panel A), and changes in the proportional bilateral imbalance (Panel B). It is clear from Panel A that the primary impact of the new U.S. and Chinese tariffs is to reduce the average value of bilateral flows between the U.S. and China. There is also evidence of some trade diversion, as U.S. trade flows with Mexico, Germany and Ireland rise slightly, but these effects are of much smaller magnitude. Panel B documents that the (proportional) imbalance between the U.S. and China also declines, but only modestly so. Therefore, the counterfactual suggests that the trade war may – in the long run – achieve the goal of reducing the U.S.-China deficit primarily by weakening trade ties between the two countries.

The model also shows the long-run reduction in the U.S.-China imbalance to be a Pyrrhic victory for two reasons. First, with the U.S. macro trade balance unchanged, U.S. net exports to every other trade partner deteriorate. This is especially stark vis-à-vis the rest of the world, where the trade war turns the largest U.S. bilateral surplus into a deficit. The second reason can be seen in Figure 15: the U.S. and China both lose equally from the trade war, with steady-state reductions in real GDP per capita and consumption per capita of around a fifth of a percent.[43] Third-country effects are generally small, with one notable exception: as U.S. imports are diverted to Mexico, the latter gains an additional .15% of GDP in the long run.[44]

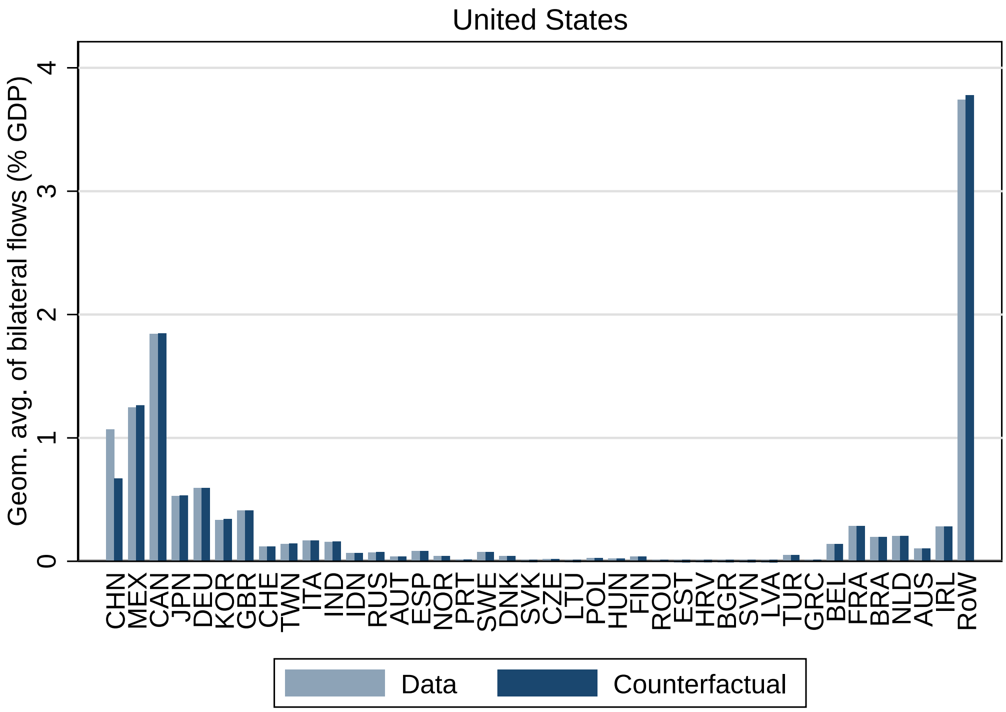
5 Conclusion

Under the common assumption that sectoral trade flows between economies obey a structural gravity equation, explaining the observed variation in bilateral trade balances requires large bilateral trade-wedge asymmetries – that is, barriers between trade partners that are higher in one direction than the other. The structural-gravity assumption is compatible with many different trade models and sufficient to obtain this finding. However, the finding is confirmed in the general-equilibrium counterfactuals of a fully-fledged dynamic

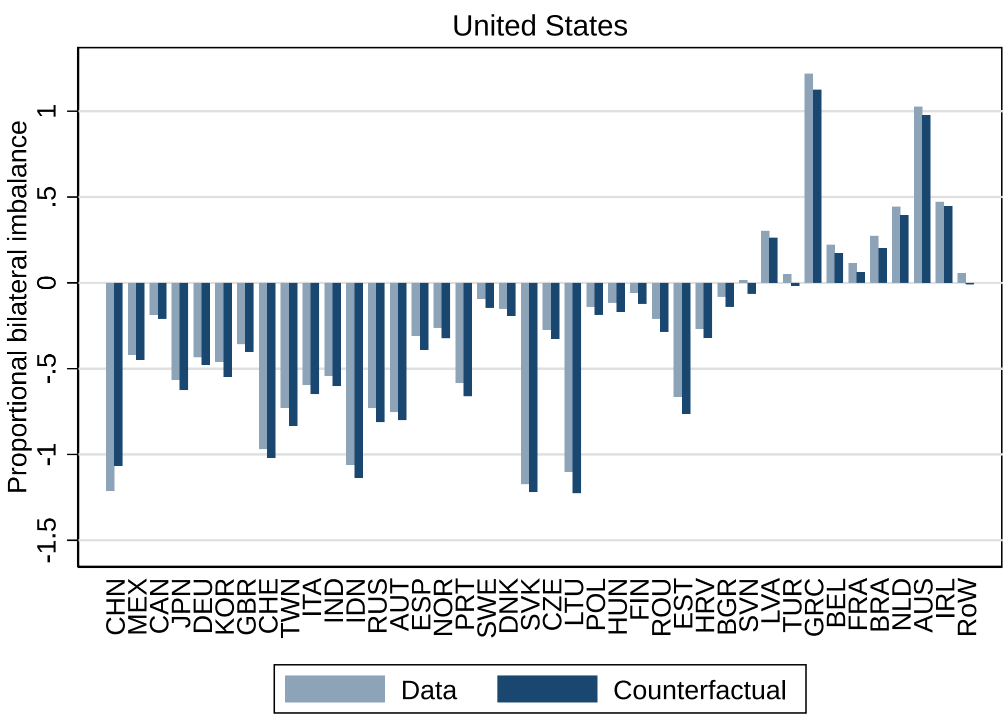
[43]Note that we continue to abstract from tariff revenue, as we are primarily interested in the impact of the trade war on trade imbalances, not welfare. Other studies have found similar-sized economic impacts from the U.S.-China trade war (see Fajgelbaum and Khandelwal, 2021 for a survey) or alternative scenarios for U.S.-China decoupling (see Cerdeiro et al., 2021).

[44]Unsurprisingly, the changes in U.S. imbalances as a result of the trade war have little effect on the global distribution of proportional bilateral imbalances: the correlation across all our pairs of economies between the empirical bilateral imbalances across and their post-trade-war counterfactual counterparts is .98.

Figure 14: Decomposing changes in U.S. bilateral net exports after U.S.-China trade war



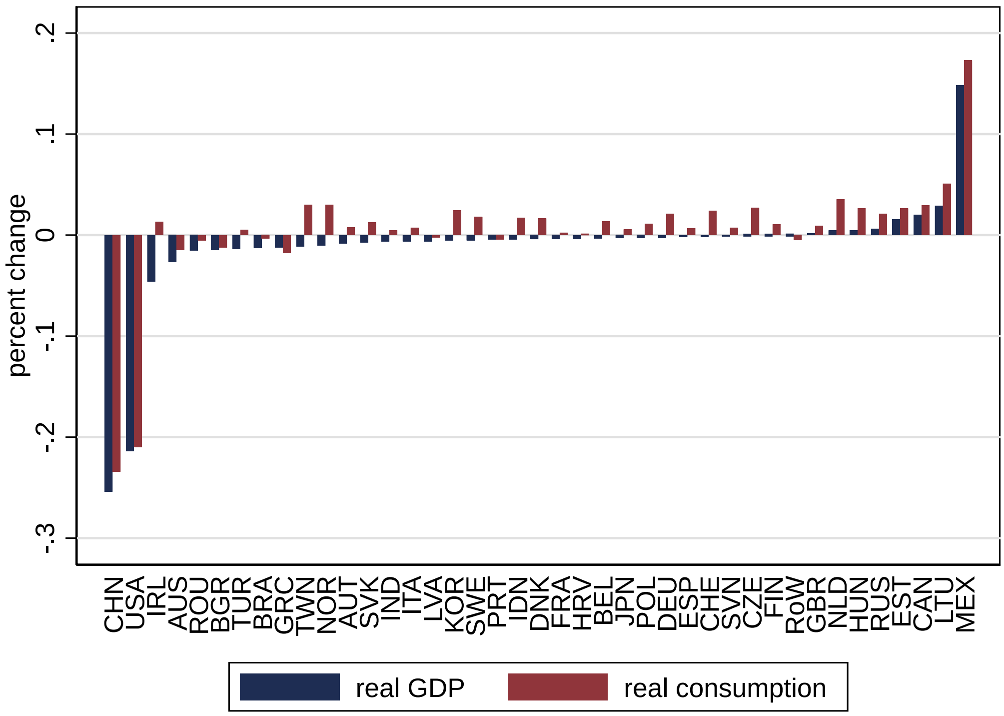
Panel A: Changes in in the geometric average of trade flows (as % of GDP) with given trading partner



Panel B: Changes in proportional bilateral imbalance with given trade partner

The "geometric average of bilateral flows (% GDP)" refers to the geometric average value of U.S. imports of goods and services from the horizontal-axis economy and U.S. exports of goods and services to the horizontal-axis economy, expressed as a percentage of U.S. GDP. The "proportional bilateral imbalance" refers to U.S. net exports to the horizontal-axis economy, expressed as a share of the geometric average average of bilateral flows. "Data" refers to actual components of bilateral net exports. "Counterfactual" refers to components of bilateral net exports in the steady state of the U.S.-China trade-war counterfactual, as described in Section 4.3 and Appendix A.5.3. Calibration on data from PWT (edition 9.0) and WIOD (2016 release), average for the years 2010-14.

Figure 15: Impact of U.S.-China trade war on real GDP and consumption



Percent change in real per-capita GDP and consumption relative to data in the U.S.-China trade-war steady state, as described in Section 4.3 and Appendix A.5.3. Calibration on data from PWT (edition 9.0) and WIOD (2016 release), average for the years 2010-14.

quantitative trade model. These counterfactuals also show that eliminating trade-wedge asymmetries would have sizeable effects on welfare and the global economy.

