Trade Interdependence in the Modern Global Economy

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Abstract

Describing and explaining global interdependence from trade require an approach that incorporates fundamental features of the modern global economy, such as trade in intermediate goods, substitutability across products, and alternative trading partners. We use theoretical models of structural gravity to construct measures of dyadic dependence that directly incorporate these features. The measures are valid under a wide variety of classical and new theories for trade. The measures describe (1) how much damage is done to a country's welfare when dyadic trade is interrupted and (2) how much additional trade it would take from their existing trade partners to compensate. We then show three important findings. First, the new measures differ from traditional measures based on aggregate trade statistics in meaningful ways. Second, they tell a new story of how dependence and interdependence have changed over time. Contrary to much common wisdom, the world has *not* marched inexorably towards greater interdependence. Average levels of dependence and interdependence – the degree of symmetry in dependence relationships – have both increased over time. But this is driven by a large increase in the degree to which countries are reliant on one partner, especially China. For many countries, dependence on China has risen to such a degree as to overwhelm any secular increase in interdependence. These important dynamics are obscured by aggregate trade statistics. Third, we use China's foreign assistance, as exemplified by the Belt and Road Initiative, to assess the degree to which states can successfully manipulate their dependence relationships. We find that the Chinese assistance has increased partners' dependence on China over time, without a reciprocal increase in Chinese dependence. These important effects of Chinese assistance are not apparent in analysis of aggregate trade statistics.

1 Introduction

The world has experienced an unprecedented explosion in international commerce since the late 20th century. The modern global economy is now characterized by historically open markets and a sprawling network of interlinked value chains. Scholarship has interpreted the skyrocketing levels of international trade as an indication of the increasing interdependence of national economies (Keohane and

Nye 1973). However, broad changes in the global economy necessitate a reevaluation of this interpretation. On the one hand, trade in intermediates and in differentiated products has increased, making many trade relationships even more valuable than nominal trade values would suggest. On the other hand, states have diversified their trading partners. They can trade with more and larger markets in the event that any single trading relationship breaks down. And these alternate trading partners are more productive than at any point in history – because, in part, of the openness of global markets (Romer and Frankel 1999). Therefore, even as states have plugged into an integrated global economy, they are also better positioned to endure interruptions in trade than ever before.

Taking account of these fundamental changes in the global economy and their countervailing effects has critical implications for fundamental questions in geopolitics, both new and old. Have states become more dependent on one another over time? Have trading relationships become more interdependent – i.e. symmetric in the degree of dependence between states – over time? Who has become more dependent on whom?

Answering these questions requires models and measurements that account for intermediates trade along value chains, the substitutability of products, and the availability of alternative foreign markets. The most commonly used existing approaches describe dependence by tallying aggregate statistics of bilateral trade flows as a fraction of GDP or total trade. These approaches were more appropriate in an earlier era when it was reasonable to assume that trade flows of equal value contributed equally to the gains from trade, and were equally easy to replace with alternate suppliers. However, in an era characterized by global value chains and productive alternative trading partners, the link between the volume of trade and dependence on trade has deteriorated. New approaches are necessary to fully capture "who is dependent on whom."

We build on recent advances in the structural gravity approach to model and measure dependence while accounting for these dimensions. For almost 60 years, economists have explained bilateral trade flows using equations that resemble Newton's theory of gravitation. Arkolakis, Costinot, and Rodríguez-Clare (2012) show that, within an extremely wide class of gravity models encompassing Armington (1969), Krugman (1980), Eaton and Kortum (2002), and Melitz (2003), a handful of

parameters are sufficient to create a measure of the gains from trade and market access. These parameters – trade elasticities, shares of domestic value-added in production, and the share of intermediate products in production – are the same regardless of whether the underlying model explains trade using international differences in factor endowments and technological knowledge,[1] increasing returns to scale, or heterogeneous products and firms.[2] These parameters also directly correspond to the key ways in which the global economy has evolved.

We extend this approach to create two new measures of bilateral dependence: how much welfare one state would lose if some or all of its trade with a partner were cut off. We construct an "upper bound" measure of dependence, which describes a country's loss of welfare if market access were interrupted and no further adjustments were made in trade flows with other partners. We also construct a "compensation" measure, which describes how much that country would have to scale up their trade flows with other partners to restore its welfare to *ex ante* levels. If only small adjustments would be needed, then that shows a low level of dependence, and vice versa. Our measures' major advantages over existing approaches are that they directly incorporate key features of the global economy over time by placing greater weight on intermediates trade that has downstream effects along production chains and by placing greater weight on flows for which there are fewer available substitute products or producers – since both of these dimensions magnify the welfare effects of trade policy. While there are of course complicated strategic interactions underlying any attempt by one country to influence another, the ability of one country to harm the welfare of another is at the core of our understanding of bilateral dependence.[3]

An additional key feature of our approach is that it directly models the counterfactual nature of dependence. D. A. Baldwin (1980) defined dependence as the opportunity cost if a country were to interrupt trade with a partner. He lamented that the counterfactual nature of opportunity cost makes it hard to operationalize. Existing measures using only aggregate trade and GDP statistics make no attempt to measure the opportunity cost of interrupted trade, since they are based solely on the nominal

[1] Rogowski (1987), Hiscox (2001)
[2] Kim and Osgood (2019)
[3] D. A. Baldwin (1980).

value of observed trade. Almost 30 years later, Mansfield and Pollins (2009) noted the persistence of this problem, since "the size of the flow of trade between states (taken either by itself or as a percentage of national income) may not accurately reflect the costs [if] economic relations were disrupted (13)". Describing the consequences if trade were interrupted requires a theoretical model of the welfare consequences of lost trade and a measurement derived from that model. Our approach answers these calls.

We describe the measure construction in detail and then present three sets of substantive findings, each tied to the questions above. First, we show that our measurement diverges from the most commonly used existing measures and that these divergences increase over time. Our measures are correlated with those based on aggregate trade statistics, but those correlations deteriorate over time and as we account for elasticities of trade, intermediates trade, and changes at the extensive margin of trade.

Second, we show that global dependence has not changed in the ways scholars often think. For Keohane and Nye (1973) and many others, the concept of complex interdependence refers to the depth and symmetry in dependence relationships. *Dependence* describes how state i's welfare is affected when its trade with state j is interrupted, either because j limits its exports or i raises tariffs on imports. *Interdependence* refers to whether i's dependence on j is similar in magnitude to j's dependence on i. Scholarly and popular descriptions of the liberal economic order often describe a broad trend in which countries became more dependent on one another overall. And over time this dependence increases to the point where it can deter conflict and encourage more cooperation among states (Friedman 2005; Keohane 1984; Keohane and Nye 1973).

We show that the data do not match these stories in several meaningful ways. Global levels of dependence have increased over time, on average. But there is intense heterogeneity in the trends. Dependence among Asian countries has broadly increased, but for many countries, dependence has decreased over time, especially among those in Europe and North America. Other countries have a U-shaped trend over time, with dependence decreasing and then increasing. We show that the common cause is skyrocketing dependence on China. Rising dependence is usually attributable to

direct dependence on China. Declining dependence usually reflects how the emergence of China as an alternate trade partner has undercut dependence on countries' existing trade partners. For many countries, dependence on China has grown to the point where they have become more dependent on China than they had ever been on their previous trading partners.

Additionally, global interdependence has not increased over time. In fact, interdependence – symmetry in dependence relationships – has decreased significantly when considering each state's primary dependency (typically, the U.S. or China). Furthermore, the trends we describe are not apparent when using aggregate trade statistics, which do tend to support the conventional wisdom about increasing dependence and symmetry. The world only looks more dependent and symmetric over time when using aggregate GDP and trade measures that assume all trade flows are equally important. Contrary to a common belief – and one supported by trends in aggregate trade – the world has not become a more egalitarian place in terms of interstate dependencies.

Third, we turn to the question of why dependence on China has grown so dramatically. Much of the rise in dependence is due to China's emergence as an economic powerhouse, but we also consider whether government policies are contributing to the trend. We study one of the most ambitious projects that could increase dependence on China: the Belt and Road Initiative (BRI), which increased Chinese foreign assistance. Using a difference-in-differences specification, we find that Chinese assistance increases recipients' dependence on China. However, the reverse is not true. China has not increased its dependence on recipients, meaning that it has further increased asymmetry in dyadic dependence. These effects are not apparent using aggregate trade statistics. Governments the world over are hyper-focused on whether they can use policy levers to manipulate dependencies. Our analysis of Chinese assistance is a critical case to study for assessing whether efforts to manipulate dependence are likely to succeed.

We conclude by describing the types of questions that we hope our approach can shed additional light on.[4] Some of these questions are again "old," such as whether interdependence fosters peace? Others are "new," such as whether the effects of climate change or evolving artificial intelligence capa-

[4]Our measures will be publicly available and updated.

bilities will change who is likely to be dependent on whom in a rapidly changing future. An approach that accounts for fundamental changes in the global economy will be critical for answering all of these questions.

2 Dependence and Interdependence

What is dependence? In the context of geopolitics and trade, term "dependence" has been used by many authors to describe a multitude of concepts.[5] We use it here to mean the opportunity cost of lost commerce – the difference in a given state's welfare when a particular trading relationship is interrupted (D. A. Baldwin 1980).[6] Dependence is a fundamentally counterfactual concept; it compares economic welfare in a status quo scenario with welfare after a trade relationship is interrupted. Neither value is observable at the same moment. Thus, dependence is a latent quantity that must be theorized and estimated.

Previous work distinguishes between sensitivity dependence and vulnerability dependence. The former generally refers to whether a change in economic conditions in one country affect conditions in another country. For example, state i is sensitive to state j if an economic downturn in the latter also causes an economic downturn in the former. Sensitivity dependence thus captures a degree of unintended contagion across countries. Vulnerability dependence describes the consequences of intentional interruptions in economic conditions. D. A. Baldwin (1980) argues that vulnerability dependence is most associated with coercive power. Vulnerability dependence is the ammunition that one country can use to coerce another. It is therefore the relevant concept for studying the structure of global economic power and deliberate attempts to manipulate or use commercial relations to influence another country (Hirschman 1980; Eaton and Engers 1992). The structure of vulnerabilities also affects international cooperation because states that fear economic coercion will be reluctant to embrace openness (Abdelal and Kirshner 1999; Carnegie 2014). Our approach below fits most clearly

[5] Coate, Griffin, and Elliott-Gower (2015)

[6] Our definition takes inspiration from D. A. Baldwin (1980) who writes that dependence captures "what the costs would be to one country should... relations be interrupted with another country" (847). See also Mansfield and Pollins (2001).

with vulnerability dependence, where one state may attempt coercion by conditioning market access on compliance with a demand.[7]

The term "interdependence" has also come to have many uses, but the most influential interpretations describe a two dimensional concept. First, interdependence requires depth, meaning that states i and j should have significant dependence on each other. Second, interdependence describes symmetry, in the sense that both state i and state j are approximately equally dependent on each other. Keohane and Nye (1973) argued that relative parity across countries in their degree of dependence on one another was a key feature of "complex interdependence."

Why should we care about dependence? Few core concepts have been linked with as many fundamental questions in international relations. Dependence plays a key role in our understanding of the origins of international cooperation (Keohane 1984). A tradition of scholarship dating back to Cooper (1968) argues that the increasing dependence of the global economy is a core motivation for states to cooperate and coordinate economic policy. Ikenberry (2018) extends this logic, arguing that the emergent norms, rules, and institutions supporting cooperation can be described as a liberal international order whose purpose is to promote democracy and "reconcile the dilemmas of sovereignty and interdependence" (8). Moreover, the expectation that interdependence will increase is itself an important driver of cooperation. Increasing interdependence establishes an expectation of mutual gains from cooperation in the shadow of the future (Axelrod and Keohane 1985). Asymmetry in dependence is concerning enough that states actively manage it with the rules-based liberal international order. The construction of the liberal international order stemmed in part from a desire to limit the hegemonic power of the United States, on whom states were very dependent (Ikenberry 2001). Small states might withdraw from the open economy if they fear that any consequent dependence might be used against them (Carnegie 2014). Powerful states subject themselves to a rules based system in order to attract greater participation in the global economy from smaller states.

Levels of dependence and expectations about future trends in dependence have also been at the core of explanations of conflict (Copeland 2014). There are generally two opposing sides: those who

[7] Threats to use dependence as an instrument of coercion must be credible (Mangini 2024). Obstacles to the credibility of economic coercion, including domestic politics and institutions, are outside the scope of this paper.

think that dependence and interdependence have a pacifying effect and those that think that it invites tension or war.[8] The former camp considers dependence as indicative of increasing the costs of conflict. States will be less likely to fight or coerce each other because they each have reciprocal dependencies that deter aggression. Put simply, they fight less because they have more to lose.

Interdependence also affects the credibility of coercive threats. States in interdependent relationships are potentially protected from non-military economic coercion via mutually assured economic destruction – neither partner is willing to risk the gains from trade. The potential for blowback undermines the credibility of some threats. State A's dependence on State B is not useful for coercive purposes if State B is even more dependent on State A. As Knorr (1975) wrote, "The world has become less coercible" (p 318). The latter camp argues that trade and dependence could exacerbate conflict, as states have more to fight over or as states fight to break dependencies.[9] Here too, symmetry of dependence relationships is important because it is thought to moderate the potentially pacifying effects of dependence. Increased dependence may decrease conflict in a dyad by raising the opportunity costs of conflict, but asymmetry allows the less dependent partner greater leeway to coerce the more dependent partner (Gartzke and Westerwinter 2016; Keohane and Nye 1973).

3 Measuring Dependence

We first review existing measures of dependence. There are two broad extant approaches: the use of aggregate trade statistics and case studies of significant products. While these existing approaches each have merit under some assumptions, neither one fully incorporates all the ways that trade flows can have different consequences for welfare. We then describe how our approach is better suited to the problem.

[8] For a summary see Mansfield and Pollins (2001).
[9] Barbieri (1996) and Mearsheimer (2015)

3.1 Measuring Dependence with Aggregate Trade Statistics

Scholars studying the dependence of a country as a whole tend to construct measures using aggregate trade statistics. Typically, scholars follow Oneal and Russet (1997) (OR) who use the sum of bilateral imports and exports divided by GDP. The intuition is straightforward. As bilateral trade increases (the numerator), there is more at stake in a particular trade relationship, and therefore more harm in cutting off trade flows. As GDP (the denominator) increases, trade is a lower fraction of the country's overall economic activity, and therefore less harm is done. Additionally, a larger GDP could indicate a greater ability to compensate for interrupted trade by increasing domestic production.

Alternative approaches within this category are generally different permutations of aggregate GDP and trade measures combined with bilateral trade flows.[10] For example, Barbieri (1996) and much subsequent work emphasizes trade shares, which equal the value of trade for a particular dyad divided by the overall trade for the country in question. Country i's dependence on country j as measured by trade shares is: $(\text{trade share})_i = \frac{\text{trade}_{ij}}{\text{trade}_i}$. Barbieri measures trade shares as well as trade salience, trade symmetry, and trade interdependence. These, too, are various functions of aggregate monadic and dyadic trade statistics. OR and Barbieri also use extensions of these measures to capture symmetry in a dyad.[11]

With some partial exceptions described below, approaches based on aggregate measures make little allowance for ways in which interrupting different flows can have very different consequences for a country. These approaches share an implicit assumption that every dollar of lost trade is equally harmful for welfare. There are three major ways that this assumption is violated.

First, not all goods have readily available substitutes. It is less disruptive to substitute brown rice for white rice, compared to finding a substitute for a specialized pharmaceutical. $10M of rice imports and $10M imports of chemotherapy drugs will have both have the same impact on measures based on aggregate trade statistics, even though substitutability means they have very different implications for

[10] Gartzke and Li (2003).

[11] OR describes trade interdependence as the minimum of bilateral dependence in a dyad and trade asymmetry as the maximum. Barbieri uses a measure of dyadic trade symmetry equal to $1 - |(\text{trade share})_i - (\text{trade share})_j|$ and a measure of trade interdependence equal to $\left(\sqrt{(\text{trade share})_i * (\text{trade share})_j}\right) * \left(1 - |(\text{trade share})_i - (\text{trade share})_j|\right)$.

welfare. Some studies of dependence have incorporated the ease with which you can find substitutes.[12] They generally use static measures of import demand elasticity at the industry level.