Measured trade-wedge asymmetries could reflect a host of factors. They may capture data errors or shortcomings of standard structural gravity models. They may also result from impacts of geography, technologies and preferences on trade flows that are not yet well understood. While a full account of the origins of these measured asymmetries is beyond the scope of this paper, we have provided evidence that they are in part related to the trade policy environment. In particular, we have documented that member countries of the European Single Market appear to enjoy more bilaterally symmetric (in addition to lower) trade barriers. This might suggest that deep cross-border integration can facilitate a reduction in bilateral imbalances.[45]

Higher trade barriers vis-à-vis a specific trade partner can also reduce an individual bilateral deficit. However, as our analysis of the U.S.-China trade war illustrates, such a policy outcome is economically costly and ultimately

[45]Recently, regional trade agreements in Asia (CPTPP and RCEP), Latin America (Pacific Alliance) and Africa (AfCFTA) have sought to create conditions for deeper trade integration among their member countries.

futile: with macro trade balances mostly unaffected, it merely shifts a deficit from one trade partner into other trade relationships.

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A Appendix

A.1 Approximating Bilateral Trade Imbalances

We can write the proportional bilateral imbalance between n and n' as:

$$\frac{M_{n'n}-M_{nn'}}{M_{n'n}^{\frac{1}{2}}M_{nn'}^{\frac{1}{2}}}=\sum_{s=1}^{S}\frac{M_{sn'n}-M_{snn'}}{M_{sn'n}^{\frac{1}{2}}M_{snn'}^{\frac{1}{2}}}\left(\frac{M_{sn'n}M_{snn'}}{M_{n'n}M_{nn'}}\right)^{\frac{1}{2}}. \tag{38}$$

Note from (1) that

$$\frac{M_{sn'n}}{M_{sn'n}^{\frac{1}{2}}M_{snn'}^{\frac{1}{2}}}=\left[\frac{(1-NX_n/D_n)}{(1-NX_{n'}/D_{n'})}\frac{d_{sn'}e_{sn}}{d_{sn}e_{sn'}}\left(\frac{\tau_{sn'n}}{\tau_{snn'}}\right)^{-\theta_s}\left(\frac{O_{sn}P_{sn'}}{O_{sn'}P_{sn}}\right)^{-\theta_s}\right]^{\frac{1}{2}}=$$

$$=e^{\frac{1}{2}\left[\ln\left(\frac{1-NX_n/D_n}{1-NX_{n'}/D_{n'}}\right)+\ln\left(\frac{d_{sn'}e_{sn}}{d_{sn}e_{sn'}}\right)-\theta_s\ln\left(\frac{\tau_{sn'n}}{\tau_{snn'}}\right)-\theta_s\ln\left(\frac{O_{sn}P_{sn'}}{O_{sn'}P_{sn}}\right)\right]}. \tag{39}$$

The first-order Taylor-series expansion of (39) centered at $\ln(1-NX_n/D_n)=0$ for all n, $\ln d_{sn}=\ln e_{sn}=\ln(D_s/D)$ for all s and n, and $\ln\tau_{sn'n}^{-\theta_s}=\ln\tau_{snn'}^{-\theta_s}=\ln\bar{\tau}_{sn'n}^{-\theta_s}$ for all s, n' and n yields[46]

$$\frac{M_{sn'n}}{M_{sn'n}^{\frac{1}{2}}M_{snn'}^{\frac{1}{2}}}\simeq\frac{1}{2}\left[\ln\left(\frac{1-NX_n/D_n}{1-NX_{n'}/D_{n'}}\right)+\ln\left(\frac{d_{sn'}e_{sn}}{d_{sn}e_{sn'}}\right)-\theta_s\ln\left(\frac{\tau_{sn'n}}{\tau_{snn'}}\right)-\theta_s\ln\left(\frac{O_{sn}P_{sn'}}{O_{sn'}P_{sn}}\right)\right], \tag{40}$$

and, hence,

$$\frac{M_{n'n}-M_{nn'}}{M_{n'n}^{\frac{1}{2}}M_{nn'}^{\frac{1}{2}}}\simeq\sum_{s=1}^{S}\left(\frac{M_{sn'n}M_{snn'}}{M_{n'n}M_{nn'}}\right)^{\frac{1}{2}}\left[\ln\left(\frac{1-NX_n/D_n}{1-NX_{n'}/D_{n'}}\right)+\ln\left(\frac{d_{sn'}e_{sn}}{d_{sn}e_{sn'}}\right)\right.$$
$$\left.-\theta_s\ln\left(\frac{\tau_{sn'n}}{\tau_{snn'}}\right)-\theta_s\ln\left(\frac{O_{sn}P_{sn'}}{O_{sn'}P_{sn}}\right)\right]. \tag{41}$$

A.2 Variance Decomposition for 1995-1999

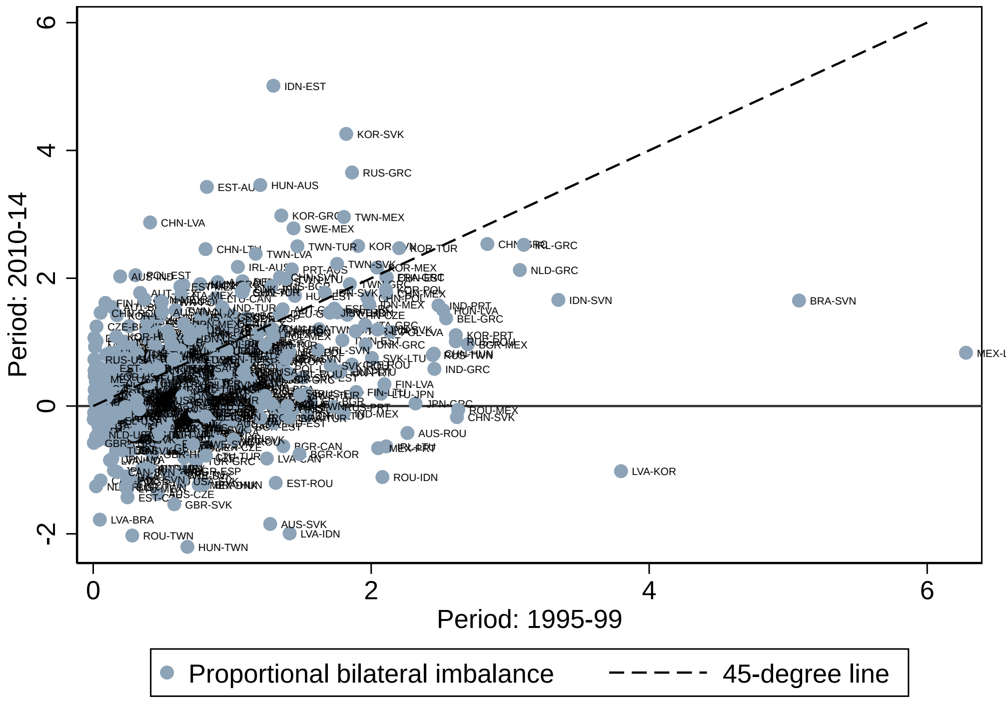
A.2.1 Data

To compile the data for 1995-1999 decomposition of the variation in bilateral imbalances, we proceed as described in Sections 2.1 and 2.2 – with one exception: we use the 2013 release of WIOD (whose data tables start in 1995), instead of the 2016 release (whose data tables start in 2000). The data allow

[46]Note from our definitions that

$$d_{sn}=\frac{D_s}{D}\quad\Leftrightarrow\quad\frac{D_{sn}}{D_s}=\frac{D_n}{D},\quad e_{sn}=\frac{D_s}{D}\quad\Leftrightarrow\quad\frac{E_{sn}}{D_s}+e_{sn}\frac{NX_n}{D_n}\frac{D_n}{D_s}=\frac{D_n}{D}.$$

Figure A1: Proportional bilateral imbalances, 2010-14 versus 1995-99



"Proportional bilateral imbalance" refers to $(M_{n'nt} - M_{nn't}) / (M_{nnt} M_{n'n't})^{1/2}$, where $M_{n'nt}$ represents the total spending by economy n on goods and services from n' in period t. On the horizontal axis, all values are the average for the 2010-14 period. On the vertical axis, all values are the average for the 1995-1999 period. The 2010-14 data is based on WIOD (2016 release), the 1995-99 data on WIOD (2013 release). The chart covers 37 individual economies.

us to aggregate trade and spending values to the same 31 sectors as described in Section 2.2 (and shown in Table A2). However, in the 2013 release Croatia, Norway and Switzerland are not covered as individual countries but grouped with the "Rest of the World". For this reason, the 1995-1999 data only cover 37 individual economies and the Rest of the World, which yields $(38 \times 37/2 =)$ 703 distinct bilateral trade imbalances.

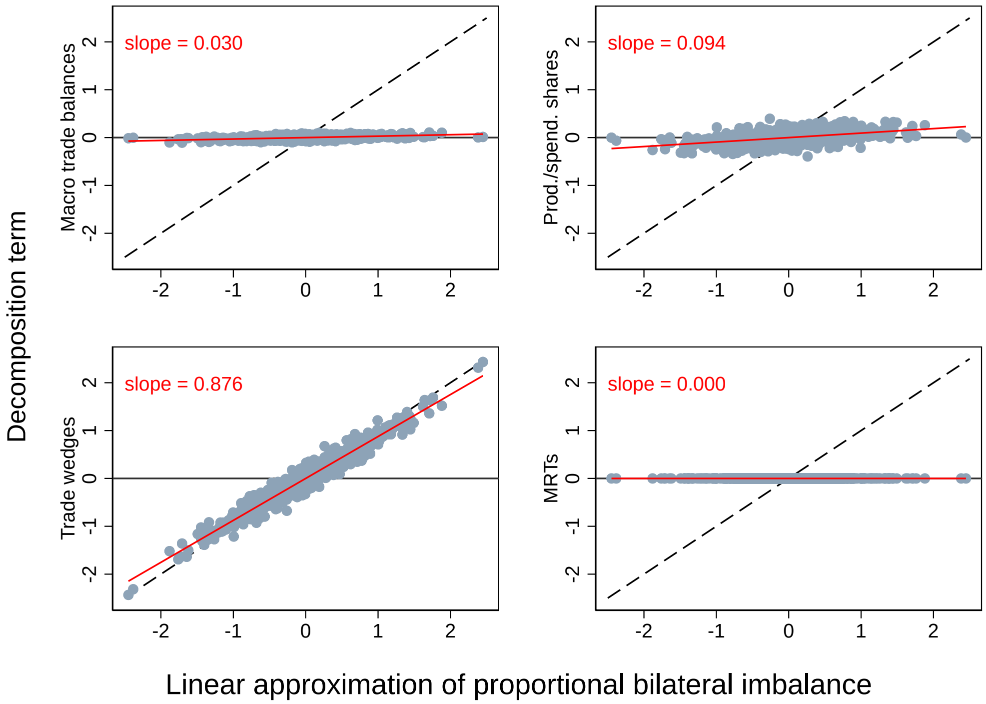
Figure A1 correlates the bilateral imbalances available in both periods with one another, using only the 703 surpluses for 1995-1999. The figure indicates that there is a fairly high degree of persistence: the correlation of the 1995-99 surplus with the 2010-14 value of the same trade balance is .36. Moreover, more than two thirds of the bilateral balances which were in surplus in 1995-1999 were still in surplus in 2010-14.