Second, some trade flows are in final, consumption goods but others are in intermediate products. Intermediates are goods that are inputs (or inputs into inputs…) of other goods. Intermediates trade has comprised a substantial portion of global trade over the last three decades.[13] Osgood (2018) labels the ability to source intermediates inputs as one of the "primary drivers of producer preferences" over liberalization. The degree to which imported intermediates affect downstream production varies across countries and time, but also across industries and across firms within industries.[14] The welfare effect of interrupting trade in final goods is direct and localized. The welfare effects of interrupting intermediates trade are more complicated, since those disruptions ripple down the value chain. If imports of integrated circuits (chips) were interrupted, this has implications for firms that use chips as inputs to circuit boards, which are inputs into electronic devices, which are inputs into the production of myriad downstream goods. Again, interruptions to final goods and intermediates have identical effects on measures based on aggregate trade statistics, even though the full implications of those interruptions differs drastically.

Third, some trade flows are more easily replaced by production from another trading partner than others.[15] Compare steel imports into the Philippines versus neighboring Malaysia. The Philippines imports 47% and 19% of its steel from China and Russia respectively. None of the remaining sources make up more than 8% of their imports. Malaysia, on the other hand, imports 26% and 19% from its two largest partners, China and Japan. Two other countries make up 12% of their imports, and a third makes up 8%. Malaysian steel imports are more evenly spread across different producers, compared to the concentrated import origins for the Philippines. Even if Malaysia and the Philippines import the same nominal values of steel from a partner, they differ greatly in their dependency on that partner, because replacing that flow could be much harder if it was concentrated in only one partner.@mansfield2001study and Barbieri (1996) recognized that the ease of replacing a lost trade

[12] Gowa (1995), Polachek (1997), Crescenzi (2003)
[13] Miroudot, Lanz, and Ragoussis (2009).
[14] Osgood (2017).
[15] Kim, Liao, and Imai (2020), Gray and Potter (2012).

flow with an alternative partner affected dependence. Barbieri's trade share measure $\left(\frac{\text{trade}_{ij}}{\text{trade}_i}\right)$ was intended to capture this. If a bilateral trade flow constitutes only a small part of a particular country's overall trade, then it is a reasonable assumption that the country has more alternative partners to draw upon for replacing the loss of any one trade flow. F. R. Chen (2021) analyzes how alliance networks amplify the potential trade costs of disputes.

Though some extensions of aggregate trade measures account for one of the three things above, none account for them all. Existing approaches are also not microfounded in any theory of international trade. Furthermore, most applications still default to the baseline OR or Barbieri measure.

3.2 Measuring Dependence with Significant Products

The second existing approach is to study trade in a small number of products which are known to be very difficult to substitute. Many of the products chosen, such as oil and semiconductors, are intuitively critical to the global economy. The underlying assumption is that a country's dependence on an entire trade relationship is correlated with its dependence on the chosen products. A group of scholars studying resource competition analyzed the relationship between oil and international conflict under the supposition that states which depend on oil imports might use military means to secure their supply (Westing 1986; Klare 2007).[16] Zeng (2024) incorporates a list of significant goods into a measure of the externalities of trade. More recently, the experience of global value chain disruption during the COVID-19 pandemic has caused U.S. policymakers to become concerned about access to semiconductors, an extremely widely used intermediate product (Farrell and Newman 2020; L. S. Chen and Evers 2023).

Unlike the aggregate trade statistics measures, this approach can differentiate between types of trade flows. However, this approach also falls short of a full accounting of dependence. First, the modern global economy includes trade in many products. The strategic goods approach misses cases where a state's political leverage does not derive from a small number of products. Small amounts of

[16] Colgan (2010) finds that petrostates are more often aggressors than targets of aggression, but he also shows that petrostates are targeted more often than non-petrostates.

dependence in a large number of products add up. This approach also uses a binary classification of flows as strategic or not, but provides no method of weighting the importance of different strategic products. Second, the modern global economy is dynamic. The relevance of any case study of a particular product might quickly become irrelevant. Some products may become significant in unanticipated ways. For example, the COVID-19 pandemic laid bare the importance of seemingly unimportant items like masks.

3.3 Estimating Dependence in the Modern Economy

The ideal measurement of dependence requires a full accounting of how an interruption in trade affects a country's welfare. This measurement should account for three major features of modern international trade: substitutability, intermediates trade, and the availability of alternative trading partners. It should do so for all trade flows, not just a small subset of significant ones. It should be microfounded in trade theory. Creating an estimate of dependence with all of these features is daunting. In principle, such an estimation could be undertaken using a structural model of bilateral trade flows. Historically, the main obstacle to such an exercise was the proliferation of models of international trade, each presumably having different implications for the gains from trade. The main tool for understanding comparative advantage trade, the Ricardian model, was not amenable to studying the gains from trade between more than two partners (Helpman 2014). Multi-country generalizations of the Heckscher-Ohlin model did not enjoy robust empirical support, making it difficult to use them as the basis for calculating the gains from trade (Bowen, Leamer, and Sveikauskas 1987; Trefler 1995). Empirical models based on a gravity-like equation were good at predicting observed trade flows, but they were not initially derived from a theoretical model of trade. The challenge was not necessarily finding a model of trade which could describe dependence, but rather choosing the right model from among the many options available.

Over the past 20 years, major developments in the economics of international trade have gradually made it possible to contemplate a direct estimation of trade dependence. First, Eaton and Kortum (2002) developed the first quantifiable multi-country generalization of the Ricardian model. It turned

out that this generalization was a member of the class of gravity models. Suddenly, by virtue of its newfound connection to Ricardian trade and its previously established robust empirical support, the gravity model approach took pole position in the race for the leading model of trade theory. But there was a litany of seemingly equally valid possible variations on the gravity model.

In a major paper, Arkolakis, Costinot, and Rodríguez-Clare (2012) (hereafter ACR) showed that all variations within a very wide class of trade models generate exactly the same gains from trade. Moreover, the gains from trade in this class depend entirely on a small number of parameters that can be estimated from standard trade data. The simplicity of the estimation procedure and its wide applicability greatly reduces the complexity of estimating dependence while strengthening the connection between the theory of international trade and the concept of dependence. Crucially for our application, these parameters have natural mappings to changes in the global economy that are not captured by looking only at aggregate trade statistics.

ACR derive an expression for the welfare effect of an interruption to trade, i.e. a trade shock, as a ratio $\hat{W}_j = W_j'/W_j$ where W_j is the economic welfare of country j in the no-shock scenario and W_j' is its welfare in the scenario with the shock. This is ideal for studying dependence in the global economy because the $\hat{W}_j$ formulation of welfare explicitly models the counterfactual nature of dependence – it compares two scenarios, one with a shock and one without. We express welfare changes as:

$$\hat{W}_j = \Pi_s (\hat{\lambda}_j^s)^{\eta_j^s/\beta_j^s \varepsilon^s}$$

where β_j^s is the share of intermediate products in production in sector s and country j, ε^s is a trade elasticity for sector s, η_j^s is the pre-shock consumption share of sector, and $\hat{\lambda}_j^s = (\lambda_j^s)'/\lambda_j^s$ is a ratio of the share of domestic expenditure across the scenarios. Remarkably, the quantity $\hat{W}_j$ is expressible in terms of four parameters, three of which (intermediates share β_j^s, the trade elasticity ε^s, and the share of domestic expenditure before the shock λ_j^s) can be directly observed or estimated from data. For ease of reading, we suppress notation for years, indexed by t.

Two of those parameters immediately incorporate two of the three features of the modern econ-

omy that we highlighted above: product substitutability and intermediate inputs. The interpretation of ε depends on the particular underlying model of trade, but the canonical interpretation suffices to build intuition here. A smaller (less negative) elasticity means that an import flow is less sensitive to trade costs. A smaller elasticity reflects how a particular trade flow is persistent even as trade costs rise, indicating its greater importance. The measure places greater weight on flows in sectors with smaller elasticities.

For an affected country and a product, β_j^s describes the (inverse) intermediate input shares, so a higher value means the sector relies on less intermediate input shares. A sector that relies more on intermediate inputs is one in which there will be greater amplification of input/output feedback in any trade disruption. As input shares increase (β_j^s decreases), a sector is more damaged by disruptions in its inputs from intermediate goods. The measure places greater weight on such a sector.

The share of domestic expenditure without a trade shock, λ_j^s, is observable from data. The share of domestic expenditure in the scenario with the shock $(\lambda_j^s)'$ is the one remaining parameter which is unobserved and therefore cannot be estimated from data. ACR note that there is one scenario in which this quantity is known with certainty: under total autarky, the share of domestic value added must be 100%. ACR calculate the total welfare gains from trade relative to autarky by plugging in $(\lambda_j^s)' = 1$. There is no way to know with certainty what the domestic share of value added will be in other scenarios. There are two margins of adjustment that could impact the share $(\lambda_j^s)'$ in the event of an interruption in trade with one partner. First, the domestic economy could adjust to the new prices by increasing production of some goods and decreasing production of others. Second, the alternative trading partners could adjust their exports in response to the new prices. Both margins affect the share of domestic value added in production and therefore could blunt the negative welfare effects from interrupting trade. Our compensation measure, described below, incorporates the second margin of adjustment.

3.4 Upper bound dependence and compensation dependence

Our first new measure estimates dependence using the above formula. Consider the effect on the welfare of the target state j if sender state i were to cease exporting to j.[17] To reduce the costs of this trade stoppage, the state might adjust its production or its imports from alternative partners. Any adjustment is for the purpose of increasing welfare. Therefore, the maximum reduction in welfare that state j could experience when state i severs its trade relationship occurs when domestic production in j is unchanged and the exports from alternative trade partners are also unchanged. Therefore, the share of domestic value added given zero exports from country i, holding all other exports and domestic production constant, represents an upper bound on the opportunity cost of interrupted trade.

This value, which will be called *upper bound dependence,* is our first major new measure of dependence. It is a direct measure of the highest possible amount of dependence in a given bilateral trade relationship. Unlike measures based on aggregate statistics, upper bound dependence can be interpreted directly. Its value represents the fraction of country j's initial welfare remaining after country i ceases to export all goods to j holding all other production values and exports constant. In other words, it is the lowest possible fraction of country j's welfare remaining if country i ceases exporting. An alternative interpretation of upper bound dependence is that it is a short run measure of dependence before enough time has passed for the new equilibrium to be reached.

Recall that the ACR approach clearly incorporated two of the three major changes to the world economy, substitutability and intermediates trade, but it did not directly incoporate the availability of alternative trade partners. Similarly, while useful, upper bound dependence also does not directly incorporate the ability of alternative trade partners to compensate for lost trade. Without further strong assumptions about the cross price elasticities for all possible goods and suppliers it is not possible to directly estimate how well alternative trade partners could replace the lost trade.

However, a single assumption can enable meaningful progress toward incorporating the availability of alternative trade partners. Assuming that the export mix from each alternative market remains constant, we can ask: how much would the existing trade partners need to increase their trade to fully

[17] This is also equivalent to considering the effects if j were to cut off its imports from i with tariffs or other restrictions.

replace the lost welfare if country i ceased exporting to country j? In other words, how much would existing partners need to scale up trade in order to make the target "whole" again. We call this value *compensation dependence*. It captures the idea that the existing trade network can buttress against any one state's dependence on another. It is the second major measure of dependence introduced in the paper.

Figure 1 depicts both measures of dependence graphically. The top pane shows the *status quo ex ante*, with B trading various amounts in various industries with three partners (A, C, and D). The thickness of each arrow shows the value of each trade flow. The dark middle bar shows B's welfare in each scenario. Suppose A cuts off exports to B, as in the bottom left. B's welfare decreases to some fraction of its original value. This drop is the upper bound measure. Now, suppose that C and D increase their exports to B enough to raise B's welfare back to its original level. The compensation measure describes how much thicker each of those export flow arrows need to become to make B's welfare "whole" again.

To reiterate, the main advantages of the upper bound and compensation measures of dependence is that they directly estimate the opportunity cost of an interruption in trade across the entire economy and they take into account key features of the modern global economy. The upper bound measure indicates a ceiling on the total possible dependence in a bilateral relationship. It up-weights flows in sectors that are harder to substitute (ε) and flows in sectors that are intermediate inputs into downstream production (β). The compensation measure accounts for the third feature of the modern economy by incorporating how easily a state's trade network could compensate for an interruption from a particular partner. These two measures are directly interpretable as statements about welfare and they depend on weaker assumptions than existing measures that rely on aggregate statistics.

Of course, neither of these measures is entirely beyond reproach. That being said, using the two measures in tandem can lessen their limitations. The primary pitfall of the upper bound approach is that it may not be a tight bound on the true bilateral dependence. It could be that upper bound dependence is high but alternative partners are readily available, meaning that the true level of dependence might be lower than estimated. But in this case compensation dependence would likely be

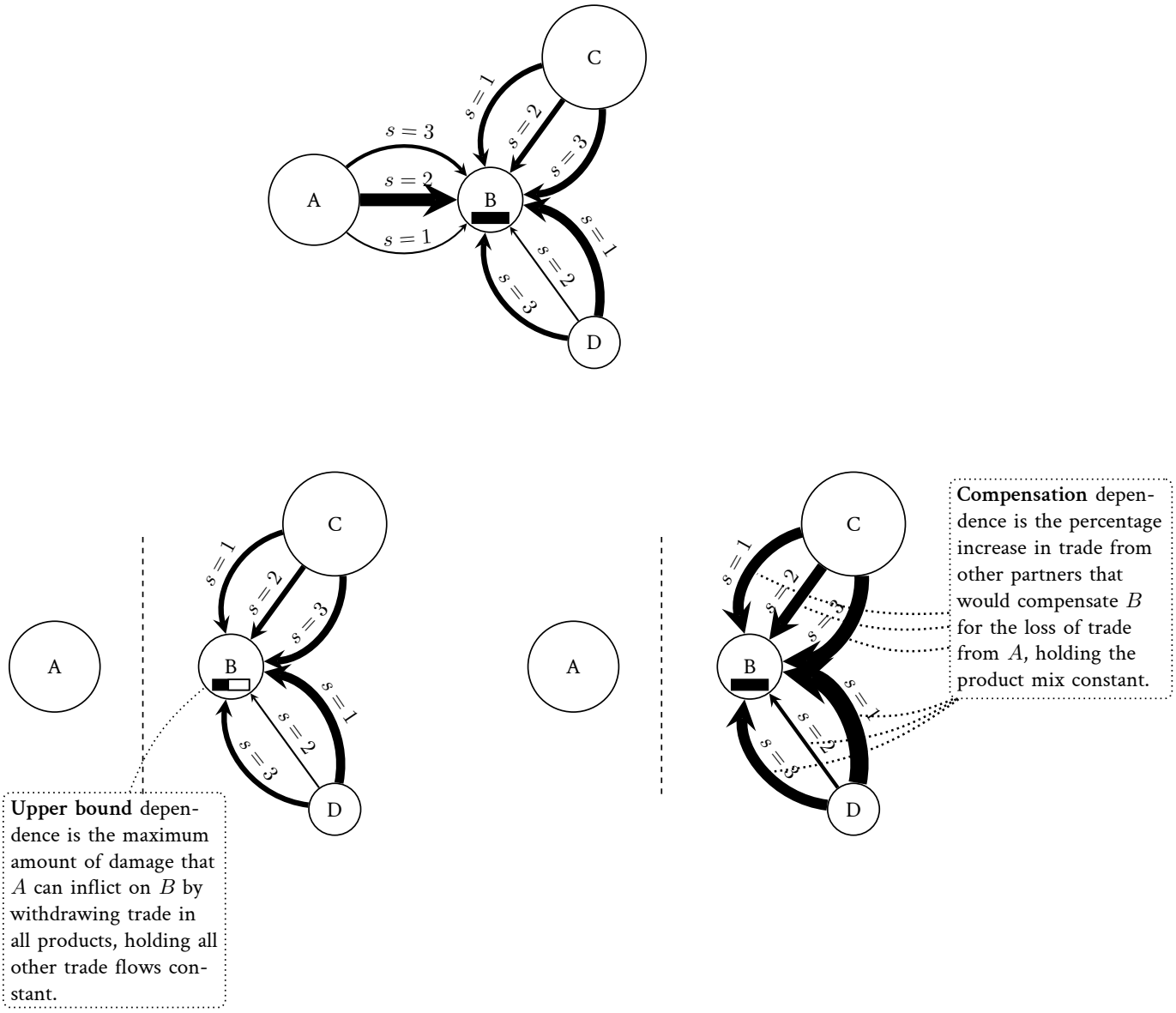

Figure 1: Upper Bound and Compensation Dependence. Four countries are depicted in each panel of the figure by circles. Trade volumes are depicted as directed edges, where the thickness of the edge is proportional to the value of country B's imports. The top inset of the figure depicts an initial scenario where country B imports three goods $s = \{1, 2, 3\}$ from three countries A, C, and D. The small rectangular bar placed inside the circle of country B depicts their welfare in the initial scenario; the bar is filled completely indicating their welfare starts at 100%. The lower left inset shows a scenario in which country A has ceased to export to country B. The rectangle is only partially filled indicating that country B's welfare has suffered. The magnitude of the decrease in welfare is the upper bound measure. Note that in this scenario the exports from countries C and D are unchanged. The lower right inset shows the compensation measure. The rectangle is now fully filled once again because the exports from countries C and D have been increased to compensate for the welfare losses caused by A's cessation of exports. The export mix, depicted by the relative thicknesses of the edges, remains unchanged in all scenarios.

relatively low. By contrast, it might be that upper bound dependence is low but the costs could be persistent due to a paucity of alternative trade partners measured by compensation dependence. The key assumption with compensation dependence is that the import mix is held constant in the counterfactual world. The importance of this deficiency is muted in cases where the upper bound dependence is low, because even when the assumption is very inappropriate the total amount of dependence puts a ceiling on the magnitude of the consequences.

Additionally, there are always margins of adjustment that determine welfare effects, which are not captured in our approach. For example, we cannot account for variation across countries or time in their ability to finance consumption by borrowing. We also cannot account for variation in the ability of countries to adapt using technological advances. We can partially account for variation in countries' ability to increase domestic production. If a country already has a large domestic value added in a particular sector, then our approach downweights that sector. This is similar to the intuition behind part of the aggregate statistics approach, which downweights trade flows for countries with larger GDPs. We would note that some of these margins of adjustment likely take a long time. For example, a country cannot rapidly advance technology to compensate for welfare losses. Ramping up domestic production also takes time and there is no guarantee that a country will reach the efficiency level of its original trade partners. This means that our measures can be thought of as short or medium term measures, before much longer term adjustments take place. Ultimately, we think the improvements offered by our approach more than make up for these shortcomings. Additionally, we would note that each of these criticisms applies as strongly to aggregate statistics approaches, too, which also do not have any way of accounting for these margins of adjustment.

Some related literature studies dependence and geopolitics under the heading of "geoeconomics."[18] Thoenig (2024) uses a structural gravity approach to estimate the opportunity costs of war from forgone trade and the destruction of production capacity. Clayton, Maggiori, and Schreger (2024a) model a hegemon who can coerce others by threatening to disrupt particular flows in global commerce. Clayton, Maggiori, and Schreger (2024b) derive a hegemon's power over a target country from a similar

[18] For a recent summary, see Mohr and Trebesch (2025).

underlying economic model to ACR and incorporate manipulation of finance as a coercive lever. Another related literature describes "weaponized interdependence."[19] This literature emphasizes the coercive leverage that the United States enjoys because of its central position in finance and information networks. Like us, they disagree with conventional wisdom about complex interdependence, but they de-emphasize trade flows as a key source of dependence. We find patterns contradicting conventional wisdom even in dyadic trade relations.

4 Data and Empirical Strategy

Recall that the expression for assessing welfare changes after a shock is $\hat{W}_{jt} = \Pi_s(\hat{\lambda}_j^{st})^{\eta_j^{st}/\beta_j^{st}\varepsilon^{st}}$, with year subscripts included. Here, we describe the data sources and calculations for each parameter. Our measures cover 76 countries for the years 1995-2020. We categorize flows using the 26 industries from the OECD TiVA 2023 data set, which are aggregations of ISIC Rev 4 classifications.

4.1 Trade elasticities

Trade elasticities describe the degree to which imports into country j from country i change as iceberg costs between the two countries, τ_{ij}, change. The exact origin and characterization of this elasticity can depend on the particular trade model chosen. Fortunately, Caliendo and Parro (2015) show that we can recover an estimate of these elasticities from any model that results in a gravity equation for trade, including the broad class of models from ACR. The procedure uses two inputs – trade flows and tariffs – to estimate ε. The intuition of this procedure is to express trade flows between three countries as an odds ratio "triplet." This is especially useful because it simplifies an expression of ε as a function of trade flows between the three countries, i, j, k, and a directed-dyad-specific trade cost: tariffs (τ).[20]

[19] Farrell and Newman (2019), D. W. Drezner, Farrell, and Newman (2021).

[20] The expression is $\frac{X_{ij}X_{jk}X_{ki}}{X_{ji}X_{kj}X_{ik}} = (\frac{\tau_{ij}\tau_{jk}\tau_{ki}}{\tau_{ji}\tau_{kj}\tau_{ik}})^{\varepsilon}$, and note that we have omitted time and industry subscripts for readability. This means that symmetric trade costs (eg distance between countries) and monadic variables (eg the size of their economies), which both affect trade flows, will cancel out, because they appear in both the numerator and denominator. This approach also entails an orthogonality condition, which says that, if we express iceberg costs as a function of tariffs, symmetric and monadic variables, then the error term is orthogonal to tariffs.

With trade flow and tariff data, the triplets can be constructed and ε can be estimated using OLS.[21]. Theoretically, elasticities must be negative. An increase in iceberg costs should decrease trade. In practice, with OLS, estimates are sometimes positive.[22] Existing work either drops these estimates or replaces them with a comparable estimate. We use a Bayesian regression to ensure that estimated elasticities are negative. We set the prior distribution for the regression coefficients to be normal, with a mean of -4.5[23] and a standard deviation of 1. We constrain the posteriors to have a maximum of -0.25 and an unbounded minimum. This ensures that we get theoretically sensible elasticity estimates that still have meaningful variation across time and industry.[24]

Our estimates of ε are industry-specific, meaning there can be a different elasticity for each industry. Elasticity estimates are *global*, meaning that they are not importer or exporter or dyad-specific. They vary by year, and show substantial variation across time.[25] The trade flow and tariff data both come from the UNCTAD Trade Analysis and Information System (Trade and Development 2024).

4.2 Consumption Shares, Import Penetration, and Intermediate Products

The variable λ_j^{st} describes the share of domestic expenditure in sector s in year t. In other words, it is one minus the import penetration ratio, where the import penetration ratio is the share of total expenditures in an industry that are from imports. We calculate λ_j^{st} as follows (again dropping industry and year subscripts for readability): $1 - \frac{\text{Imports}}{\text{Production - Exports + Imports}}$. The import/export values are totals, across all partners.

Recall, $\lambda_j^{st'}$ refers to a possible counterfactual where one of j's partners, i, cuts off exports of a certain product to country j, with a corresponding value of x_{ij}. For our upper bound measure, λ_j' therefore equals $1 - \frac{\text{Imports}-x_{ij}}{\text{Production}-\text{Exports}+\text{Imports}-x_{ij}}$. Data for domestic production and bilateral imports and exports come from the OECD's Trade in Value Added (TiVA) dataset. The consumption shares (η_j^s) are calculated from the same data and defined as $\frac{\text{Production}-\text{Exports}+\text{Imports}}{\text{Total Production}-\text{Total Exports}+\text{Total Imports}}$ where the

[21] For alternate methods for estimating trade elasticities, see also Boehm, Levchenko, and Pandalai-Nayar (2023), Feenstra (1994), Head and Ries (2001), and Romalis (2007). For an overview see Bohlmann (2021).

[22] This is a well established challenge in the economics literature. See Boehm, Levchenko, and Pandalai-Nayar (2023).

[23] The approximate sample average from Caliendo and Parro (2015).

[24] In practice, our analyses and conclusions are similar if we use other approaches to estimating elasticities. See appendix.

[25] See appendix.

term "Total" aggregates across all sectors and trade partners by state-year.

Also recall that β_j^s is the share of domestic value added production, measured at the country-year-industry level. The value of β_j^s reflects the importance of intermediate products in that sector. These measures also come from the TiVA dataset.[26]

5 Comparison of measures

Are the upper bound and compensation measures actually different from measures based on aggregate statistics? Here, we show that the answer is yes, and we provide further construct validity for our measures by showing that they diverge from aggregate statistics measures in ways that we would expect. We focus here on comparing our measures with the Oneal and Russett (OR) measures, since they are most commonly used across a wide range of applications (Gartzke and Li 2003).[27]

Figure 2 shows one visualization of how the compensation and OR measures relate and how they have changed over time. For each country, we calculated the maximum value of each dyadic dependence measures for each year. This monadic quantity is a good starting point because it asks "of all a country's dyadic dependencies, what is the most dependent they are on a single partner?"[28] Since our measures and the OR measure have difference scales, we normalized them to the unit interval. Each pane shows approximately one decade in our sample.

The two measures start fairly well-correlated. Many observations – and the line of best fit for the points – are quite close to the 45-degree line. In the 2001-2010 time period, this begins to change. Clusters of observations move away from the 45-degree line, in both directions. The line of best fit becomes shallower as the measures begin to diverge for many countries. This trend gets even more stark from 2011-2020. Divergence between the two measures increases.

The increasing divergence in measures over time makes clear why our measures have substantial

[26] Note that TiVA sometimes has zero or negative values for the domestic share of value added in production. For these observations, we replace the value with the global mean for the domestic value added of production for that industry-year. This is akin to assuming that the zero or negatively-value added share observations are not representing countries that have radically different production technologies from the rest of the world.

[27] We find similar results and trends comparing our measures with other aggregate statistics measures. See appendix.

[28] For all analysis using maximums, we can show similar results using average dependence levels. We can also show similar results using our upper bound measure. See appendix.

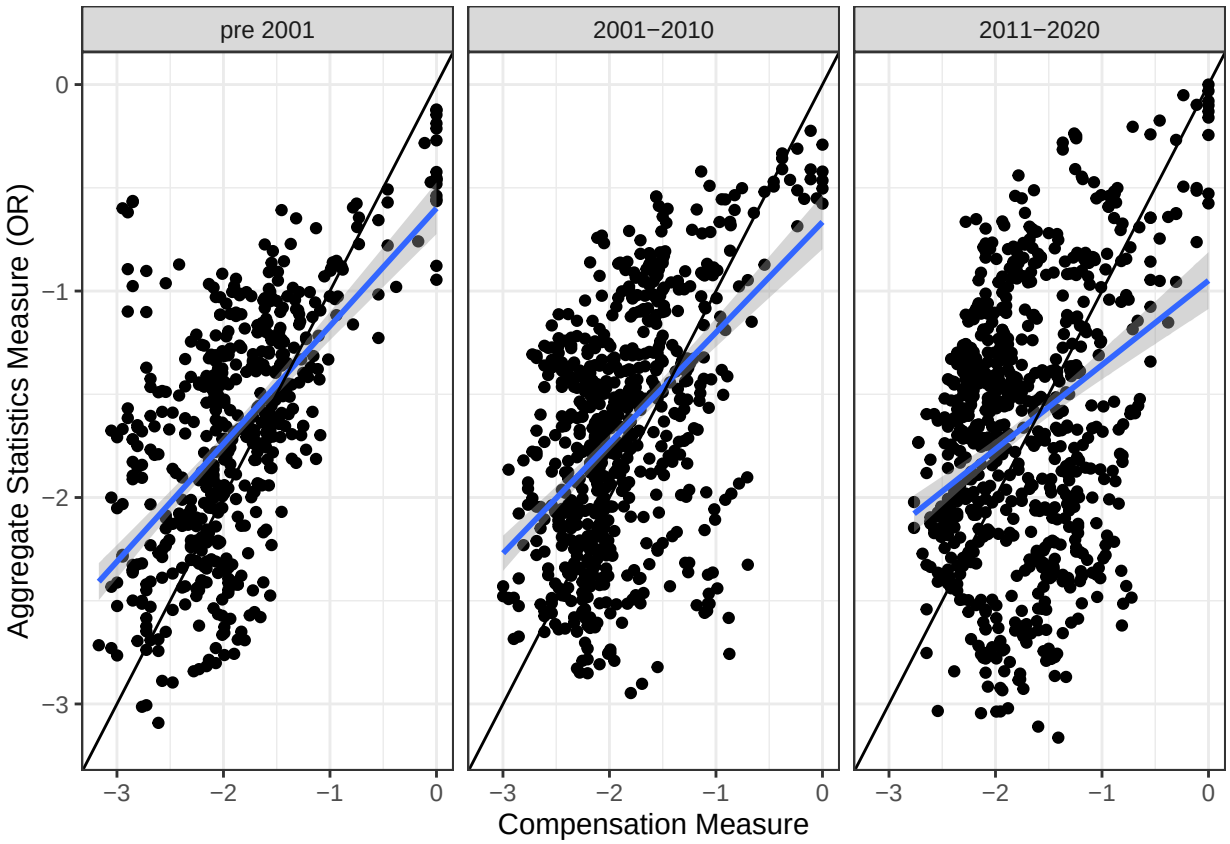

Figure 2: Compensation dependence versus Oneal and Russett aggregate statistics measure, compared over three periods. Each dot represents a country's maximum level of dependence for a given year, across all its partners. The measures are normalized to the unit interval to ensure comparability of the scales across measures. Each point represents, for every state, its maximum dependence across all trade partners in a given year, logged.

advantages over conventional approaches. There is much variation across time, industries, and countries in the three key drivers of divergence between the two measures: accounting for substitutability, intermediates trade, and the availability of alternative trading partners. Consider intermediates trade first. The percent of trade made up of intermediates varies substantially across countries and it varies across time, within country. The United Nations classifies trade flows in particular by Broad Economic Categories (BEC): consumption goods, intermediate goods, and capital formation.[29] BEC categorizations therefore give a broad measure of how much of a country's imports and exports fall into each use category.

Countries vary greatly in the percentage of their imports consisting of intermediates. This percentage ranges from roughly 6% to 25%, with a mean and median of roughly 15%. There is also a great deal of within-country variation over time, in terms of where countries fall in this distribution. To see this, we ranked each country by year in terms of the percentage of their imports made up of intermediates. From 2010-2021, 48 out of 78 countries in the BEC dataset changed their rank by 5 places or more. Thirty two countries changed their rank by 10 places or more! The import profiles of many countries, in terms of the percentage of their imports made up of intermediates, changed a great deal over that decade. Some increased this percent, while others decreased, and this movement was spread all over the distribution.[30] There were similar changes in the preceding decade, from 1998-2009, though slightly smaller in magnitude.

The tremendous amount of variation across countries, industries, and time in the concentration of trade among partners helps drive divergence between our measures and conventional ones. Some countries import a substantial amount of value added for a particular industry from a small number of partners, while others' imports are spread over many partners. The typical country imports 80% of its value added in mining and energy from only 3-4 partners. Though, for some countries, their mining and energy imports are spread over as many as 13 partners or as few as 1. For the average country, 80% of their food imports are spread over 12 partners, but this too ranges from 2 to over 25, depending on

[29] The first two categories are self-explanatory. Capital goods are used in production but not *used up*. E.g. a can of soup is the consumption good; the tin for the can is an intermediate; the machine that seals the lid is capital.

[30] See appendix for full descriptions and plots.

the country. The dispersal of imports across partners also varies over time.[31]

Variation across industries and time in estimated elasticities of trade also contributes substantially to divergence in measures. From 1995-2021, the industry with the largest over-time variation is "Chemical and chemical products" (C20). It has a minimum elasticity estimate of approximately -18.3 in 2021, compared to -1.8 in 1995. In contrast, the industry "Mining and quarrying, energy producing products" (B05_06) had a much tighter range over time, with the difference between its minimum and maximum being only 0.7.