A.2.2 Variance Decomposition

Figure A2 is the analogue for the 1995-1999 period of Figure 4 in the main text. The quantitative results of the variance decomposition are remarkably similar.

Variation in economies' aggregate trade balances accounts for 3% of the

Figure A2: Variance decomposition for 1995-99



In each panel, the horizontal-axis variable is the first-order linear approximation of $(M_{n'n} - M_{nn'}) / (M_{n'n}M_{nn'})^{1/2}$ from equation (6), represents the total spending by economy n on output from n'. The vertical-axis variable is one each of the four right-hand-side terms in expression (6). The red line represents the line of best fit, whose respective slope is also printed in red. All data is based on WIOD (2013 release), averaged for the years 1995-99. The data covers 37 individual economies and the Rest of the World.

variation in bilateral trade imbalances. Differences in production and spending patterns ("triangular trade") account for 9% of the variation, and asymmetric trade wedges account for the remaining 88%.

A.3 Dynamic Model

A.3.1 Agents' Optimality

The utility maximisation problem of an agent born in t' can be written as

$$\max_{\{C_{nt}(t')\}_{t=t'}^{\infty}} \sum_{t=t'}^{\infty} \left(\frac{1-\xi}{1+\rho_n}\right)^{t-t'} \ln C_{nt}\left(t'\right) \tag{42}$$

subject to

$$P_{nt}^{C}C_{nt}\left(t'\right) + P_{nt}^{I}I_{nt}\left(t'\right) + B_{nt+1}\left(t'\right) = w_{nt}H_{nt} + \frac{r_{nt}}{1-\xi}K_{nt}\left(t'\right) + \frac{R_t}{1-\xi}B_{nt}\left(t'\right), \tag{43}$$

$$K_{nt+1}\left(t'\right) = I_{nt}\left(t'\right) + (1-\delta)\,K_{nt}\left(t'\right), \tag{44}$$

$$K_{nt'}\left(t'\right) = B_{nt'}\left(t'\right) = 0, \tag{45}$$

where $I_{nt}(t')$ is the agent's investment in t; $B_{nt}(t')$ denotes bond holdings; $K_{nt}(t')$ denotes capital holdings; P^C_{nt} is the final-consumption price level; P^I_{nt} is the investment price level; w_{nt} is the wage rate; and r_{nt} is the rental rate of capital in n. The resulting Euler equation is

$$\frac{C_{nt+1}(t')}{C_{nt}(t')} = \frac{P^C_{nt}}{P^C_{nt+1}}\frac{R_{t+1}}{1+\rho_n}, \tag{46}$$

and the optimal portfolio requires

$$\frac{r_{nt+1} + P^I_{nt+1}(1-\delta)}{P^I_{nt}} = R_{t+1}. \tag{47}$$

A.3.2 Steady-State Optimal Savings

We can analytically characterise the steady-state consumption and savings decisions of an agent born in period t' as a function of their period-t asset and human wealth:

$$P_n C_{nt}(t') = \frac{\rho_n+\xi}{(1-\xi)(1+\rho_n)} R A_{nt}(t') + \frac{R(\rho_n+\xi)}{[R-\gamma(1-\xi)](1+\rho_n)} w_n H_{nt}, \tag{48}$$

$$A_{nt+1}(t') = \frac{1}{1+\rho_n} R A_{nt}(t') + \frac{[R-\gamma(1+\rho_n)](1-\xi)}{[R-\gamma(1-\xi)](1+\rho_n)} w_n H_{nt}. \tag{49}$$

Define $A_{nt} \equiv (1-\xi)^{-1}\sum_{t'=-\infty}^{t}\xi(1-\xi)^{t-t'}A_{nt}(t')$. Then,

$$a_{nt+1} = \frac{1-\xi}{\gamma}\left[\frac{R}{1+\rho_n}a_{nt} + \frac{R-\gamma(1+\rho_n)}{[R-\gamma(1-\xi)](1+\rho_n)}w_n\right], \tag{50}$$

where $a_{nt} \equiv A_{nt}/H_{nt}$. There is a stationary distribution of assets in steady state as long as $\frac{1-\xi}{1+\rho_n}\frac{R}{\gamma} < 1$. Under this condition,

$$A_{nt} = \frac{(1-\xi)[R-\gamma(1+\rho_n)](1-\alpha_n)}{[\gamma(1+\rho_n)-R(1-\xi)][R-\gamma(1-\xi)]} f_n K^{\alpha_n}_{nt} H^{1-\alpha_n}_{nt}, \tag{51}$$

$$P_n C_{nt} = \frac{\gamma\xi(\rho_n+\xi)R(1-\alpha_n)}{[\gamma(1+\rho_n)-R(1-\xi)][R-\gamma(1-\xi)]} f_n K^{\alpha_n}_{nt} H^{1-\alpha_n}_{nt}. \tag{52}$$

A.3.3 Steady-State Net Exports

In steady state,

$$K_{nt} = \frac{\alpha_n}{\eta_n P_n(R-1+\delta)} f_n K^{\alpha_n}_{nt} H^{1-\alpha_n}_{nt}. \tag{53}$$

This in turn implies

$$\eta_n P_n I_{nt} = \frac{\alpha_n (\gamma - 1 + \delta)}{R - 1 + \delta} f_n K_{nt}^{\alpha_n} H_{nt}^{1-\alpha_n}. \tag{54}$$

From the definition of GDP,

$$f_n K_{nt}^{\alpha_n} H_{nt}^{1-\alpha_n} = P_n C_{nt} + \eta_n P_n I_{nt} + NX_{nt}. \tag{55}$$

This, together with (52) and (54), gives us the steady-state trade balance-to-GDP ratio.

A.4 Exact-Hat Algebra

A.4.1 Key Outcomes and "Own Spending" Shares

In the spirit of Arkolakis et al. (2012), we can re-write a number of key conditions in terms of "own spending" shares. Specifically, from (20)-(28),

$$P_n = \frac{f_n}{Z_n} \prod_{s=1}^{S} v_{snn}^{\frac{1}{\theta_s} \frac{\sigma_{sn}}{1-\sum_s \sigma_{sn}\mu_{sn}}}, \tag{56}$$

$$p_{sn} = \frac{f_n}{z_{sn} Z_n^{\mu_{sn}}} \left(\prod_{s=1}^{S} v_{snn}^{\frac{1}{\theta_s} \frac{\sigma_{sn}}{1-\sum_s \sigma_{sn}\mu_{sn}}} \right)^{\mu_{sn}}, \tag{57}$$

$$v_{sn'n} = \left(\frac{\tau_{sn'n} p_{sn'}}{\tau_{snn} p_{sn}} \right)^{-\theta_s} v_{snn}, \tag{58}$$

$$R = \frac{\alpha_n}{\eta_n} \left(\prod_{s=1}^{S} v_{snn}^{-\frac{1}{\theta_s} \frac{\sigma_{sn}}{1-\sum_s \sigma_{sn}\mu_{sn}}} \right) Z_n k_n^{\alpha_n - 1} + 1 - \delta, \tag{59}$$

where $v_{sn'n} \equiv M_{sn'n} / \sum_{n'} M_{sn'n} = (\tau_{sn'n} p_{sn'})^{-\theta_s} \Big/ \sum_{n'} (\tau_{sn'n} p_{sn'})^{-\theta_s}$ is the economy-n' trade share in economy-n expenditure in sector s.

A.4.2 Changes in Trade Costs and Productivity

For any steady-state outcome x_n, define $\tilde{x}_n$ as the new outcome after a parameter change; and $\hat{x}_n \equiv \tilde{x}_n / x_n$. The only exogenous parameter changes we consider in this section are changes in $\{\tau_{sn'n}\}_{s,n' \neq n}$ and uniform changes in sectoral productivities , where $\hat{z}_{n'} = \hat{z}_{sn'}$ for all s, n.

Then:

$$\hat{v}_{sn'n}=\frac{\left[\frac{\hat{\tau}_{sn'n}\hat{f}_{n'}}{\hat{z}_{n'}^{1+\mu_{sn'}/\left(1-\sum_s\sigma_{sn'}\mu_{sn'}\right)}}\left(\prod_{s=1}^{S}\hat{v}_{sn'n'}^{\frac{1}{\theta_s}\frac{\sigma_{sn'}}{1-\sum_s\sigma_{sn'}\mu_{sn'}}}\right)^{\mu_{sn'}}\right]^{-\theta_s}}{\sum_{n'=1}^{N}\left[\frac{\hat{\tau}_{sn'n}\hat{f}_{n'}}{\hat{z}_{n'}^{1+\mu_{sn'}/\left(1-\sum_s\sigma_{sn'}\mu_{sn'}\right)}}\left(\prod_{s=1}^{S}\hat{v}_{sn'n'}^{\frac{1}{\theta_s}\frac{\sigma_{sn'}}{1-\sum_s\sigma_{sn'}\mu_{sn'}}}\right)^{\mu_{sn'}}\right]^{-\theta_s}v_{sn'n}}, \tag{60}$$

$$\hat{f}_n\hat{k}_n^{\alpha_n}h_n=\sum_{s=1}^{S}\left(1-\mu_{sn}\right)\sum_{n'=1}^{N}\hat{v}_{snn'}v_{snn'}\sigma_{sn'}\left(\tilde{q}_{n'}-\tilde{nx}_{n'}\right)\hat{f}_{n'}\hat{k}_{n'}^{\alpha_{n'}}h_{n'}, \tag{61}$$

$$\tilde{q}_n\hat{f}_n\hat{k}_n^{\alpha_n}h_n=\sum_{s=1}^{S}\sum_{n'=1}^{N}\hat{v}_{snn'}v_{snn'}\sigma_{sn'}\left(\tilde{q}_{n'}-\tilde{nx}_{n'}\right)\hat{f}_{n'}\hat{k}_{n'}^{\alpha_{n'}}h_{n'}, \tag{62}$$

$$\tilde{nx}_n=1-\frac{\alpha_n\left(1-\frac{1-\delta}{\gamma}\right)}{\frac{\tilde{R}}{\gamma}-\frac{1-\delta}{\gamma}}-\frac{\xi\left(\rho_n+\xi\right)\frac{\tilde{R}}{\gamma}\left(1-\alpha_n\right)}{\left[1+\rho_n-\frac{\tilde{R}}{\gamma}\left(1-\xi\right)\right]\left[\frac{\tilde{R}}{\gamma}-\left(1-\xi\right)\right]}, \tag{63}$$

$$\sum_{n=1}^{N}\tilde{nx}_n\hat{f}_n\hat{k}_n^{\alpha_n}h_n=0, \tag{64}$$

$$\frac{\tilde{R}-1+\delta}{R-1+\delta}=\hat{z}_n^{\frac{1}{1-\sum_s\sigma_{sn}\mu_{sn}}}\left(\prod_{s=1}^{S}\hat{v}_{snn}^{-\frac{1}{\theta_s}\frac{\sigma_{sn}}{1-\sum_s\sigma_{sn}\mu_{sn}}}\right)\hat{k}_n^{\alpha_n-1}, \tag{65}$$

$$\hat{y}_n=\left(\prod_{s=1}^{S}\hat{v}_{snn}^{-\frac{1}{\theta_s}\frac{\sigma_{sn}}{1-\sum_s\sigma_{sn}\mu_{sn}}}\right)\hat{z}_n^{\frac{1}{1-\sum_s\sigma_{sn}\mu_{sn}}}\hat{k}_n^{\alpha_n}, \tag{66}$$

$$\hat{c}_n=\frac{\gamma\xi\left(\rho_n+\xi\right)\tilde{R}\left(1-\alpha_n\right)}{\left[\gamma\left(1+\rho_n\right)-\tilde{R}\left(1-\xi\right)\right]\left[\tilde{R}-\gamma\left(1-\xi\right)\right]}\hat{y}_n, \tag{67}$$

where $nx_n=NX_{nt}/f_nk_n^{\alpha_n}H_{nt}$ denotes the economy-n aggregate net exports to GDP ratio, $h_n\equiv f_nk_n^{\alpha_n}H_{nt}/\sum_n\left(f_nk_n^{\alpha_n}H_{nt}\right)$ is the economy-n share in world nominal GDP, and $q_n\equiv\sum_s p_{sn}Q_{snt}/\left(f_nk_n^{\alpha_n}H_{nt}\right)$ is the economy-n gross-output-to-GDP ratio.

Equations (60)-(62) describe the exact-hat algebra for our model conditional on given changes in trade balances and per-worker capital stocks, $\{\tilde{nx}_n,\hat{k}_n\}_n$. If factor endowments and trade balances were taken as exogenous as in static trade models of the kind used, for example, in Dekle et al. (2007, 2008), this set of equations would be sufficient to perform counterfactuals exploring the trade impact of changes in trade wedges and productivities (as well as the exogenous factor endowments and trade balances). In this sense, they represent the "static block" of our exact hat algebra. Equations (63)-(65) reflect the endogeneity of trade balances and capital stocks – via asset-market clearing and portfolio optimality, respectively – in the steady state of our dynamic model. They represent the "dynamic block" of our exact-hat algebra. Finally, equations (66) and (67) translate the exogenous and endogenous changes in the combined static and dynamic blocks into real-GDP and consumption changes.

A.4.3 Financial Autarky

We only consider the transition from our baseline assumption of perfectly integrated international asset markets (no barriers to international asset trade) to complete financial autarky (prohibitive barriers to international asset trade). The latter requires all net holdings of the international bond to be zero in equilibrium: $B_{nt} = 0$ for all n and t. Since economies differ in their production technologies and intertemporal preferences, each economy must have its "own" interest rate R_{nt} (instead of R_t) for this to be an equilibrium outcome.

Assuming an economy-specific interest rate R_{nt}, we can proceed as in Section A.3 to show that in steady state,

$$\frac{A_{nt}}{f_n K_{nt}^{\alpha_n} H_{nt}^{1-\alpha_n}} = \frac{(1-\xi)\left[R_n - \gamma(1+\rho_n)\right](1-\alpha_n)}{\left[\gamma(1+\rho_n) - R_n(1-\xi)\right]\left[R_n - \gamma(1-\xi)\right]}, \tag{68}$$

$$\frac{\eta_n P_n K_{nt}}{f_n K_{nt}^{\alpha_n} H_{nt}^{1-\alpha_n}} = \frac{\alpha_n}{R_n - 1 + \delta}. \tag{69}$$

Financial autarky requires $B_n = 0$, which implies $A_{nt} = \eta_n P_n K_{nt}$. Equating (68) and (69) yields a quadratic equation in permissible values of R_n.[47] This quadratic equation has only one positive root, which corresponds to the steady-state interest rate:

$$\frac{R_n}{\gamma} = (1+\rho_n)\left\{1 - \frac{1}{2}\left[1 - \frac{(1-\alpha_n)(1-\delta)}{\gamma(1+\rho_n)} - \alpha_n\left(\frac{1-\xi}{1+\rho_n} + \frac{\xi}{1-\xi}\right)\right] + \right.$$
$$\left. + \frac{1}{2}\sqrt{\left[1 - \frac{(1-\alpha_n)(1-\delta)}{\gamma(1+\rho_n)} - \alpha_n\left(\frac{1-\xi}{1+\rho_n} + \frac{\xi}{1-\xi}\right)\right]^2 + 4\alpha_n \frac{\xi}{1-\xi}\frac{\xi+\rho_n}{1+\rho_n}}\right\}. \tag{70}$$

It is straightforward to show that $B_{nt} = 0$ implies $NX_{nt} = 0$ for all n and t.

The exact-hat algebra required to compute outcomes in the new financial-autarky steady state is now summarised by the following system of equations:

[47] Note that $R_n \in \left[\gamma(1+\rho_n), \gamma(1+\rho_n)/(1-\xi)\right]$ is required for $A_{nt}/\left(f_n K_{nt}^{\alpha_n} H_{nt}^{1-\alpha_n}\right)$ to be positive and finite.

$$\hat{v}_{sn'n} = \frac{\left[\hat{f}_{n'}\left(\prod_{s=1}^{S}\hat{v}_{sn'n'}^{\frac{1}{\theta_s}\frac{\sigma_{sn'}}{1-\sum_s \sigma_{sn'}\mu_{sn'}}}\right)^{\mu_{sn'}}\right]^{-\theta_s}}{\sum_{n'=1}^{N}\left[\hat{f}_{n'}\left(\prod_{s=1}^{S}\hat{v}_{sn'n'}^{\frac{1}{\theta_s}\frac{\sigma_{sn'}}{1-\sum_s \sigma_{sn'}\mu_{sn'}}}\right)^{\mu_{sn'}}\right]^{-\theta_s} v_{sn'n}}, \tag{71}$$

$$\hat{f}_n \hat{k}_n^{\alpha_n} h_n = \sum_{s=1}^{S}(1-\mu_{sn})\sum_{n'=1}^{N}\hat{v}_{snn'}v_{snn'}\sigma_{sn'}\tilde{q}_{n'}\hat{f}_{n'}\hat{k}_{n'}^{\alpha_{n'}}h_{n'}, \tag{72}$$

$$\tilde{q}_n \hat{f}_n \hat{k}_n^{\alpha_n} h_n = \sum_{s=1}^{S}\sum_{n'=1}^{N}\hat{v}_{snn'}v_{snn'}\sigma_{sn'}\tilde{q}_{n'}\hat{f}_{n'}\hat{k}_{n'}^{\alpha_{n'}}h_{n'}, \tag{73}$$

$$\frac{R_n - 1 + \delta}{R - 1 + \delta} = \left(\prod_{s=1}^{S}\hat{v}_{snn}^{-\frac{1}{\theta_s}\frac{\sigma_{sn}}{1-\sum_s \sigma_{sn}\mu_{sn}}}\right)\hat{k}_n^{\alpha_n - 1}, \tag{74}$$

$$\hat{y}_n = \left(\prod_{s=1}^{S}\hat{v}_{snn}^{-\frac{1}{\theta_s}\frac{\sigma_{sn}}{1-\sum_s \sigma_{sn}\mu_{sn}}}\right)\hat{k}_n^{\alpha_n}, \tag{75}$$

$$\hat{c}_n = \frac{\gamma\xi(\rho_n + \xi) R_n (1-\alpha_n)}{[\gamma(1+\rho_n) - R_n(1-\xi)][R_n - \gamma(1-\xi)]}\hat{y}_n, \tag{76}$$

where R_n is given in equation (70) and, from the reasoning above, $\tilde{nx}_n = 0$ for all n.

A.5 Additional Details on Counterfactuals

A.5.1 Bilateral Exposure and Global Trade-Wedge Symmetry

Beyond real GDP and consumption effects, one way in which counterfactual global trade-wedge may impact the global economy is by altering the relative dependence of economies on different trade partners. We refer to this as economies' bilateral "exposures". Specifically, we define the "exposure" of economy n to n' as the percent change in economy-n steady-state real GDP in response to a permanent 1 percent increase in the aggregate productivity of economy n', $\{\hat{z}_{n'}\}_{n' \neq n}$. We focus on permanent changes as our model is geared towards comparisons of steady states, but our findings may be indicative of possible business-cycle-frequency co-movements as well.

We compute the matrix of bilateral exposures, as defined above, for all economies in our data using the exact-hat algebra in equations (60)-(66). Figure A3 gives an overview of the results in matrix form. The matrix shows the row economy's GDP response to a 1 percent aggregate-productivity increase in the column economy. Diagonal elements showing economies' exposures to themselves are omitted, and the off-diagonal elements are colour-coded: darker shades of green indicate greater positive exposures (economy-n real GDP rises