6 Global Dependence and Interdependence

6.1 Dependence over time

Has dependence increased over time? The presumption of much existing work is that the answer is yes. To describe global dependence, we again look at the maximum value of the compensation measure for each country-year observation across its partners. This approach asks "Of all the countries you are dependent upon, how dependent is your most dependent relationship?" This is a good way to summarize dependence because the maximum dependency represents a kind of worst case scenario for that state. It describes the height of potential economic coercion for that state, since no other trade partner can do more damage. The maximum dependency is also arguably more relevant than, for example, the mean dependence across all of a state's trading partners. A small decline in dependence on a dozen trading partners might be more than cancelled out by a large increase in dependence on a single large partner. Looking at the distribution of maximum dependencies is also theoretically grounded. Ikenberry (2001) and Keohane (1984) have argued how hegemonic power profoundly shapes the logic of international cooperation. Studying maximum dependencies describes the international structure of states' dependence on hegemonic power(s).

Figure 3 plots trends in maximum dependence according to the compensation and the OR measure over time. Since there are many observations per year, we plot the mean of the measure across

[31] See appendix for full descriptions and plots.

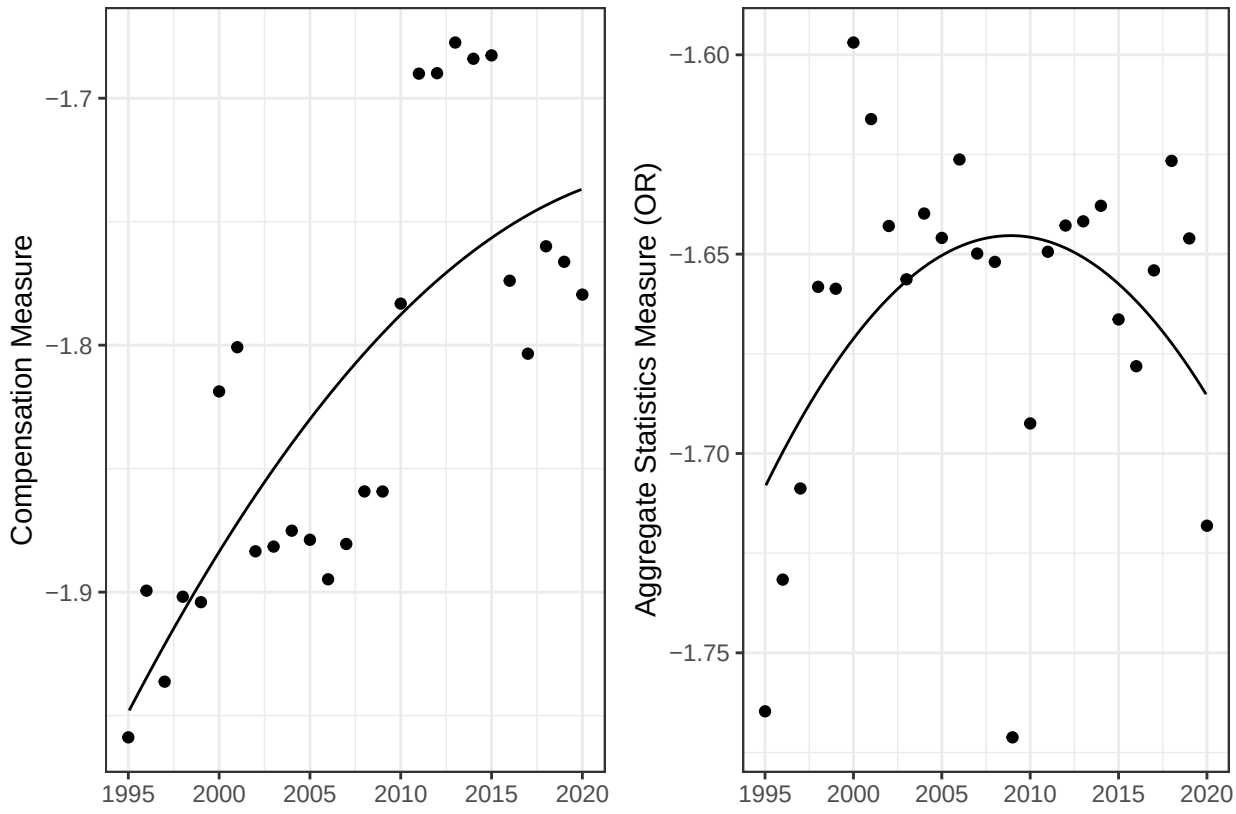

Figure 3: Bin scatter of the max measure after taking the natural logarithm. Both variables are normalized to the unit interval before taking logs to equalize their support and facillitate comparison.

countries for each year and also include a third degree polynomial line to make trends more readable.[32] We take the logarithm due to the high skewness in the measures due to a few states being highly dependent. The left side shows the maximum compensation dependence measure. The right side shows the maximum OR measure. Both measures are normalized to the unit interval to equalize their support, and the natural logarithm is applied to both measures because of their highly skewed distribution. The vertical axis is negative since it shows the natural log of a number between zero and one.

Maximum compensation dependence has generally increased over time. OR dependence has also increased, but in a more non-monotonic way. In particular, the OR measure is sensitive to years in which a global crisis caused a temporary decrease in trade as a share of world GDP. For example, OR dependence is quite low in 2008/2009 because of the financial crisis and again in 2020 as COVID decreased trade. However, lower levels of trade may indicate lower levels of dependence according to the OR measure, they do *not* necessarily mean lower levels of dependence according to our measures. Suppose a shock (like the financial crisis or COVID) interrupted nearly all trading relationships. In some ways, dependence has gone down since a country now trades less with each partner and overall. But at the same time, dependence on the remaining relationships may have increased substantially, even if aggregate trade flows are lower. Dependence is especially likely to increase during a crisis if potential alternative partners withdraw from global trade. The compensation measure is less sensitive to changes in global trade volumes.

[32] We follow procedures for optimal binned scatter plots from Cattaneo et al. (2019) implemented via the R package `binsreg`.

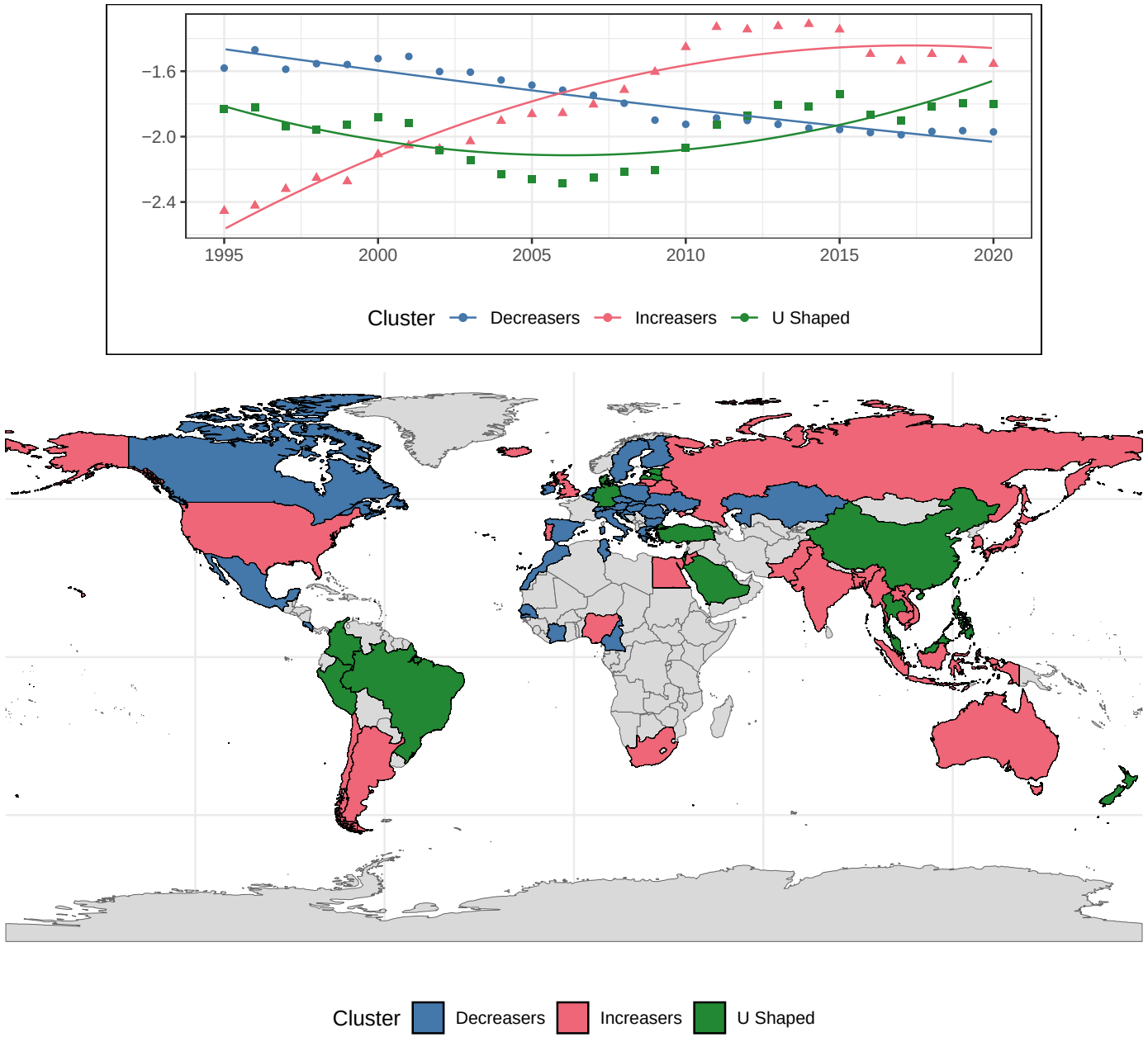

Figure 4: Clustering countries by their trends in compensation dependence. Blue countries have decreasing dependence. Red countries have increasing dependence. Green have U-shaped trends.

Furthermore, there is immense heterogeneity across countries in how compensation dependence has changed over time. Figure 4 shows results from a clustering algorithm designed to detect how changes over time differ across groups of countries.[33]. We found three general types of trends: countries whose compensation dependence monotonically increased, monotonically decreased, and whose dependence was U-shaped, decreasing and then increasing. What explains and characterizes the three groups of countries? It turns out that the three trends have a common cause: increased dependence on China.

[33]Our preferred clustering technique identifies three clusters using a partitional approach with centroids calculated by barycenter averaging under data time warp and distance measured via global alignment kernels. We implement the clustering using the R package `dtwclust`.

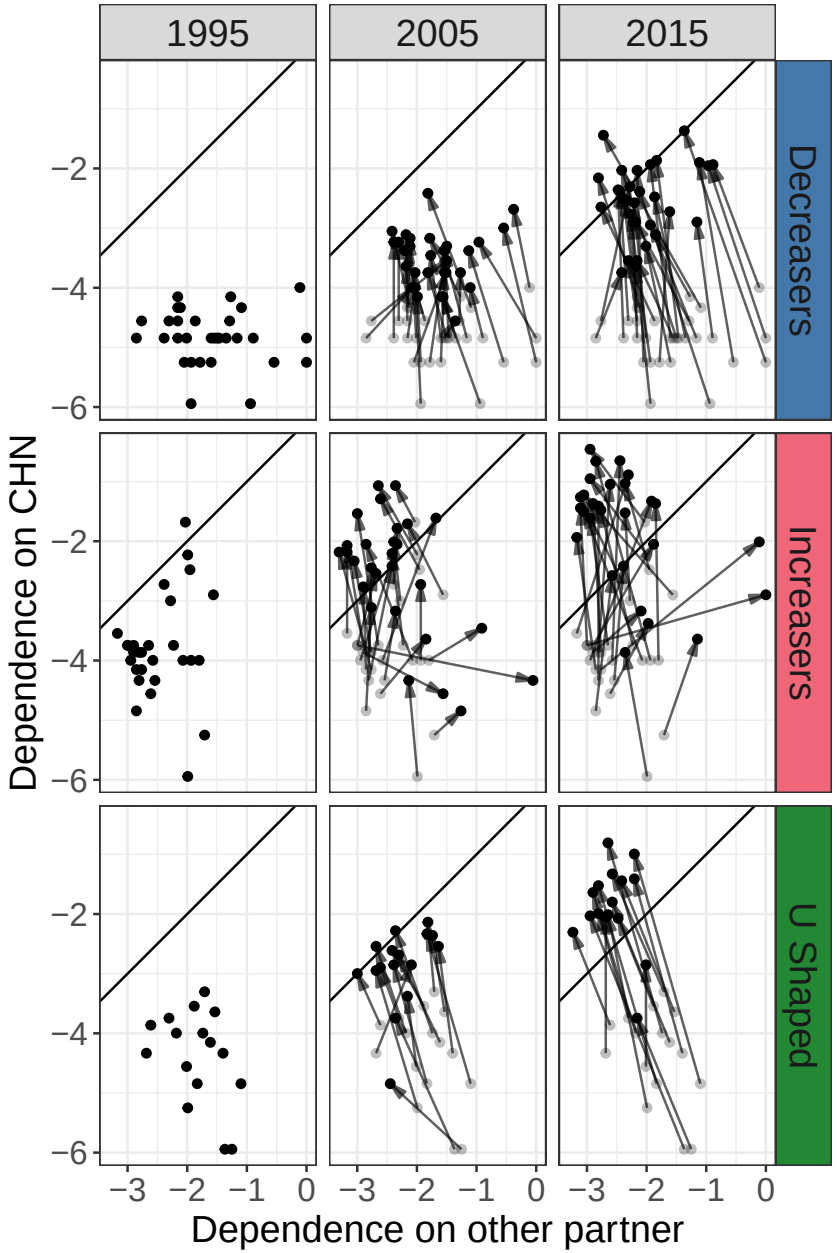

Figure 5: Vectors indicating change over time in a country's dependence on China (vertical axis) and its maximum dependence on any other (non-China) partner. Lines connect the initial values for each state in 1995 to their values in the year shown. The diagonal black line is a 45 degree line. Points above the line are most dependent on China. Dependence is plotted after normalization to the unit interval and after taking the natural log.

Figure 5 illustrates the role of China in explaining these patterns of trade dependence. The vertical axis measures each state's dependence on China while the horizontal axis measures its greatest dependence on any partner other than China. Often, this is the United States, but not always. The first column shows each country's starting point in 1995. Points above the 45 degree line are most dependent on China while points below the line are most dependent on some other state. The middle and right columns show how each country's dependence on China and the other partner has changed in that time period. We have broken this plot out by countries, grouping them into the same groups as in Figure 4. This helps show why the trends differ for each cluster of countries.

Consider first the group of states with decreasing dependence over time. These states (especially European states) have historically been relatively dependent on traditional powers other than China. Their dots tend to cluster in the lower right portion during the earlier years. Yet, over time, their dependence on China increases. Dependence on their original traditional partners has fallen as China has become a more productive alternative trade partner. As indicated by the vectors in the middle and right columns, these states approach but generally do not cross the 45 degree line from below.

Consider next the group with increasing dependence over time. States whose dependence is increasing tend to have always had relatively strong economic connections with China. Countries in this cluster cross the 45 degree line relatively early and continue moving towards the northwest corner of the graph. These places have become more dependent on China during its economic rise. Finally, the U shape states seem to have both patterns occurring simultaneously. Initially, China's rise reduces their dependence on traditionally powerful trade partners like the United States. But then at some point China becomes a superior trading partner causing dependence on China to increase. These points begin relatively far below the 45 degree line, but they quickly cross it and then move northwest.