Figure A3: Bilateral exposures

	AUS	AUT	BEL	BGR	BRA	CAN	CHE	CHN	CZE	DEU	DNK	ESP	EST	FIN	FRA	GBR	GRC	HRV	HUN	IDN	IND	IRL	ITA	JPN	KOR	LTU	LVA	MEX	NLD	NOR	POL	PRT	ROU	RUS	RoW	SVK	SVN	SWE	TUR	TWN	USA
AUS		.00	.01	.00	.00	.00	.01	.17	.00	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.01	.01	.01	.03	.00	.00	.00	.02	.01	.00	.00	.00	.02	-.12	.00	.00	.01	.00	.02	-.06
AUT	.00		.01	.00	.00	.00	.02	.10	.01	.16	.00	.00	.00	.00	.01	.00	.00	.00	.01	.00	-.01	.01	.03	.00	.02	.00	.00	.00	.02	.01	.01	.00	.00	.01	-.13	.00	.00	.01	.00	.01	-.06
BEL	.00	.00		.00	.00	.00	.02	.09	.01	.04	.00	.00	.00	.00	.03	.01	.00	.00	.00	.00	-.01	.02	.01	.00	.02	.00	.00	.00	.05	.00	.00	.00	.00	.01	-.11	.00	.00	.01	.00	.01	-.07
BGR	.00	.02	.02		-.01	.00	.02	.14	.02	.11	.01	.00	.00	.00	.00	.00	.00	.00	.01	.00	-.02	.01	.02	.00	.03	.00	.00	.00	.03	.01	.01	.00	.01	.01	-.20	.01	.00	.01	.02	.01	-.10
BRA	.00	.00	.01	.00		.00	.01	.13	.00	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	-.01	.01	.01	.00	.03	.00	.00	.00	.02	.01	.00	.00	.00	.02	-.17	.00	.00	.01	.00	.01	-.08
CAN	.00	.00	.00	.00	.00		.01	.11	.00	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.00	.02	.00	.00	.01	.01	.01	.00	.00	.00	.01	-.11	.00	.00	.01	.00	.01	.03
CHE	.00	.01	.01	.00	.00	.00		.07	.00	.08	.00	.00	.00	.00	.01	.01	.00	.00	.00	.00	.00	.01	.02	.00	.02	.00	.00	.00	.02	.01	.00	.00	.00	.01	-.04	.00	.00	.01	.00	.01	-.03
CHN	.00	.00	.01	.00	.00	.00	.01		.00	.06	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	-.01	.01	.01	.01	.03	.00	.00	.00	.02	.01	.00	.00	.00	.02	-.13	.00	.00	.01	.00	.02	-.06
CZE	.00	.02	.02	.00	.00	.00	.02	.14		.19	.01	.01	.00	.00	.02	.01	.00	.00	.02	.00	-.01	.01	.03	.00	.03	.00	.00	.00	.03	.01	.04	.00	.00	.03	-.17	.04	.00	.01	.01	.02	-.08
DEU	.00	.01	.01	.00	.00	.00	.02	.10	.01		.01	.01	.00	.00	.02	.01	.00	.00	.01	.00	.00	.01	.02	.00	.02	.00	.00	.00	.02	.01	.01	.00	.00	.01	-.11	.00	.00	.01	.01	.01	-.04
DNK	.00	.00	.01	.00	.00	.00	.01	.09	.01	.08		.00	.00	.00	.00	.01	.00	.00	.00	.00	.00	.01	.01	.00	.02	.00	.00	.00	.02	.07	.01	.00	.00	.01	-.03	.00	.00	.03	.00	.01	-.05
ESP	.00	.00	.01	.00	.00	.00	.01	.10	.01	.06	.00		.00	.00	.01	.00	.00	.00	.00	.00	-.01	.01	.01	.00	.02	.00	.00	.00	.02	.01	.00	.00	.00	.01	-.16	.00	.00	.01	.00	.01	-.08
EST	.00	.01	.01	.00	.00	.00	.01	.11	.01	.08	.01	.00		.06	.00	.00	.00	.00	.01	.00	-.01	.01	.01	.00	.02	.02	.03	.00	.05	.02	.03	.00	.00	.04	-.07	.00	.00	.06	.00	.01	-.06
FIN	.00	.00	.00	.00	.00	.00	.01	.10	.00	.06	.00	.00	.01		.00	.00	.00	.00	.00	.00	.01	.01	.01	.00	.02	.00	.00	.00	.01	.01	.00	.00	.00	.01	-.14	.00	.00	.01	.00	.01	-.06
FRA	.00	.00	.01	.00	.00	.00	.01	.09	.00	.07	.00	.01	.00	.00		.01	.00	.00	.00	.00	-.01	.01	.02	.00	.02	.00	.00	.00	.02	.01	.00	.00	.00	.01	-.11	.00	.00	.01	.00	.01	-.06
GBR	.00	.00	.01	.00	.00	.00	.01	.10	.00	.06	.00	.00	.00	.00	.01		.00	.00	.00	.00	.00	.02	.01	.00	.02	.00	.00	.00	.02	.01	.00	.00	.00	.01	-.09	.00	.00	.00	.00	.01	-.05
GRC	.00	.00	.00	-.01	-.01	.00	.02	.15	.01	.08	.00	-.01	.00	.00	-.01	.00		.00	.00	.00	-.02	.01	.00	.00	.03	.00	.00	.00	.02	.01	.00	.00	.00	.01	-.27	.00	.00	.01	-.01	.01	-.11
HRV	.00	.02	.01	.00	.00	.00	.01	.08	.01	.06	.00	.00	.00	.00	.00	.00	.00		.01	.00	.00	.01	.05	.00	.02	.00	.00	.00	.02	.01	.01	.00	.00	.01	.00	.00	.02	.01	.00	.01	-.05
HUN	.00	.01	.01	.00	.00	.00	.01	.11	.02	.16	.01	.01	.00	.00	.02	.01	.00	.00		.00	-.01	.01	.03	.00	.03	.00	.00	.01	.02	.01	.02	.00	.01	.01	-.11	.01	.01	.01	.01	.01	-.05
IDN	.01	.00	.01	.00	.00	.00	.02	.19	.00	.08	.01	.00	.00	.00	.00	.00	-.01	.00	.00		-.01	.01	.01	.01	.04	.00	.00	.00	.03	.02	.00	.00	.00	.02	-.22	.00	.00	.01	.00	.03	-.10
IND	.00	.00	.01	.00	-.01	.00	.01	.15	.00	.07	.01	.00	.00	.00	.00	.00	-.01	.00	.00	.01		.01	.00	.00	.03	.00	.00	.00	.02	.01	.00	.00	.00	.02	-.21	.00	.00	.01	.00	.02	-.10
IRL	.01	.01	.03	.00	.00	.01	.03	.15	.01	.10	.01	.02	.00	.00	.02	.10	.00	.00	.00	.00	.00		.03	.00	.03	.00	.00	.01	.04	.01	.01	.00	.00	.02	.04	.00	.00	.02	.00	.02	-.04
ITA	.00	.01	.01	.00	.00	.00	.02	.12	.01	.08	.00	.00	.00	.00	.01	.01	.00	.00	.00	.00	-.01	.01		.00	.03	.00	.00	.00	.02	.01	.01	.00	.00	.01	-.20	.00	.00	.01	.00	.01	-.08
JPN	.00	.00	.00	.00	.00	.00	.01	.10	.00	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	-.01	.01	.00		.02	.00	.00	.00	.01	.01	.00	.00	.00	.01	-.15	.00	.00	.01	.00	.02	-.05
KOR	.00	.00	.00	.00	-.01	.00	.01	.15	.00	.07	.00	.00	.00	.00	.00	.00	-.01	.00	.00	.00	-.01	.01	.01	.02		.00	.00	.01	.02	.01	.00	.00	.00	.02	-.24	.00	.00	.01	.00	.01	-.08
LTU	.00	.01	.00	.00	-.01	-.01	.02	.16	.01	.08	.01	-.01	.02	-.01	-.02	-.03	-.01	.00	.01	.00	-.02	.01	.02	.00	.03		.04	.00	.02	.02	.00	.00	.00	.00	-.26	.00	.00	.01	.00	.02	-.16
LVA	.00	.01	.01	.00	.00	.00	.02	.12	.01	.08	.01	.00	.03	.02	.00	.01	.00	.00	.00	.00	-.01	.01	.01	.00	.03	.07		.00	.05	.02	.03	.00	.00	.04	-.03	.00	.00	.02	.00	.01	-.07
MEX	.01	.01	.01	.00	.00	.01	.02	.24	.01	.11	.01	.00	.00	.00	.00	.00	-.01	.00	.00	.01	-.01	.02	.01	.01	.05	.00	.00		.03	.02	.00	.00	.00	.03	[illegible]	.00	.00	.01	.00	.03	-.01
NLD	.00	.00	.03	.00	.00	.00	.01	.12	.01	.08	.00	.01	.00	.00	.01	.01	.00	.00	.00	.01	.00	.01	.02	.00	.02	.00	.00	.00		.01	.01	.00	.00	.01	-.08	.00	.00	.01	.00	.01	-.06
NOR	.00	.00	.01	.00	.00	.01	.01	.13	.01	.08	.02	.00	.00	.00	.00	.03	-.01	.00	.00	.00	-.01	.01	.01	.00	.03	.00	.00	.00	.04		.01	.00	.00	.02	-.16	.00	.00	.03	.00	.02	-.08
POL	.00	.01	.01	.00	.00	.00	.01	.12	.02	.10	.01	.01	.00	.00	.01	.01	.00	.00	.01	.00	-.01	.01	.02	.00	.03	.00	.00	.00	.02	.01		.00	.00	.02	-.15	.01	.00	.01	.01	.01	-.07
PRT	.00	.00	.01	.00	.00	.00	.01	.10	.00	.07	.00	.02	.00	.00	.01	.00	.00	.00	.00	.00	-.01	.01	.01	.00	.02	.00	.00	.00	.02	.01	.00		.00	.01	-.14	.00	.00	.01	.00	.01	-.08
ROU	.00	.01	.01	.00	-.01	.00	.02	.16	.01	.12	.01	.00	.00	.00	.01	.00	-.01	.00	.01	.00	-.01	.01	.04	.00	.04	.00	.00	.00	.03	.02	.01	.00		.02	-.22	.00	.00	.01	.01	.02	-.11
RUS	.00	.00	.00	.00	.00	.00	.01	.09	.01	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.02	.00	.00	.00	.01	.01	.01	.00	.00		-.05	.00	.00	.00	.00	.01	-.04
RoW	.00	.00	.01	.00	.00	.01	.02	.18	.00	.07	.01	.00	.00	.00	.00	.01	-.01	.00	.00	.01	.00	.01	.01	.01	.04	.00	.00	.01	.02	.01	.00	.00	.00	.02		.00	.00	.01	.00	.02	-.06
SVK	.00	.00	.01	.00	.00	.00	.01	.13	.07	.12	.01	.01	.00	.00	.03	.02	.00	.00	.02	.00	-.01	.01	.03	.00	.04	.00	.00	.00	.02	.01	.02	.00	.00	.02	-.07		.00	.01	.01	.02	-.07
SVN	.00	.04	.01	.00	.00	.00	.01	.08	.01	.11	.01	.01	.00	.00	.02	.00	.00	.02	.02	.00	.00	.01	.07	.00	.02	.00	.00	.00	.02	.01	.01	.00	.01	.01	-.02	.01		.01	.01	.01	-.04
SWE	.00	.01	.01	.00	.00	.00	.01	.11	.01	.08	.02	.00	.00	.01	.00	-.01	.00	.00	.00	.00	-.01	.01	.01	.00	.03	.00	.00	.00	.02	.02	.01	.00	.00	.01	-.16	.00	.00		.00	.01	-.07
TUR	.00	.01	.01	.00	-.01	.00	.02	.19	.01	.12	.01	.00	.00	.00	.01	.01	-.01	.00	.00	.01	-.01	.01	.02	.00	.04	.00	.00	.00	.03	.02	.01	.00	.00	.04	[illegible]	.00	.00	.01		.02	-.12
TWN	.01	.00	.00	.00	-.01	.00	.02	.18	.00	.08	.00	.00	.00	.00	.00	.00	-.01	.00	.00	.00	-.02	.01	.00	.05	.04	.00	.00	.00	.02	.01	.00	.00	.00	.02	-.18	.00	.00	.01	.00		-.08
USA	.00	.00	.00	.00	.00	.01	.01	.11	.00	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	-.01	.01	.00	.00	.02	.00	.00	.01	.01	.01	.00	.00	.00	.01	-.15	.00	.00	.01	.00	.01	

Each cell shows the percentage change in the row economy's steady-state real GDP per capita in response to a 1 percent increase in the aggregate productivity of the column economy. See Section A.5.1 for details. Calibration on data from PWT (edition 9.0) and WIOD (2016 release), average for the years 2010-14.

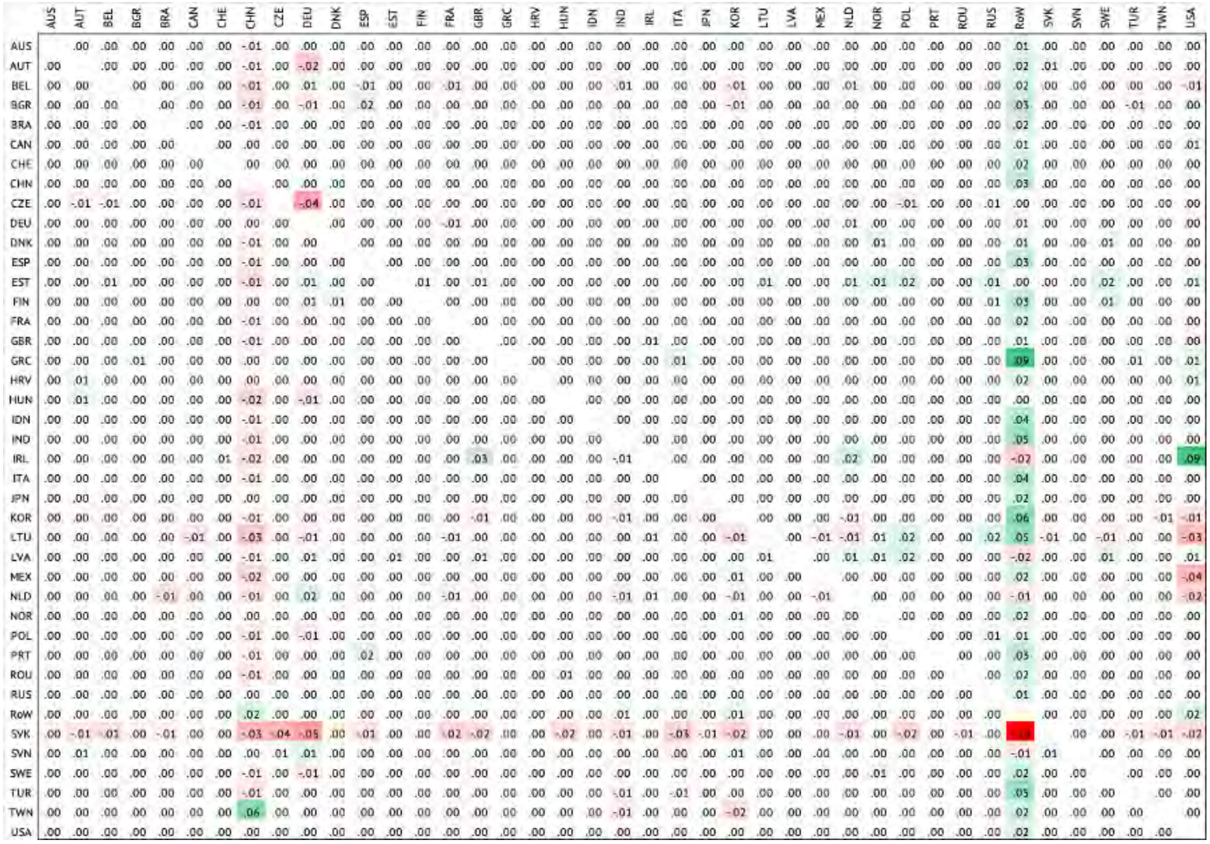
in economy-n' aggregate productivity); darker shares of red indicate greater negative exposures (economy-n real GDP declines in economy-n' aggregate productivity).

As would be expected, most bilateral exposures are small in absolute value. However, productivity changes in the larger economies – notably, the U.S., China, and Germany – have economically significant effects on the real incomes of *all* economies. China in particular stands out, with the median country gaining .12 percent of real income for from a 1 percent increase in Chinese aggregate productivity. This reflects China's centrality in global value chains that has been widely noted elsewhere.[48]

By our measures, most economies' trade wedges in importing from China are lower than China's wedges in importing from them. As a result, for most economies global trade-wedge symmetry implies a trade liberalisation vis-à-vis trade partners *other than China*. We now explore to what extent this changes the patterns of bilateral exposure. We do so by using the exact-hat

[48]See, for example, Baldwin and Freeman (2021) for a recent discussion and evidence on China's centrality in global value chains.

Figure A4: Changes in bilateral exposures due to global trade-wedge symmetry



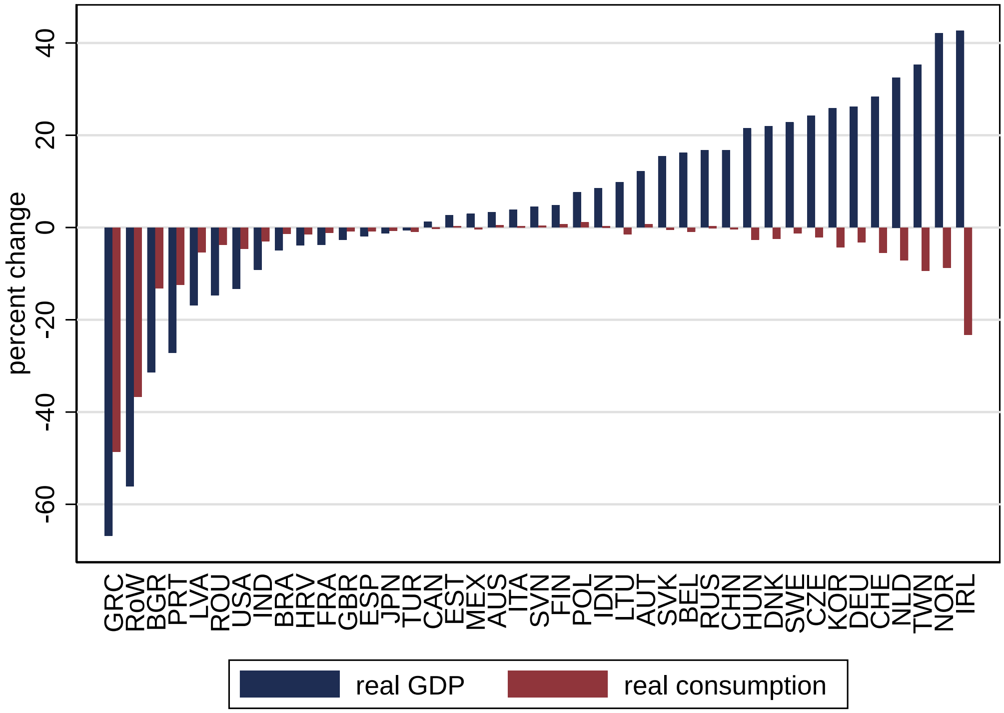
Each cell shows the percentage change in the row economy's "exposure" to the column economy. See Section A.5.1 for details. Calibration on data from PWT (edition 9.0) and WIOD (2016 release), average for the years 2010-14.

algebra in equations (60)-(66) to compute bilateral exposures for all economies *after* global trade wedges have been made symmetric. Figure A4 presents the *changes* in bilateral exposures relative to what is shown in Figure A3. Again, matrix elements are colour-coded: darker shades of green indicate greater positive changes; darker shades of red indicate greater negative changes. As expected the exposure to China declines for the large majority of economies, with a .01 percentage point decline for the median economy. By contrast, global trade-wedge symmetry increases almost all economies exposure to the Rest of the World.

While these changes are quantitatively small, they point to an intriguing possibility. In recent months, G7 policy makers have expressed a concern that the global economy's resilience to economic shocks may have been undermined by an over-reliance on China's manufacturing capacity in (some) global value chains.[49] Our results suggest that, in addition to China's size and comparative advantages, the current prominence of China in cross-border production networks may also be owed to a particular configuration of trade-wedge asym-

[49]See, for example, G7 Panel on Economic Resilience (2021).

Figure A5: Impact of financial autarky on real GDP and consumption



Percent change in real per-capita GDP and consumption relative to data in the financial-autarky steady state, as described in Section 3.4 and Appendix A.5.2. Calibration on data from PWT (edition 9.0) and WIOD (2016 release), average for the years 2010-14.

metries.

A.5.2 Financial Autarky

Figure A5 gives a graphical overview of the macroeconomic impact of financial autarky across economies. The real-GDP and real-consumption changes primarily reflect a dramatic relocation of capital. Economies with net negative international bond holdings under full financial integration (towards the left-hand side of Figure A5) see their capital stocks and real income levels shrink in financial autarky. Meanwhile, economies with net positive bond holdings under financial integration (towards the right-hand side of Figure A5) see their capital stocks and real incomes grow. However, both groups experience a decline in their real consumption levels. This is because the former lose the benefit of higher wages supported by externally financed capital investments, while the latter lose the benefit of higher foreign investment returns.

The disappearance of macro trade surpluses and deficits also prompts changes in real incomes via the "transfer effect": expenditure shifts towards the output of former trade-surplus economies, which causes a terms-of-trade in their favour, raising their real incomes, and lowering the real incomes of former trade-deficit economies. However, as found in Dekle et al. (2007, 2008), these effects are quantitatively small, and they are dwarfed for most economies by the impact of financial autarky on their capital stocks.

A.5.3 Sources and Concordances for U.S.-China Trade War Tariffs

We obtain data on tariff changes and import values at the 10-digit level of HS for the U.S. from Bown (2019). For China, we take data on tariff changes and import values at the 8-digit level of HS from Bown et al. (2019).[50] Using a concordance from HS to ISIC Rev. 4, we aggregate the tariff changes at the (roughly) 2-digit level of ISIC used in the WIOD (2016 release). We then aggregate further to obtain tariff changes for the coarser set of sectors used throughout this paper (see Section 3). The resulting changes in trade wedges, upon which we base our counterfactual, are shown in Table A4.