The story of dependence in the global economy between 1995 and 2020 is the story of competition between the United States and China. As illustrated above, dependence on China has grown dramatically over time. Figure 6 shows how the measure used gives very different answers for when, how fast, and why this change occured? The OR measure shows a weak, slow decline in dependence on the

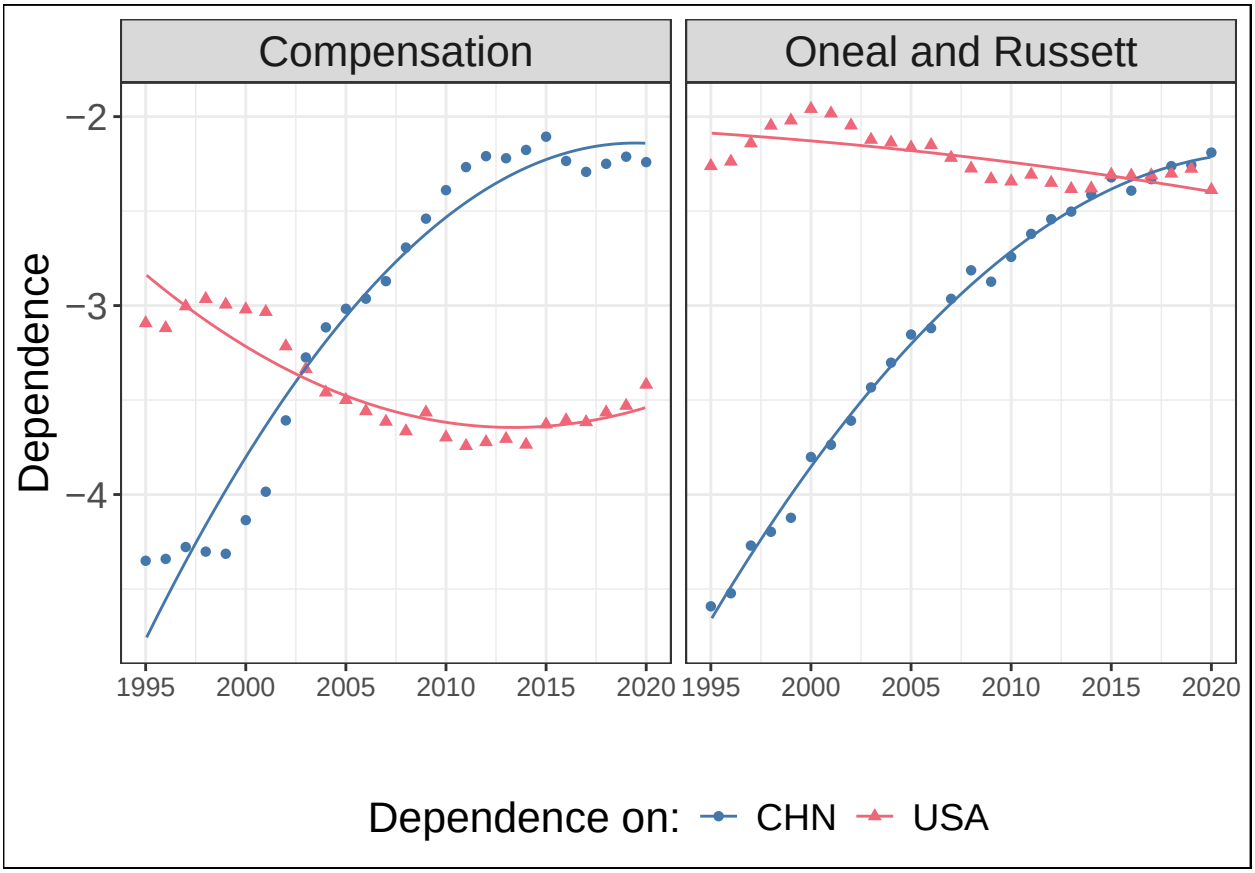

Figure 6: Global dependence on USA and CHN over time

US. Since trade with most countries increases with the US over this time, the OR measure (because of how it is constructed) can only explain this by saying that trade with the US has not risen as quickly as GDP growth in its partner countries. The compensation measure tells a different story. The decline in dependence on the US starts much earlier and is much steeper. The US fell further, faster. This means that the additional changes that our measure accounts for – trade in intermediates, sector level trade elasticities, and alternative trade partners – combined to undercut other countries' dependence on the US. The decline is not simply explained by other countries' GDP growth.

6.2 Interdependence over time

How interdependent is the world? Figure 7 illustrates the entire dyadic dataset by averaging dependence across years for each pair of states. The horizontal axis shows sender states and the vertical axis shows targets. The color of each cell represents the compensation dependence of the "target" state on the vertical axis on the "sender" state on the horizontal axis. Darker, redder squares mean that the target is more dependent on the sender. The order of states is determined by their average dependence as a sender, from left to right.

The plot highlights the extent to which dependence is dominated by a small number of great power sender states. If trade were perfectly symmetric and interdependent then the matrix would also be symmetric. Clearly it is not – there are many brighter colors above the diagonal than below. Most states are highly dependent on China, the US, or Germany. In turn, these great powers depend on relatively few other partners. Notably, states of the former Soviet Union including Belarus, Kazakhstan, and Ukraine tend to be particularly dependent on Russia. The largest dependencies in the entire dataset are in South Asia – Japan and Cambodia are highly dependent on China. These findings are not necessarily at odds with the standard narrative about interdependence. After all, in a hegemonic world theorists would expect some degree of concentrated economic power. What seems to matter more to the standard theory is whether the global economy is becoming more interdependent over time.

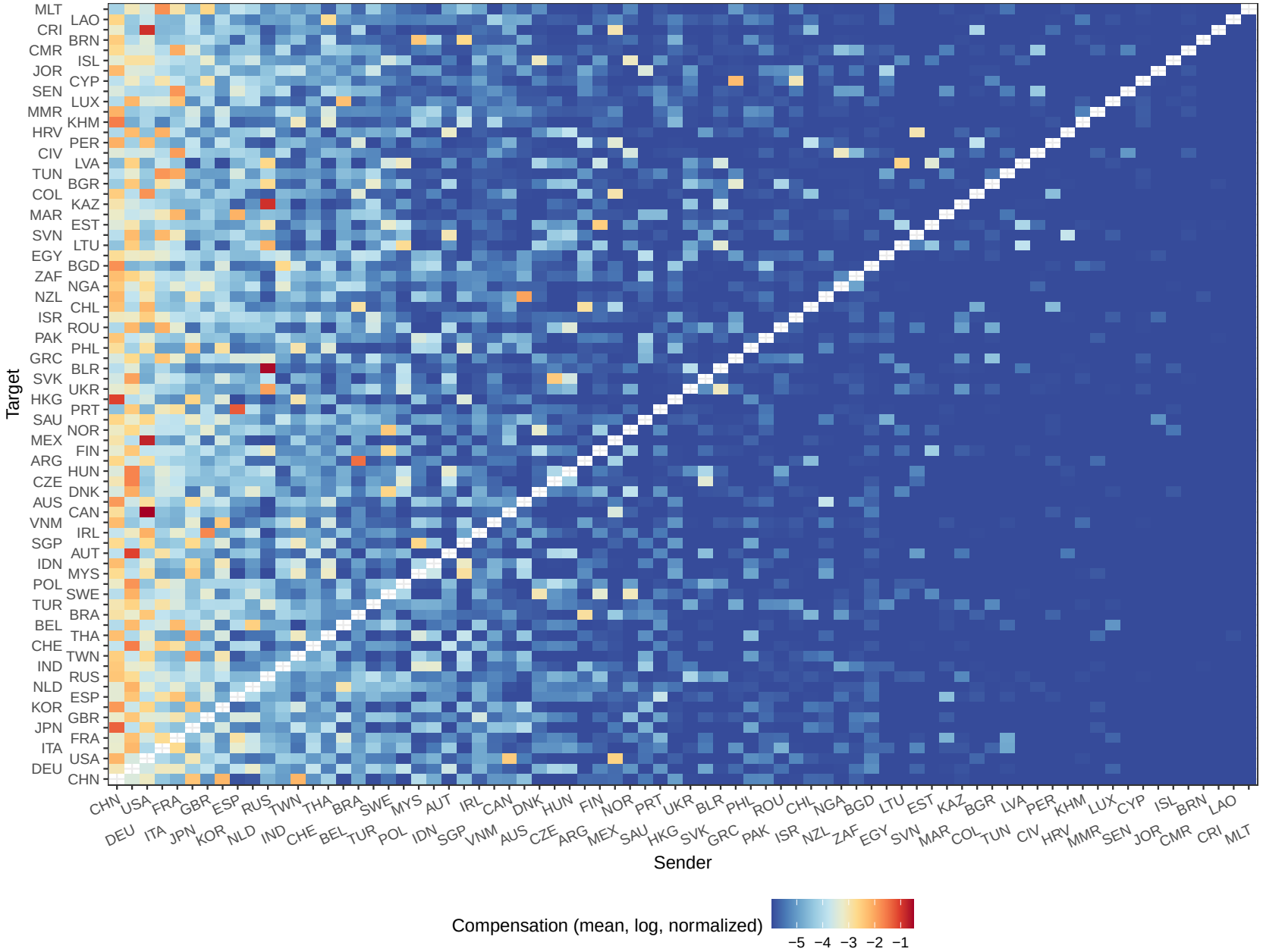
Target
Sender
MLT CRI CMR JOR SEN MMR HRV CIV TUN COL MAR SVN EGY ZAF NZL ISR PAK GRC SVK HKG SAU MEX ARG CZE AUS VNM SGP IDN POL TUR BEL CHE IND NLD KOR JPN ITA DEU
LAO BRN ISL CYP LUX KHM PER LVA BGR KAZ EST LTU BGD NGA CHL ROU PHL BLR UKR PRT NOR FIN HUN DNK CAN IRL AUT MYS SWE BRA THA TWN RUS ESP GBR FRA USA CHN
CHN USA FRA GBR ESP RUS TWN THA BRA SWE MYS AUT IRL CAN DNK HUN FIN NOR PRT UKR BLR PHL ROU CHL NGA BGD LTU EST KAZ BGR LVA PER KHM LUX CYP ISL BRN LAO
DEU ITA JPN KOR NLD IND CHE BEL TUR POL IDN SGP VNM AUS CZE ARG MEX SAU HKG SVK GRC PAK ISR NZL ZAF EGY SVN MAR COL TUN CIV HRV MMR SEN JOR CMR CRI MLT
Compensation (mean, log, normalized)
−5 −4 −3 −2 −1

Figure 7

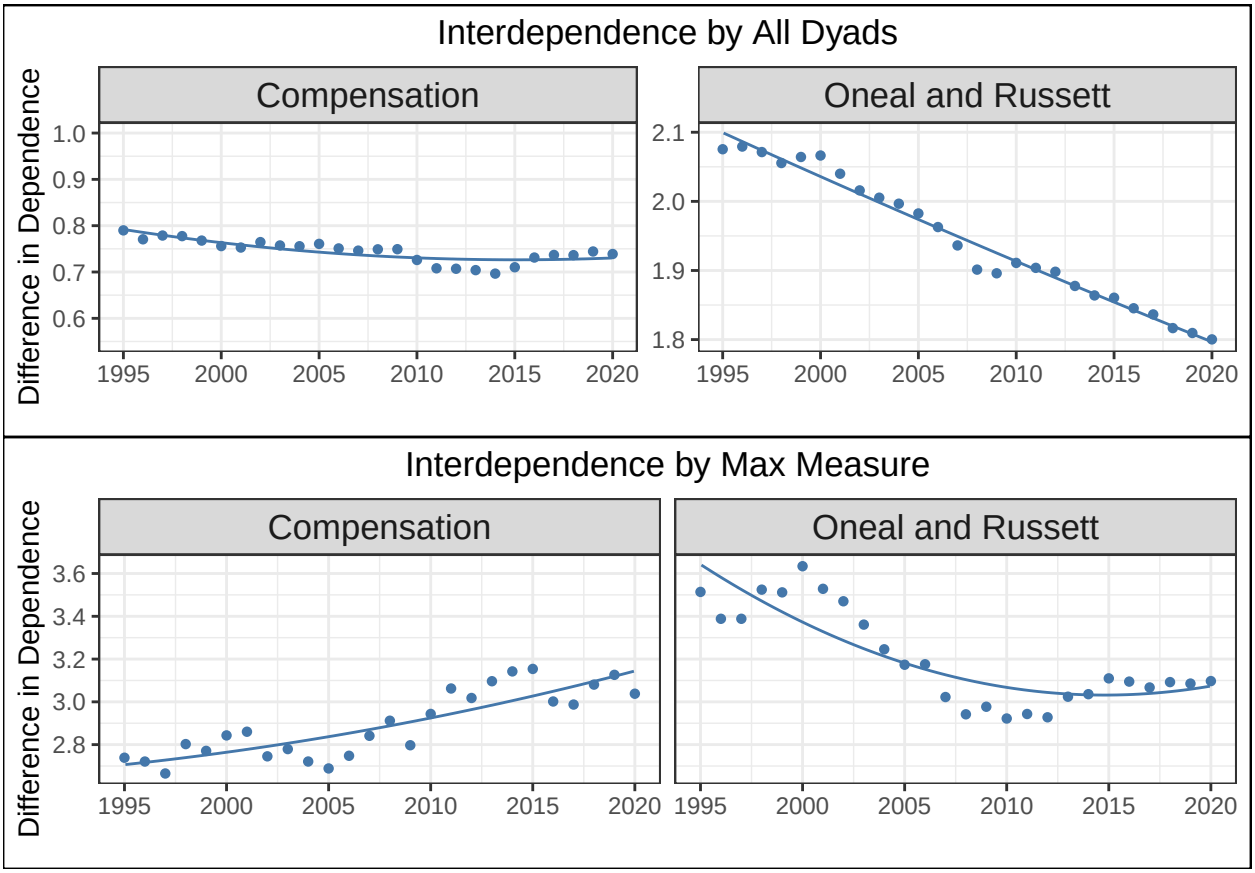

Figure 8: Interdependence over time. Points show differences in directed dyadic dependence over time, averaged across dyads. The top pane shows this difference for all dyads. The bottom pane shows this for maximally dependent dyads.

How has interdependence evolved over time? As in the previous section, we can investigate whether dependence is becoming more symmetric for all dyads. The top two panels of Figure 8 shows trends in interdependence across all dyads, using the compensation measure and the OR aggregate statistics measure. For each dyad, we calculate the difference in i's dependence on j and j's dependence on i. We then take the absolute value of this difference, for each measure. As before, both measures are normalized to the unit interval and log-transformed before taking differences. Smaller values reflect more interdependence.

For the aggregate statistics measure, the difference in dependencies for a dyad are steeply decreasing over time. This would indicate that interdependence is rising quickly. This is not the case for compensation dependence. Differences in compensation dependence are very weakly decreasing over

time.

Arguably what matters more for theories of international relations is the relationship of each state to the hegemon and other great powers. Thus, we also need to investigate whether interdependence is increasing according to the maximum degree of dependency for a country. The bottom two panels of Figure 8 makes the same calculations for differences in dependencies, but this time using only the maximum dependency for a country, as in the preceding section. As above, we take each country and find the partner on whom they are most dependent. Then we take the difference in the dependency measure for that dyad. In other words, this asks "Who are you most dependent on, and how dependent are they on you?" It therefore describes trends in interdependence, when looking only at a country's most dependent relationships.

Compensation dependence tells a very different story from the aggregate statistics. Once again, the OR series declines over time, showing that interdependence is rising even among highly dependent partners. But the compensation measure actually shows the world becoming less interdependent among maximally dependent relationships. Countries' maximum values of compensation dependence are increasing, and those partners that they greatly depend on are not becoming corresponding more dependent on them.

One interpretation of these two results is that symmetry in compensation interdependence among all dyads is rising because compensation interdependence has become greatly imbalanced when looking at maximimum dependencies. Higher dependence on states like China in general is increasing the symmetry of dependence between states, by comparison. For example, consider two States called A and B. In 1995 an interruption in trade between the two might have caused more economic pain in State A than in State B according to compensation dependence. However, by 2015 both states trade extensively with China. Although they are both now more dependent on China than they ever depended on any other state, an interruption between States A and B is now a relatively minor problem that can be solved by increasing imports from China by a small percentage. In other words, it looks like A and B are closer to parity in their dependence on each other, only because they have both become tremendously dependent on another partner. Figure 9 shows that this describes the experience

of Japan, Korea, and the US as a potential target. This figure shows compensation dependence on China and the highest non-China potential sender for each state. In each panel dependence on non-China states is displaced by dependence on China, and the dependence on China hits a higher peak than with any other state.

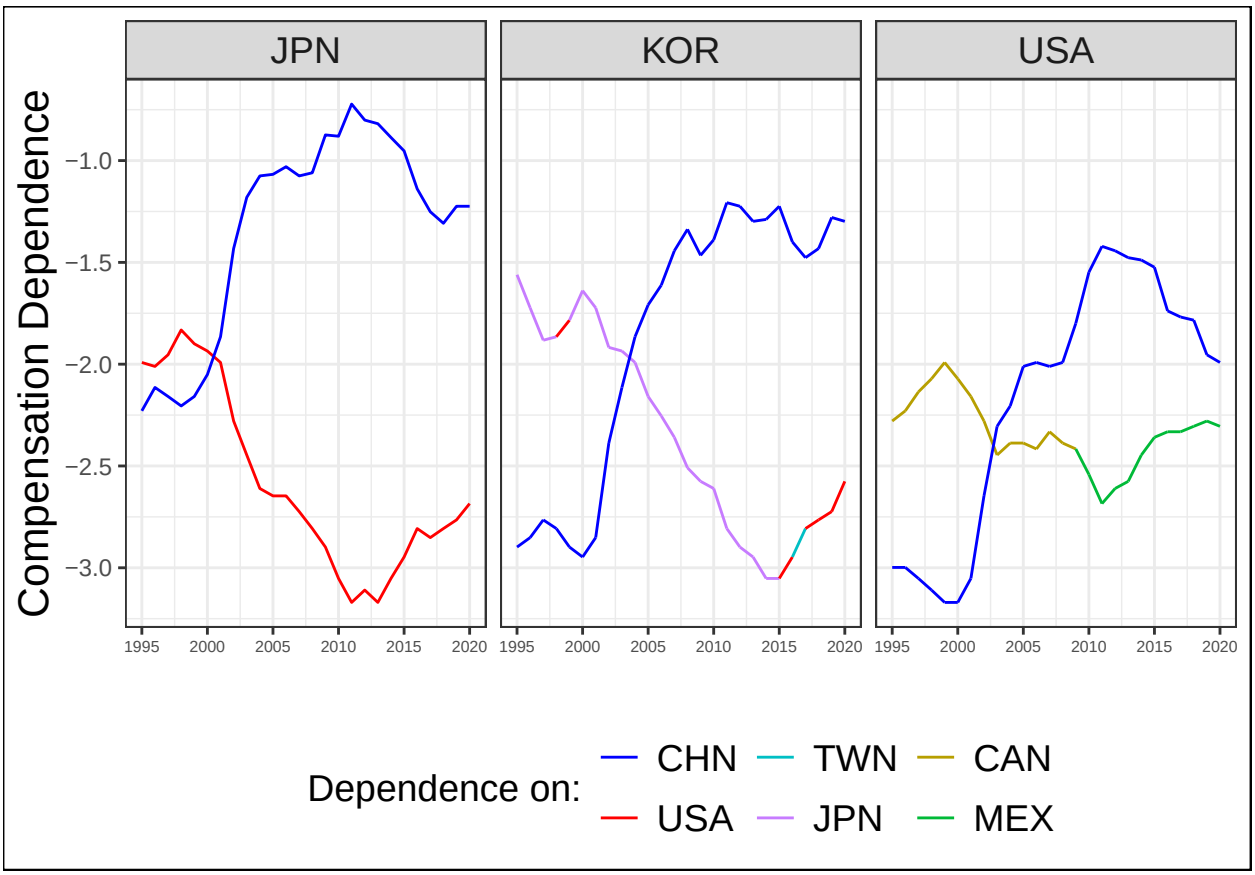

Figure 9: Example for dependence of Japan, Korea, and the USA on various partners. These examples show how interdependence can fall among all dyads even while it rises for when looking at maximum levels of dependence.

7 Is Chinese Foreign Assistance a Conduit of Dependence?

One pattern in the preceding analysis is that other countries' dependence on China rose rapidly. Why? A related, broader question is: to what degree can states manipulate others' dependence on them and their own dependence on others?

Whether states can influence dependencies has long been recognized as an important question.

As Waltz (1979) wrote: "states seek to control what they depend on or to lessen the extent of their dependency. … their imperial thrusts to widen the scope of their control and their autarchic strivings toward self-sufficiency" (p 106). More recently, the COVID-19 pandemic laid bare the degree to which many supply chains had links concentrated in certain countries.[34] The question has taken on added urgency as the backlash against globalization in many developed Western countries has made policymakers more eager to manipulate trade policy for geopolitical gains. In the opening salvos of the Trump administration's trade war, the President used high tariffs to decrease imports from targeted countries.[35] As D. Drezner et al. (2023) describes, "a bipartisan elite consense has calcified this fear [of excessive dependence]."

China has also proved willing to manipulate trade for political purposes. For example, China retaliated against countries that hosted unsanctioned visits from the Dalai Lama with policies that decreased imports from those countries into China.[36] The specter of economic coercion via trade dependence loomed so large that the European Union preemptively armed itself with a process designed to fast-track retaliatory tariffs against economic coercion. The Anti Coercion Instrument has been called a "bazooka" intended to deter coercion in the first place.[37]

Countries try and inoculate themselves from this type of leverage by decreasing their dependence on others. The Chinese Communist Party touts "national independence" and "self-reliance" as among their key achievements and guiding aspirational goals for policymaking. The CCP's plenary session in 2021 concluded with the adoption of a landmark, overarching resolution in which these terms appear three times in the preamble alone.[38] The "Made in China 2025" initiative stress "indigenous innovation" and "self-sufficiency" as core motivations for policies designed to replace foreign-origin technology with Chinese components.[39] The U.S. CHIPS act mirrors Chinese techno-nationalism

[34]Sutter et al. "COVID-19: China Medical Supply Chains and Broader Trade Issues." Congressional Research Service. Dec. 23, 2020. https://sgp.fas.org/crs/row/R46304.pdf.

[35]Fajgelbaum et al. (2024).

[36]Fuchs and Klann (2013).

[37]Bounds, Andy. "EU prepares to hit Big Tech in retaliation for Donald Trump's tariffs." Financial Times. February 5, 2025.

[38]"Resolution of the CPC Central Committee on the Major Achievements and Historical Experience of the Party over the Past Century," November 16, 2021.

[39]Wübbeke et al. (2016).

with its emphasis on using illiberal policies to decrease US dependence on others for semiconductors and other key goods.[40] Former U.S. Treasury Secretary Yellen touted "friendshoring" and "allyshoring" as steps to move U.S. supply chains away from China and other countries thought of as adversaries.[41] There is much debate over whether such efforts can work. The depth of "de-coupling" between the United States and China remains unclear.[42]

The above examples focus on how states decrease their dependence on others. But equally important is how states try to make others dependent on them in the first place. Sometimes, states use coercive interventions to facilitate dependence.[43] More often, states use positive inducements to plant the seeds for the recipient to become more dependent on the country offering the inducement. Here, we focus on the effect of Chinese foreign assistance. China's Belt and Road Initiative (BRI) is one of the most significant examples of assistance and investment policy initiatives that could increase dependence. Announced by President Xi in 2013, it generally consists of financing and direct assistance for major infrastructure projects in partner countries.

While part of its original impetus was to provide an outlet for excess production capacity, Chinese foreign assistance and the BRI have become understood as a broader initiative to provide an alternative to the US-led international order.[44] The goals of these policies are multifaceted and complex, but many analysts think that they are intended to increase China's influence over recipients. Initial fears focused on whether Chinese finance would lead to "debt-trap" diplomacy, where recipients became beholden to China because of unfavorable loans.[45]

There are many ways that Chinese assistance could increase dependence. The investment projects themselves could increase exports from China into recipient countries, especially via greater flows of goods directly associated with infrastructure and construction.[46] Investments in infrastructure, like ports, can greatly lower the costs of trade (Brancaccio, Kalouptsidi, and Papageorgiou 2024). Highway

[40] Luo and Van Assche (2023).
[41] Kollewe, Julia. "Friendshoring: what is it and can it solve our supply problems?" The Observer. Aug. 6, 2022.
[42] Hirsh, Michael. "The U.S. and China Haven't Divorced Just Yet." Foreign Policy. June 22, 2022.
[43] Berger et al. (2013).
[44] Callahan (2016), Huang (2016)
[45] Lai, Lin, and Sidaway (2020).
[46] "How Is the Belt and Road Initiative Advancing China's Interests?" Center For Strategic and International Studies, 2024.

and rail networks can also improve transportation within the state, further increasing the efficiency of trade (Redding and Turner 2015). Kohl (2019) uses a general equilibrium gravity model to estimate the effects of reduced trade costs from BRI and potential free trade agreements on value added trade. They both have positive effects on Chinese trade with connected parters. Yu et al. (2020) find that BRI involvement increased the degree to which exports from China to a recipient matched predictions from a gravity model. Broz, Zhang, and Wang (2020) find a positive association between trade with China and leaders' decisions to attend a prominent BRI conference. Clayton, Maggiori, and Schreger (2024a) also describe the joint effects of lending and trade in a geoeconomic model. A recipient country might import more from China, because this endogenously raises their costs from defaulting on loans from China. This, in turn, relaxes constraints on the amount and terms of Chinese lending to the recipient.

The potential effects of Chinese assistance are also indirect through their impact on other sectors. In canonical models of trade,[47] only the most productive firms can justify the up-front expenses needed to make contacts abroad to facilitate exports. Overcoming fixed costs is potentially "contagious" across firms or even industries. Once one firm overcomes the hurdles to exporting to a particular destination, this can make it easier for another firm to do so. In China, where state-owned enterprises (SOEs) play a large role in exports, this contagion could be even more pronounced. In a fully competitive market, firms are loathe to share insights about how to better take advantage of export markets, since doing so can only hurt them. In a centrally planned market, sharing experiences and information across SOEs is a good thing from the central planner's perspective. Early firm-level analysis of Chinese exports to BRI recipients suggested that effects were most pronounced for SOEs.[48]

On the other hand, assistance and infrastructure projects in recipient countries could increase domestic capacity, which might decrease dependence on China. For example, investments in infrastructure could lead to a general decrease in trade costs with all trade partners. Investments made by a distant foreign state could actually cause a greater increase in trade between the recipient and its nearby neighbors, thereby reducing dependence on the state funding the investment. Lu et al. (2024)

[47] Melitz (2003)
[48] Görg and Mao (2020).

find that BRI investments increase the centrality of recipients in the trade and investment network, which could mean that recipients have themselves cultivated alternative suppliers that would mitigate dependence on China. There are also prominent examples of backlash against and cancellation of BRI projects, which could blunt or reverse any gains.

Ultimately, assessing the ultimate downstream effects of Chinese assistance will determine how history judges the success or failure of massive projects like BRI. The stakes are high for the liberal international order and domestic politics within China. Whether the BRI succeeds in increasing interconnectedness can affect the survival prospects of the CCP.[49]

7.1 Effect on Compensation Dependence

For this analysis, we use our compensation dependence measure as the outcome variable. Specifically, we use the compensation dependence of country i on China in year t. The treatment variable is a binary indicator that equals 1 in the first year in which China gave the recipient $1 million or more in ODA-like funding according to data from the AidData project.[50] We focus on actual disbursement of money, rather than announced participation in BRI, since the former describes the time period in which economic transactions actually begin.

Our empirical approach needs to distinguish the effect of increased Chinese assistance from the effects of China's general rise in the world economy. A simple correlation of Chinese assistance with dependence on China could mean that programs like BRI have increased dependence, but it could also be an artifact of how most states increased their dependence on China regardless of whether they receive any Chinese assistance. To better isolate the effects of Chinese assistance on dependence, we leverage China's staggered assistance and investment around the world in a difference-in-differences framework. Our objective is to estimate the dependence of states having received Chinese assistance under the counterfactual where they received none. The difference-in-differences framework relies on an identification assumption: the observed trajectory of dependence for states that did not receive assistance is an estimate of what would have happened in states that did receive it. Due to the staggered

[49] Weiss and Wallace (2021), Tan, Steinberg, and McDowell (2025)

[50] Dreher et al. (2022);Custer et al. (2023).

nature of assistance, we use the Callaway and Sant'Anna (2021) estimator to properly weight cohorts of states that received assistance at different times. This estimator has the additional advantage of producing average treatment effects of the treated for each cohort and calendar year. We include the recipient's GDP, trade with China, and level of democracy (measured by VDEM) as controls.

Figure 10 shows the results. The top panel shows our estimated treatment effects on the vertical axis, with the years since entry into treatment on the horizontal axis. Treatment has a relatively quick, large and durable positive effect on compensation dependence. The treatment effect is statistically distinguishable from zero starting a few years after treatment. It remains positive and generally grows in magnitude in subsequent years.

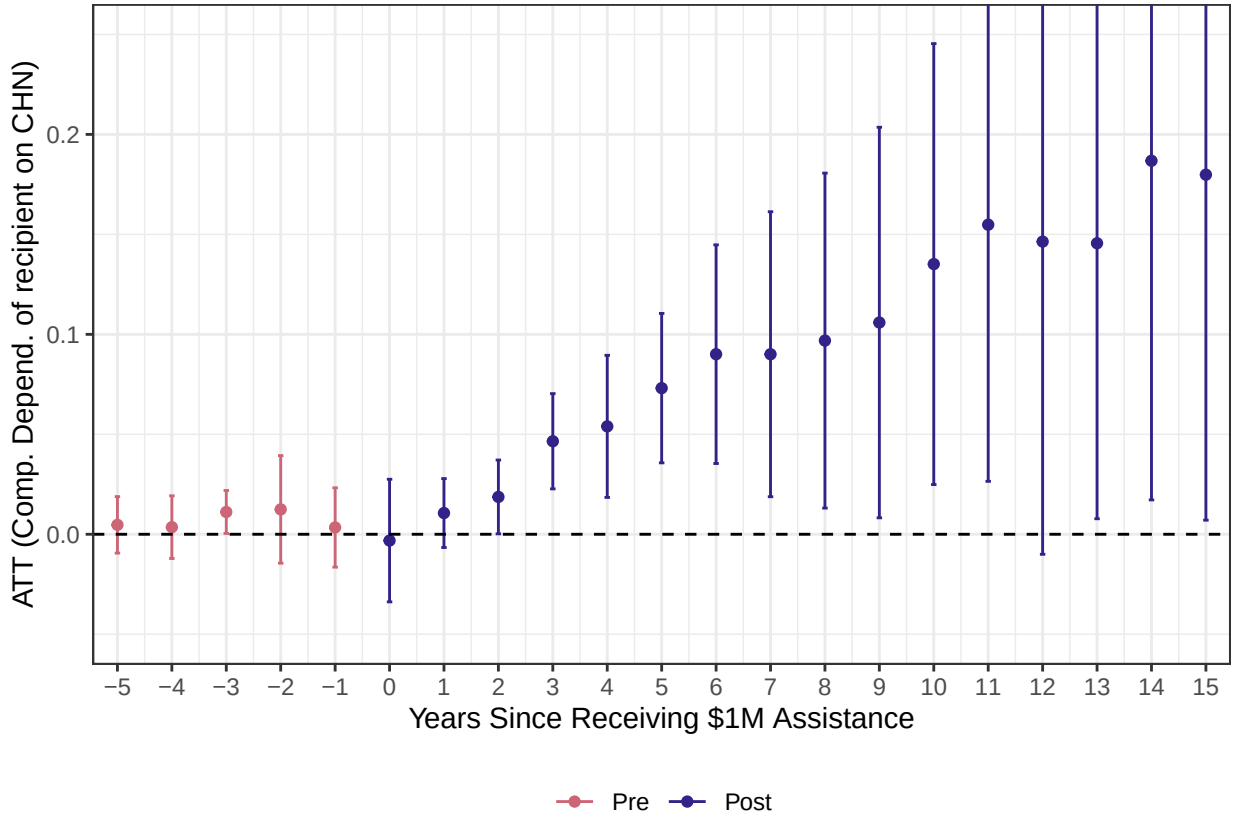

Figure 10: Effect of Chinese assistance on recipient's dependence on China. The compensation dependence measure is the outcome variable.