A.6 Eaton and Kortum (2002)

This section presents a version of the Eaton-Kortum (2002) model that delivers the same steady-state relationships as our benchmark Armington model. We maintain most of the assumptions made in Section 3, but replace the Armington side of the model, equations (17) and (18), with the assumption that the non-tradable sector-s input is assembled from tradable varieties according to the CES production function

$$X_{snt} = \left[\int_0^1 x_{snt}^{\frac{\chi_s - 1}{\chi_s}}(i)\, di\right]^{\frac{\chi_s}{\chi_s - 1}}, \tag{77}$$

where $\chi_s \geq 0$. x_{snt} represents the use of variety i in the production of the sector-s input by economy n. Varieties are produced with technology

$$Q_{snt}(i) = z_{sn}(i)\left[\frac{K_{snt}^{\alpha_n}(i) H_{snt}^{1-\alpha_n}(i)}{1-\mu_{sn}}\right]^{1-\mu_{sn}} \left[\frac{J_{snt}(i)}{\mu_{sn}}\right]^{\mu_{sn}}, \tag{78}$$

where $\alpha_n, \mu_{sn} \in (0, 1)$. $K_{snt}(i)$, $H_{snt}(i)$, and $J_{snt}(i)$ respectively represent the capital, efficiency units of labour, and economy-n final good used in the production of variety i. Productivity shifter $z_{sn}(i)$ is the realisation of a random variable drawn independently for each i from a place-specific Fréchet probability distribution:

$$F_{sn}(Z) = Pr(z_{sn}(i) \leq Z) = e^{-\left(z_{sn}^{\beta_s}\right) Z^{-\beta_s}}, \tag{79}$$

where $z_{sn}^{\beta_s} \geq 0$ and $\beta_s > \chi_s - 1$.

[50] We would like to thank Chad Bown for making this data available.

Goods markets continue to be perfectly competitive, and international trade is subject to the same iceberg transport costs: $\kappa_{sn'n} \geq 1$ units of the economy-n', sector-s variety must be shipped for one unit to arrive in economy n. Production factors can move freely between activities within economies, but cannot move across borders.

Under these assumptions, the steady-state relationships in section 3.1.4 must be adjusted as follows:

$$P_n^C = P_n^J = \frac{P_n^I}{\eta_n} = \prod_{s=1}^{S} \Xi_s^{\sigma_{sn}} \left[\sum_{n'=1}^{N} \left(\kappa_{sn'n} p_{sn'} \right)^{-\beta_s} \right]^{-\frac{\sigma_{sn}}{\beta_s}} \equiv P_n, \tag{80}$$

$$p_{sn}(i) = \frac{1}{z_{sn}(i)} f_n^{1-\mu_{sn}} P_n^{\mu_{sn}}, \quad f_n \equiv \left(\frac{r_n}{\alpha_n} \right)^{\alpha_n} \left(\frac{w_n}{1-\alpha_n} \right)^{1-\alpha_n} \tag{81}$$

respectively replace equations (20) and (21), where $\Xi_s \equiv \{ \mathit{\Gamma} \left[\left(\beta_s + 1 - \chi_s \right) / \beta_s \right] \}^{1/(1-\chi_s)}$, $\mathit{\Gamma}\left[\cdot\right]$ is the gamma function, and p_{sn} is still as defined in equation (21); and

$$M_{sn'nt} = \frac{\left(\kappa_{sn'n} p_{sn'} \right)^{-\beta_s}}{\sum_{n''=1}^{N} \left(\kappa_{sn''n} p_{sn''} \right)^{-\beta_s}} \sigma_{sn} \left(\sum_{s=1}^{S} p_{sn} Q_{snt} - NX_{nt} \right) \tag{82}$$

replaces equation (24).

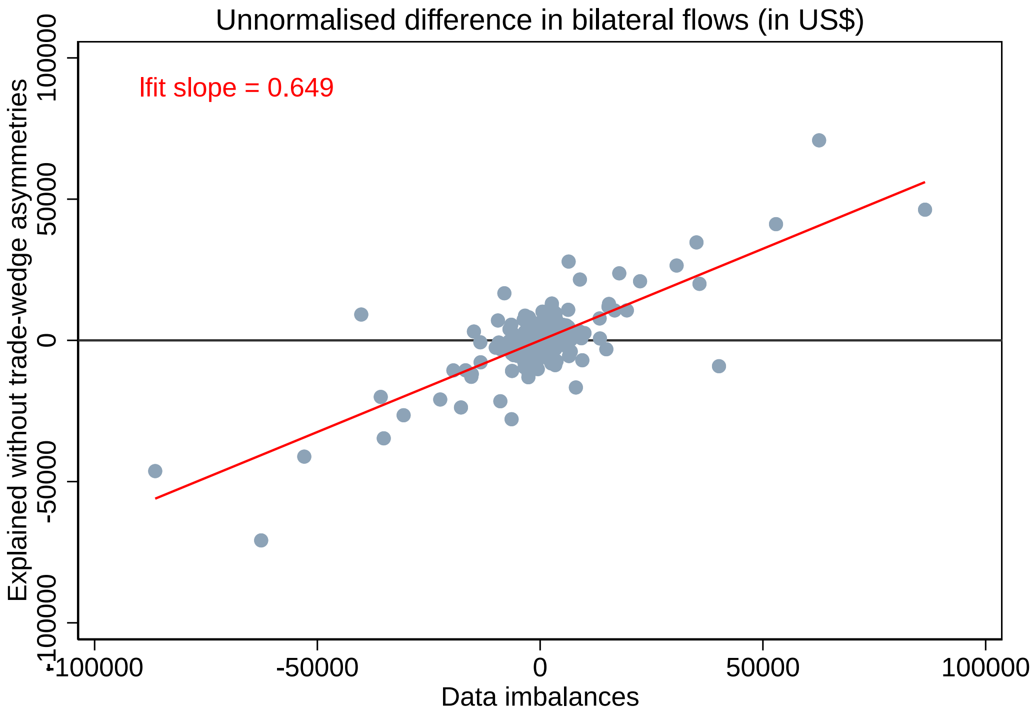
Re-defining $\kappa_{sn'n} \equiv \tau_{sn'n}$, $\beta_s \equiv \theta_s$ and $Z_n \equiv \prod_{s=1}^{S} \left[z_{sn} / \left(\Xi_s \tau_{snn} \right) \right]^{\sigma_{sn} / \left(1 - \sum_s \sigma_{sn} \mu_{sn} \right)}$, it is easy to show that all key steady-state relationships remain the same, and we can proceed with the calibration and counterfactuals as described in Sections 3.2 and Appendix A.4.

A.7 Dollar-Value versus Proportional Bilateral Imbalances

In their pioneering analysis of bilateral trade balances, Davis and Weinstein (2002) investigate how much of the variation across country pairs in the US-dollar value of bilateral trade balances can be explained using a gravity equation under the assumption of symmetric trade barriers. They conclude that a large portion remains unexplained – and term this the "mystery of the excess trade balances". However, their gravity equation does not control for multilateral resistance either through appropriate fixed effects or a theory-consistent non-linear regression model.

Felbermayr and Yotov (2021) revisit the estimation of Davis and Weinstein (2002) in a recent paper, updating it to control for multilateral resistance. As they find that the resulting gravity-predicted trade flows can be used to explain variation in the dollar value of bilateral trade balances well, they argue that

Figure A6: Accounting for economy-pair variation in the simple differences of bilateral flows



"Unnormalised difference in bilateral trade flows" refers to $M_{n'n} - M_{nn'}$, where $M_{n'n}$ is the value (in million US$) of imports by economy n from n'. "Data imbalances" are the unnormalised differences observed in the data. "Explained..." are the unnormalised differences predicted on the basis of equations (83) and (84) in Appendix A7. All data is based on WIOD (2013 release), averaged for the years 1995-99. The data covers 37 individual economies and the Rest of the World.

this solves the "mystery".

By contrast, our analysis focuses on variation across trade-partner pairs in *proportional* bilateral balances (bilateral trade balances relative to the geometric average of bilateral trade flows). Our approach is fully structural, and takes account of multilateral resistance. We find that, with respect to proportional bilateral trade balances, the "mystery" remains: a large part of their variation cannot be explained unless we allow for black-box asymmetries in trade wedges. As we argue in Section 2.1.2, we consider this the most appropriate test of the ability of structural gravity to explain trade imbalances: an analysis of the variation in the unnormalised dollar value of bilateral trade balances conflates the (well-understood) ability of structural gravity to explain variation in average trade flows across trade-partner pairs with the (less well-studied) inability of gravity to account for variation in the proportional gap between bilateral flows.

To give a sense of the effect of conflating the two, we use PPML to estimate a gravity regression of the form

$$M_{n'n} = e^{\{\Omega_{n'}+\Pi_n+\delta_{n'n}\}}\varepsilon_{n'n}, \tag{83}$$

where $\Omega_{n'}$ is an economy-n'-exporter dummy; Π_n is an economy-n-importer dummy; $\delta_{n'n} = \delta_{nn'}$ is a pair dummy; and $\varepsilon_{n'n} \neq \varepsilon_{nn'}$ is a mean-zero error.[51] As the left-hand-side variable, we use the 1995-1999 average value of bilateral trade flows from WIOD (2013 release) for 37 individual economies and the "Rest of the World" (= 1406 pairs). We use this data to facilitate comparison with Davis and Weinstein (2002), who use data for 1995. Based on our estimates, we then construct

$$\hat{M}_{n'n} = e^{\left\{\hat{\Omega}_{n'}+\hat{\Pi}_n+\hat{\delta}_{n'n}\right\}}, \tag{84}$$

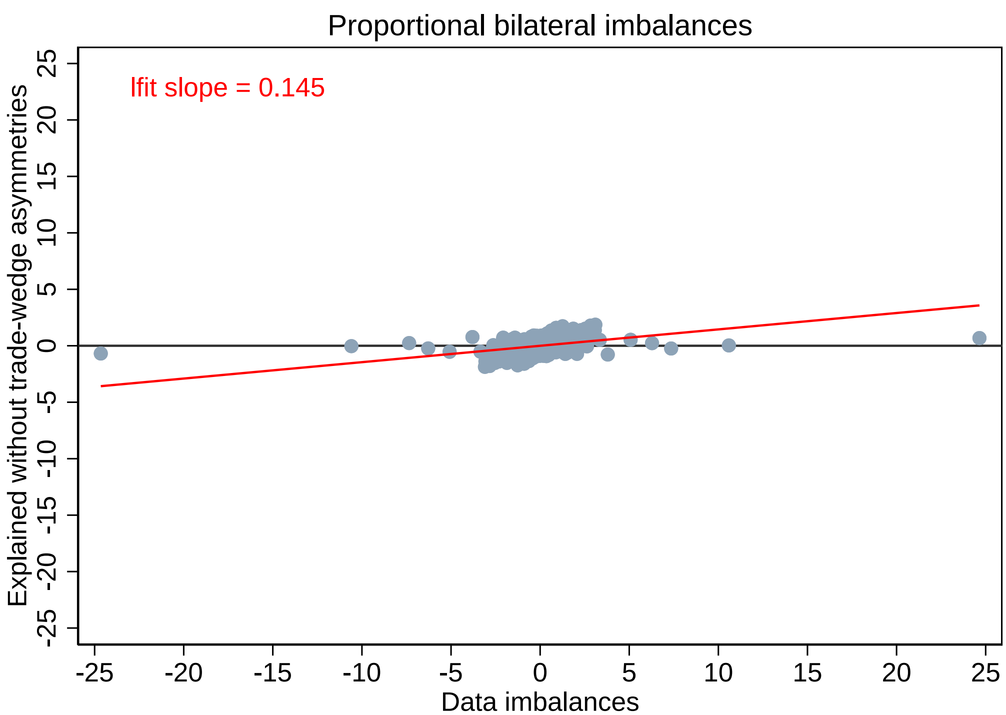
i.e. the gravity trade value exempting any trade-wedge asymmetries (the magnitude of which is captured by $\ln\hat{\varepsilon}_{n'n} - \ln\hat{\varepsilon}_{nn'}$).