Our preferred estimates are also very robust to alternate specifications. In the appendix, we show results adding one covariate at a time to demonstrate that the results are not sensitive to the inclusion

of control variables.[51] We also include a specification where the control group includes only "not yet treated" units. We produce a two way fixed effects specification to show that our results do not depend on the use of the Callaway and Sant'Anna estimator. We also include specifications for different definitions of treatment. The statistical and substantive significance of the results is unchanged whether we define treatment as the first year in which a state received greater than zero, $\$0.5$ million, $\$1$ million, or $\$5$ million in financing from China. Across all specifications, the coefficients on treatment are always between 0.089 and 0.124. Furthermore, we use the Goodman-Bacon decomposition to ascertain whether whether our results are driven by a small group of treated units (Goodman-Bacon 2021). The results indicate that units treated in 2000 receive a weight of 0.2 in the estimate, more than twice that of the next highest cohort of treated units. We demonstrate that excluding these units from the procedure does not change the estimate.

Figure 11 shows identical analysis, only it uses China's dependence on the recipient as the outcome measure. The treatment effects are all near zero. This suggests that Chinese assistance facilitated dependence on China but did not increase interdependence. We do not see evidence of a corresponding increase in China's dependence on the recipient.

Figure 12 shows results from an identical estimation, except using the O'Neal and Russett measure of trade dependence as the outcome measure. The results are very different. The effects of aid on the OR measure of dependence are generally indistinguishable from zero and are generally *negative*. Using this measure, we would reach the opposite conclusion of the above analysis. This would suggest that Chinese aid has, if anything, decreased the degree to which recipients depend on China.[52] We contend that the former analysis is more accurate, since it captures the myriad ways that trade patterns could subtly change. Those changes could affect bilateral dependence, even if they had minimal (or even positive or negative) effects on aggregate trade statistics.

[51] Table 13.

[52] When Chinese dependence on the recipient using the OR measure is the outcome variable, the results are near-zero and insignificant, as well. See appendix.

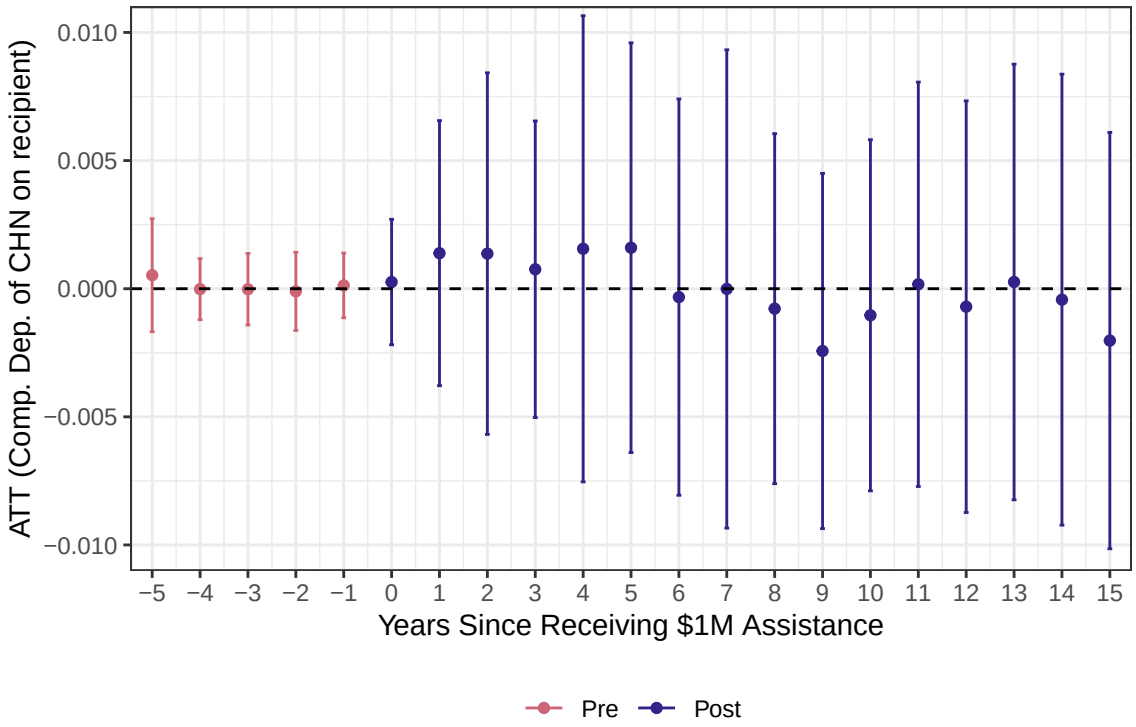

Figure 11: Effect of Chinese assistance on China's dependence on the recipient. The compensation dependence measure is the outcome variable.

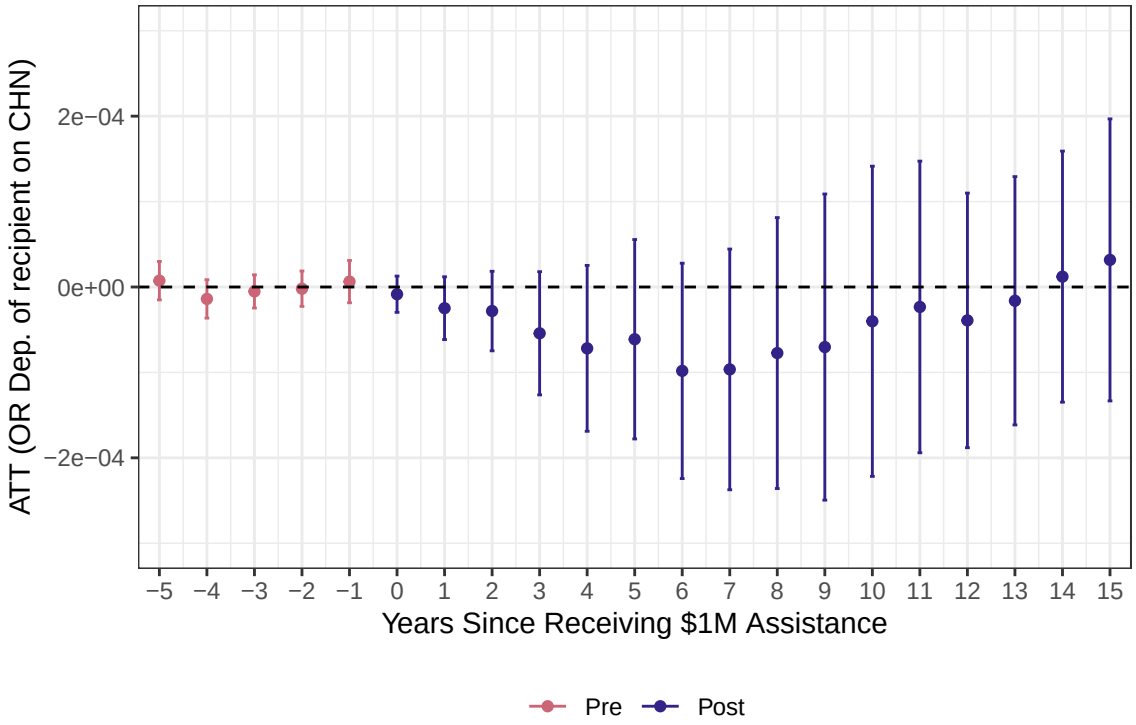

Figure 12: Effect of Chinese assistance on recipient's dependence on China. The OR aggregate statistic dependence measure is the outcome variable.

8 Conclusions

Who is dependent upon whom? This fundamental question in international politics speaks directly to the structure of power and leverage in the international system. Answering this question requires measures of the welfare effects on a country if trade is interrupted. As the global economy has evolved in the composition of trade, the prevalence of intermediate products, and the availability of alternate sources, it is important for us as researchers to keep up. Our measures incorporate these key changes in the global economy in a theoretically grounded way. Our global analysis of trends over time uncovered how dependence and interdependence have evolved in nontrivial ways that depart from standard intuition. Global dependence on China rose faster and earlier than shown in aggregate trade statistics. The world has only become more interdependent in a very narrow sense. Rather, dependence on one partner, often the US or China, has increased to such a degree that it makes most dyads look balanced by comparison. Our analysis of Chinese assistance, exemplified by the BRI, also uncovered its success in cultivating recipients' dependence on China, without a reciprocal increase in Chinese dependence. Both the global and program-specific findings would have yielded very different conclusions using aggregate trade statistics.

There are myriad additional questions that our approach could answer. For example, as countries think about how to manipulate others' dependence on them and inoculate themselves from foreign influence, which products and partnerships should they target? What flows have the greatest effect on dependence? Some intermediate inputs are undoubtedly strategically valuable, like semiconductors. What other products are flying under that radar, perhaps not as flashy as computer chips, but which may also have outsized influence on the welfare of other countries?

Going even further, if a country wants to build a coalition to influence a target, what is the optimal coalition to achieve a desired amount of leverage? President Trump's second-term trade war has included broadsides against traditional partners like Canada and Mexico, while continuing to target China. This indiscriminate approach all but guarantees that would-be allies for a trade war against his primary target – China – will not help. How much more effective could U.S. coercion towards China be if President Trump courted partners to jointly place pressure on China (Cha 2023), compared to

his scorched earth approach?

As the United States wages broad economic warfare, this puts this international system in a state of flux. Countries that had generally followed or fell in line with US demands may find themselves tempted to follow other leaders. This could manifest inside existing international institutions or in the creation of new ones or in influence campaigns wholly outside of the liberal international order. As Tan (2021) writes, "China is now well positioned to influence the development of international institutions" (22). Our analysis agrees and further shows that this influence grew more quickly, more broadly, and earlier than previously thought.

The world is also facing large, potentially structural changes like climate change and increased automation. Both could affect patterns of dependence in ways that go beyond simple, aggregate trade statistics. Climate change can affect production locations, endowments, and demand for goods, with effects that vary across region and industry. Scholars have begun to model potential effects on trade flows.[53] Our approach gives researchers a way to generate insights into and predictions for which countries will rise and fall with climate change from a geopolitical perspective in the degree to which their partners depend on them.

Automation could bring similarly large structural changes. Like climate change, automation can change the location of production or demand. Links in supply chains that were previously outsourced might be reshored and performed by newly automated processes.[54] Some effects on demands are already obvious, as competition over semiconductors has reached fever pitch. Automation's recent manifestations with artificial intelligence could also have huge effects on services trade, which we have so far excluded from the above analysis.[55] Services trade flows and potential disruptions from technological changes could be incorporated into our approach with more detailed input-output tables. There is a growing awareness of how dependence on automation could affect the demand and supply of policies designed to manipulate foreign reliance, which could place automation squarely in the crosshairs previously occupied by trade.[56] Our approach allows analysis of the dependence impli-

[53] Dellink et al. (2017), Martínez-Martínez et al. (2023)
[54] Stapleton (2019).
[55] R. Baldwin (2022).
[56] Chaudoin and Mangini (2024).

cations of these changes and many more.

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10 Appendix Items for Section 3: Measure construction

10.1 Bayesian trade elasticity estimates

Figure 13 shows our time varying estimates of trade elasticities by industry. Most of the estimated values fall in the 0 to -5 interval. These are larger in magnitude than the short run estimates in Boehm, Levchenko, and Pandalai-Nayar (2023), though closer to their long run estimate of -2. Their appendix (B3) also has a good comparison of estimates and samples across numerous papers. Caliendo and Parro (2015) originally constructed estimates at the industry level that were time-invariant. They ranged from -0.37 to 51.08, with an average of -4.55 (Table 1).

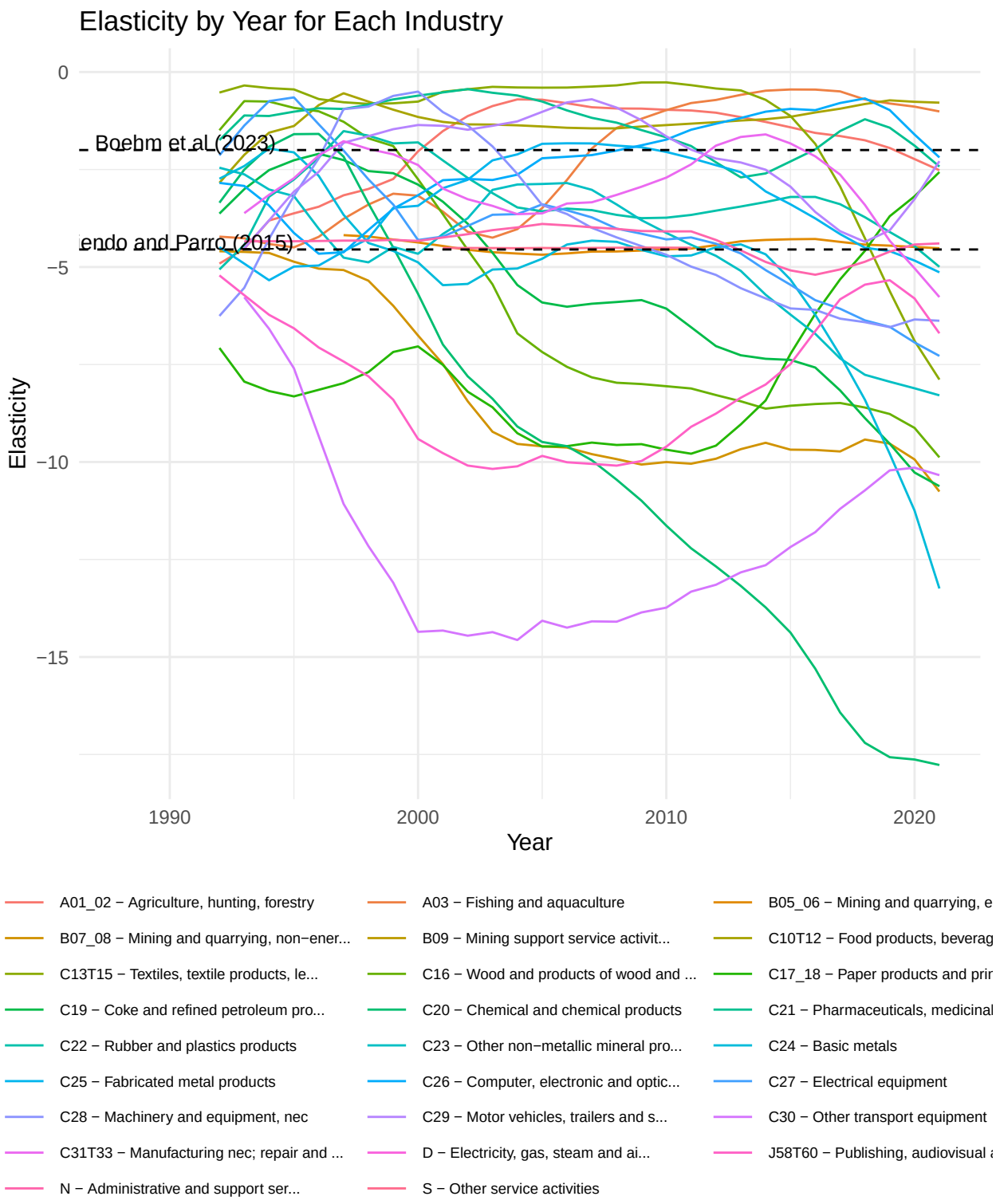

Figure 13: Bayesian time-varying estimates of elasticities

11 Appendix Items for Section 4: Our measures versus other measures over time

11.1 Average dependencies

Figure 2 compared the maximum of the log-standardized compensation dependence measure with the Oneal and Russett measure over time. It showed how there was increasing divergence between the two measures over. Here, we show that this divergence is not just present when we use the maximimum of the log-standardized measure. Figure 14 shows correlation coefficient between the compensation measure and the OR measure over time. The different lines show this correlation coefficient for different subsamples of the data. The red line shows the trend for the entire sample. Two additional lines limit the sample only to a country's 5 partners that have the highest value for compensation or OR for that particular year. In other words, we have calculated the correlation coefficient only for the 5 partners upon whom you are most dependent according to that measure. Two additional lines limit the sample to only the partner upon whom you are maximally dependent in that year. In other words, it is similar to the data in Figure 2, but without any log-standardization.

The trends over time are apparent and consistent across subsamples. All lines are downward sloping. The correlation between our measure and the OR measure deteriorates over time. Divergences are especially pronounced during the aftermath of the financial crisis.

Figure 15 shows the same correlation coefficients, only using the Barbieri measure instead of OR. The trends are very similar. They show the same deterioration over time and large dip around 2010.