Figure A6 plots $\hat{M}_{n'n} - \hat{M}_{nn'}$ against $M_{n'n} - M_{nn'}$. The figure is analogous to Figure 1 in Davis and Weinstein (2002). However, while they find that the coefficient of fitted on actual trade imbalances is .06, in Figure A6 this coefficient is .65. Based on an analysis of unnormalised dollar-value bilateral trade balances, one might thus be led to conclude that a structural gravity model can explain most of the variation in bilateral imbalances in the absence of asymmetric trade wedges.

By contrast, Figure A7 plots $(\hat{M}_{n'n} - \hat{M}_{nn'})/(\hat{M}_{n'n}^{1/2}\hat{M}_{nn'}^{1/2})$ against $(M_{n'n} - M_{nn'})/(M_{n'n}^{1/2}M_{nn'}^{1/2})$. The coefficient of fitted on actual trade imbalances is now only .15. This is quantitatively in line with the conclusion drawn in the present paper − that most of the variation in *proportional* bilateral imbalances must be attributed to asymmetric trade wedges. It also shows that most of the seeming "success" of structural gravity in Figure A6 is due to the well-documented success of estimations such as (83) in explaining the variation in the *average value* of bilateral trade flows across pairs of economies, rather than its ability to explain pairwise *imbalances* in these flows.

[51] This is a simplified version of the structural gravity model estimated by Felbermayr and Yotov (2021). The authors use PPML to estimate a non-linear model under the inclusion of theory-consistent mass variables and multilateral resistance terms. As Fally (2015) shows, this is equivalent to estimating a PPML gravity equation with a full set of importer and exporter fixed effects.

Figure A7: Accounting for economy-pair variation in proportional bilateral imbalances



"Proportional bilateral imbalances" refers to $(M_{n'n} - M_{nn'})/\left(M_{n'n}^{1/2} M_{nn'}^{1/2}\right)$, where $M_{n'n}$ is the value (in million US\$) of imports by economy n from n'. "Data imbalances" are the proportional imbalances observed in the data. "Explained..." are the proportional imbalances predicted on the basis of equations (83) and (84) in Appendix A4. All data is based on WIOD (2013 release), average for the years 1995-99. The data covers 37 individual economies and the Rest of the World.

A.8 Appendix Tables

Table A1: Sample of economies

WIOD (2016)		Final data	
Economy	Code	Economy	Code
Australia	AUS	Australia	AUS
Austria	AUT	Austria	AUT
Belgium	BEL	Belgium	BEL
Brazil	BRA	Brazil	BRA
Bulgaria	BGR	Bulgaria	BGR
Canada	CAN	Canada	CAN
China	CHN	China	CHN
Croatia	HRV	Croatia	HRV
Cyprus	CYP	Rest of the World	RoW
Czech Republic	CZE	Czech Republic	CZE
Denmark	DNK	Denmark	DNK
Estonia	EST	Estonia	EST
Finland	FIN	Finland	FIN
France	FRA	France	FRA
Germany	DEU	Germany	DEU
Greece	GRC	Greece	GRC
Hungary	HUN	Hungary	HUN
India	IND	India	IND
Indonesia	IDN	Indonesia	IDN
Ireland	IRL	Ireland	IRL
Italy	ITA	Italy	ITA
Japan	JPN	Japan	JPN
Korea	KOR	Korea	KOR
Latvia	LVA	Latvia	LVA
Lithuania	LTU	Lithuania	LTU
Luxembourg	LUX	Rest of the World	RoW
Malta	MLT	Rest of the World	RoW
Mexico	MEX	Mexico	MEX
Netherlands	NLD	Netherlands	NLD
Norway	NOR	Norway	NOR
Poland	POL	Poland	POL
Portugal	PRT	Portugal	PRT
Rest of the World	RoW	Rest of the World	RoW
Romania	ROU	Romania	ROU
Russia	RUS	Russia	RUS
Slovakia	SVK	Slovakia	SVK
Slovenia	SVN	Slovenia	SVN
Spain	ESP	Spain	ESP
Sweden	SWE	Sweden	SWE
Switzerland	CHE	Switzerland	CHE
Taiwan, Prov. of China	TWN	Taiwan, Prov. of China	TWN
Turkey	TUR	Turkey	TUR
U.K.	GBR	U.K.	GBR
U.S.	USA	U.S.	USA

The “WIOD (2016)” column shows economies and regions as covered in the 2016 release of WIOD. The “Final data” column shows economies and regions as grouped for our analysis.

Table A2: Sector sample

WIOD (2016)		Final data
Sector	ISIC 2-dg.	New code
Crop and animal production...	1	1
Forestry and logging	2	1
Fishing and aquaculture	3	1
Mining and quarrying	5-9	2
Manufacture of food products,...	10-12	3
Manufacture of textiles,...	13-15	4
Manufacture of wood and...	16	5
Manufacture of paper and...	17	6
Printing and reproduction...	18	6
Manufacture of coke and...	19	7
Manufacture of chemicals...	20	8
Manufacture of basic pharma...	21	8
Manufacture of rubber and...	22	9
Manufacture of other non-metal...	23	10
Manufacture of basic metals	24	11
Manufacture of fabricated metal...	25	11
Manufacture of computer,...	26	13
Manufacture of electrical equip...	27	13
Manufacture of machinery and...	28	12
Manufacture of motor vehicles,...	29	14
Manufacture of other transport...	30	14
Manufacture of furniture; other...	31-32	15
Repair and installation...	33	15
Electricity, gas, steam and...	35	16
Water collection, treatment...	36	16
Sewerage; waste collection,...	37-39	16
Construction	41-43	17
Wholesale and retail...	45	18
Wholesale trade, except...	46	18
Retail trade, except of...	47	19
Land transport and...	49	21
Water transport	50	22
Air transport	51	23
Warehousing and support...	52	24
Postal and courier activities	53	25
Accommodation and food...	55-56	20
Publishing activities	58	6
Motion picture, video and...	59-60	6
Telecommunications	61	25
Computer programming,...	62-63	28
Financial service activities,...	64	26
Insurance, reinsurance and...	65	26
Activities auxiliary to financial...	66	26
Real estate activities	68	27
Legal and accounting activities;...	69-70	28
Architectural and engineering...	71	28
Scientific research and...	72	28
Advertising and market research	73	28
Other professional, scientific...	74-75	28
Administrative and support...	77-82	28
Public administration and...	84	31
Education	85	29
Human health and social work...	86-88	30
Other service activities	90-96	31
Activities of households...	97-98	28
Activities of extraterritorial...	99	31

The "WIOD (2016)" column shows sector names and codes as covered in the 2016 release of WIOD. The "Final data" column shows the new codes for the sector groups created for our analysis.

Table A3: Sector sample and trade elasticities

Final data		
New code	Sector	Trade elasticity
1	Agriculture, hunting, forestry and fishing	8.11
2	Mining and quarrying	15.72
3	Food, beverages and tobacco	2.55
4	Textiles and textile products; leather, leather apparel and footwear	5.56
5	Wood and products of wood and cork	10.83
6	Pulp, paper; paper, printing and publishing	9.07
7	Coke, refined petroleum and nuclear fuel	51.08
8	Chemicals and chemical products	4.75
9	Rubber and plastics	1.66
10	Other non-metallic, mineral products	2.76
11	Basic metals and fabricated metal	7.99
12	Electrical and optical equipment	10.60
13	Machinery, nec	1.52
14	Transport equipment	0.37
15	Manufacturing, nec; recycling	5
16	Electricity, gas and water supply	5
17	Construction	5
18	Wholesale trade, commission trade, including motor vehicles and motorcycles	5
19	Retail trade, except of motor vehicles and motorcycles	5
20	Hotels and restaurants	5
21	Inland transport	5
22	Water transport	5
23	Air transport	5
24	Other supporting and auxiliary transport activities; activities of travel agencies	5
25	Post and telecommunications	5
26	Financial intermediation	5
27	Real estate activities	5
28	Other business activities	5
29	Education	5
30	Health and social work	5
31	Public admin, defence, social security and other public services	5

"New code" shows the new codes for the sector groups created for our analysis. "Sector" shows the corresponding sector names. "Trade elasticity" shows the corresponding trade elasticities. Trade elasticities are based on Caliendo and Parro (2015), and Costinot and Rodríguez-Clare (2014).

Table A4: Trade-cost changes as a result of the USA-CHN trade war

Final data			
New code	Sector	$\hat{\kappa}_{s,CHN,USA}$	$\hat{\kappa}_{s,USA,CHN}$
1	Agriculture, hunting, forestry and fishing	1.16	1.25
2	Mining and quarrying	1.06	1.10
3	Food, beverages and tobacco	1.19	1.19
4	Textiles and textile products; leather, leather apparel and footwear	1.05	1.14
5	Wood and products of wood and cork	1.20	1.19
6	Pulp, paper; paper, printing and publishing	1.20	1.16
7	Coke, refined petroleum and nuclear fuel	1.18	1.25
8	Chemicals and chemical products	1.14	1.11
9	Rubber and plastics	1.13	1.08
10	Other non-metallic, mineral products	1.17	1.12
11	Basic metals and fabricated metal	1.18	1.19
12	Electrical and optical equipment	1.18	1.10
13	Machinery, nec	1.11	1.08
14	Transport equipment	1.23	1.00
15	Manufacturing, nec; recycling	1.10	1.06
16	Electricity, gas and water supply	1.23	1.06

"New code" shows the new codes for the sector groups created for our analysis. "Sector" shows the corresponding sector names. $\hat{\kappa}_{sn'n}$ shows the new iceberg cost for imports by economy n from n' in sector s in the trade-war scenario. $\hat{\kappa}_{sn'n} = 1$ for all s, $n'$and n not shown in the table. Iceberg-cost changes are based on data from Bown (2019) and Bown et al. (2019). See Appendix A.5.3 for more details.

Bilateral Trade Imbalances

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