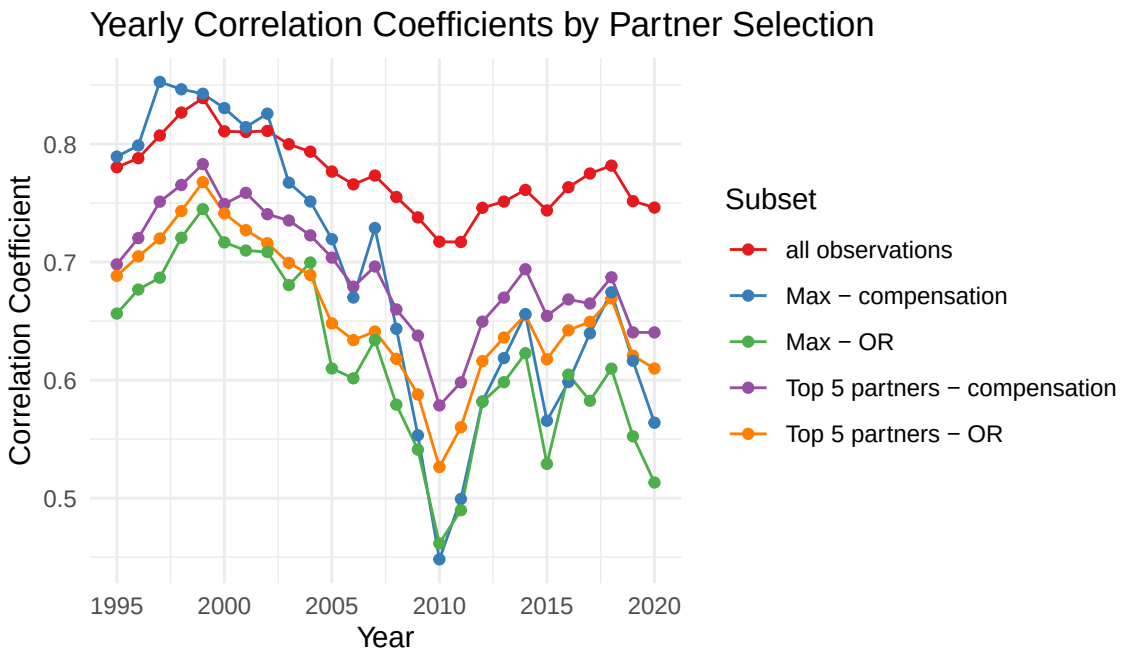

Figure 14: Correlation coefficients between compensation dependence and Oneal-Russett measure over time.

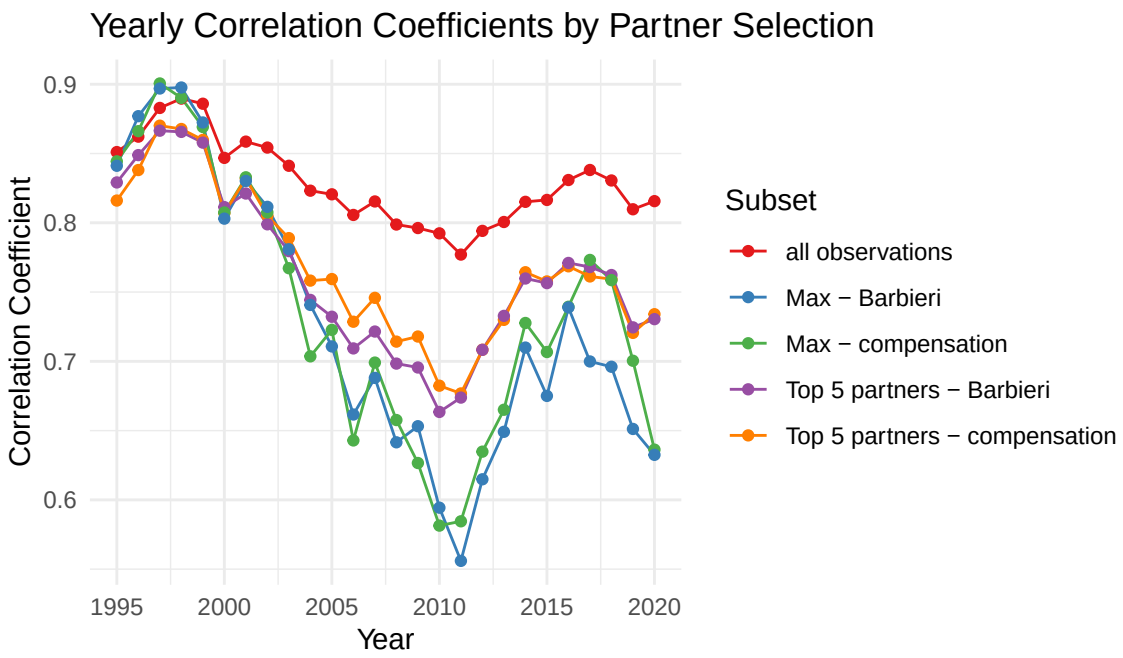

Figure 15: Correlation coefficients between compensation dependence and Barbieri measure over time.

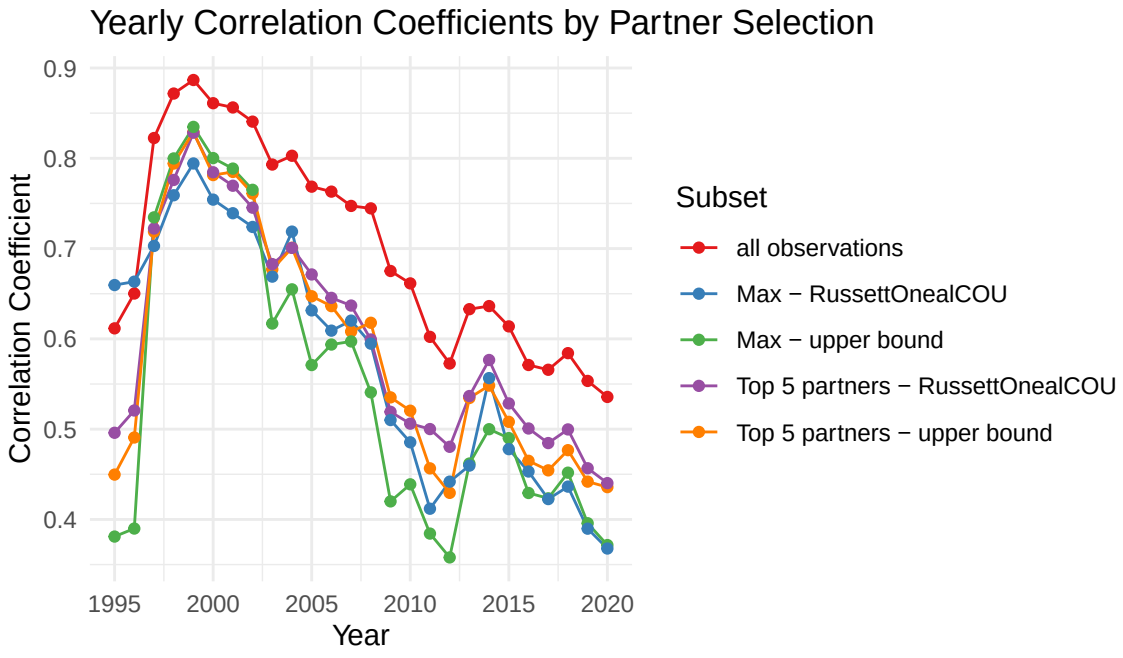

Figure 16: Correlation coefficients between upper bound dependence and OR measure over time.

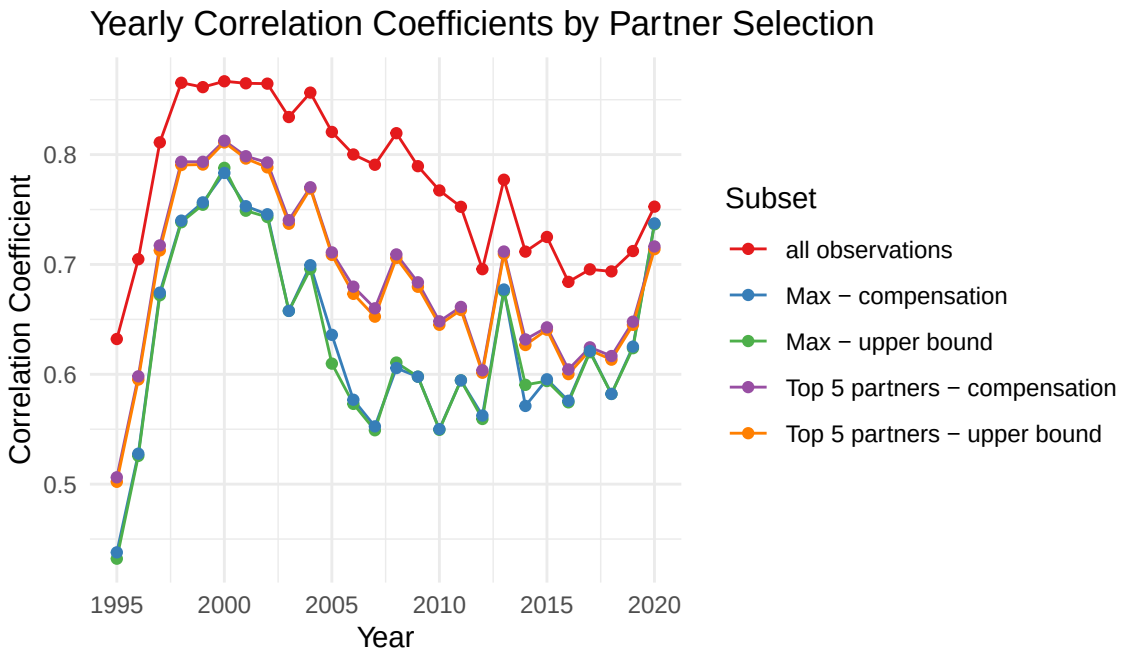

Figure 17: Correlation coefficients between upper bound dependence and compensation dependence measure over time.

11.2 Movement in intermediates shares over time

In the main manuscript, we described how countries change the share of their imports that are made up of intermediates over time. Here, we show this in greater detail. BEC data are divided into a hierarchy of commodity codes. For reasons that are not immediately apparent to us, the number of observations in the BEC data increases substantially in 2010. It nearly doubles. So for the descriptive plots below, we show data from before and after this jump.

For Figure 18, we calculated each country's share of total imports that were made up of intermediates for each year. We then calculated the country's rank in that distribution, eg a lower rank means the country-year observation has a higher intermediates share of total imports. The top pane shows these as line plots for 1998-2009 and the bottom pane for 2010-2021. If a country's rank went up by 10 or more slots, comparing the start of that time period to the end, then its line is colored red If its rank went down, it is colored blue.

There is a lot of movement within-country across-time in where they stand in the distrubtion of intermediates shares. In the first time period, almost 36% of countries had a rank-difference of at least 10. In the second period, almost 33% had a similarly large shift.[57] Movement was also not concentrated in any part of the distribution. Some high-rank countries went up, while others went down, and vice versa for countries that started lower in the rankings.

[57]Note that we limited the plots to only countries with complete data for a particular time period, so the denominator for this calculation changes slightly.

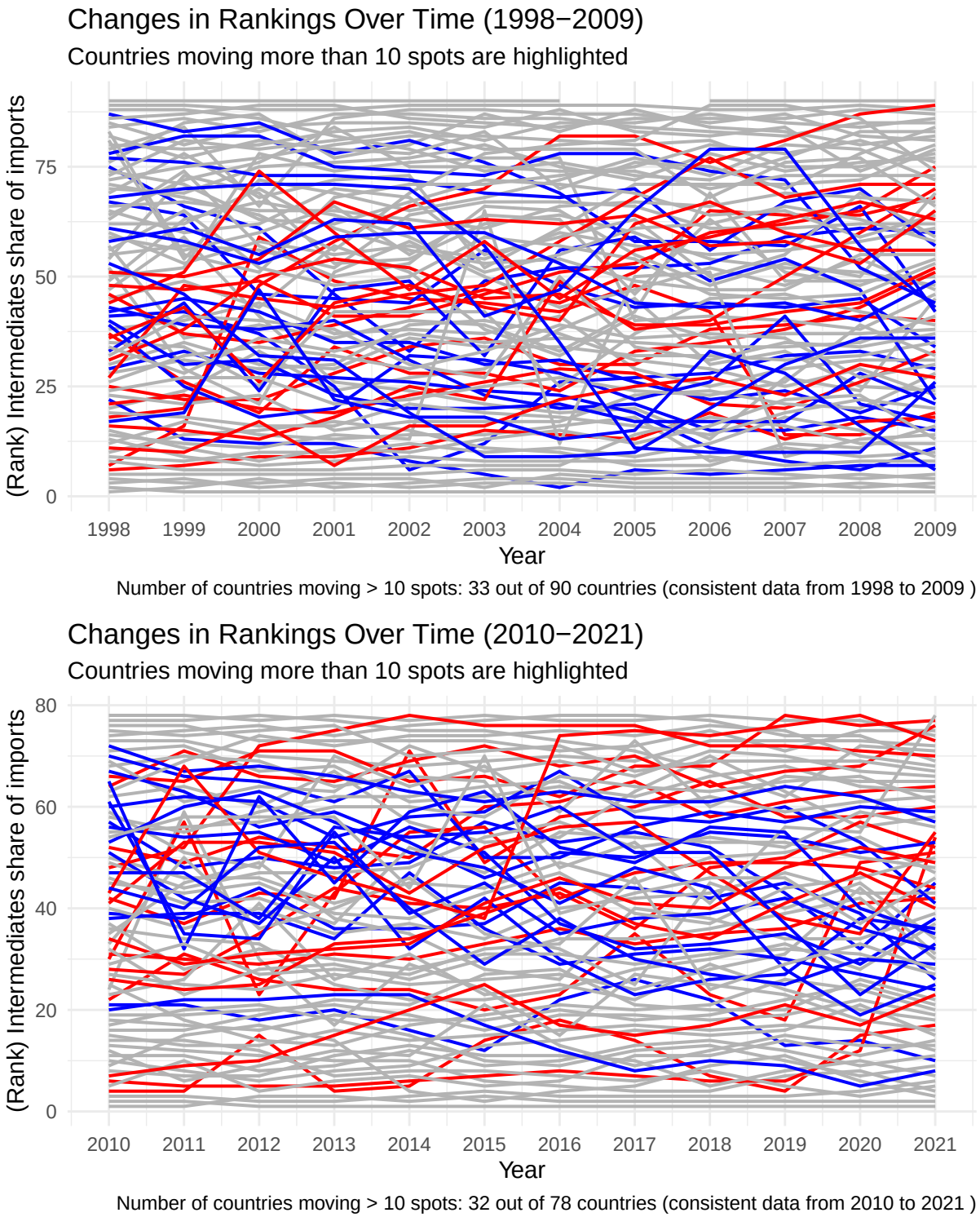

Figure 18: Plots showing countries that changed their intermediates share of imports the most over different time periods.

11.3 Movement at the extensive margin of trade over time

One potential driver of differences between our measures and others is the degree to which a country trades at the extensive margin. More trade spread across more partners could decrease compensation dependence. Figures 19 and 20 shows one way of conceptualizing variation at the extensive margin. For each country and industry, we calculated the number of partner countries that it takes to make up at least 80% of that country's imported value added. For example, if a country's imports of a particular industry were spread equally over 100 partners, this measure would equal 80. If a country imported all of that good from one partner, the measure would equal 1.

Figures 19 shows box and whiskers describing the distribution of this value across countries and industries, for all years. The middle line for each industry shows the mean across countries. The boxes show the interquartile range and the whiskers show 1.5x the interquartile range. Red dots mark outliers.

There is substantial variation in the degree to which certain industries are concentrated or spread out across different trading partners. For the average country, approximately 3-4 partners make up 80% of their imports for energy and mining imports. Yet, the average country has 80% of its food imports spread over more than 12 partners. These values can also vary over time.

There is also substantial variation across countries, even within a particular industry. Across nearly all industries, there are countries that import at least 80% from a single partner in at least one of the sample years. Across all industries, the distributions of these values are spread out across countries.

Figure 20 shows the mean of this value across countries for each industry-year. The degree of partner-concentration can increase or decrease for different industries over time.

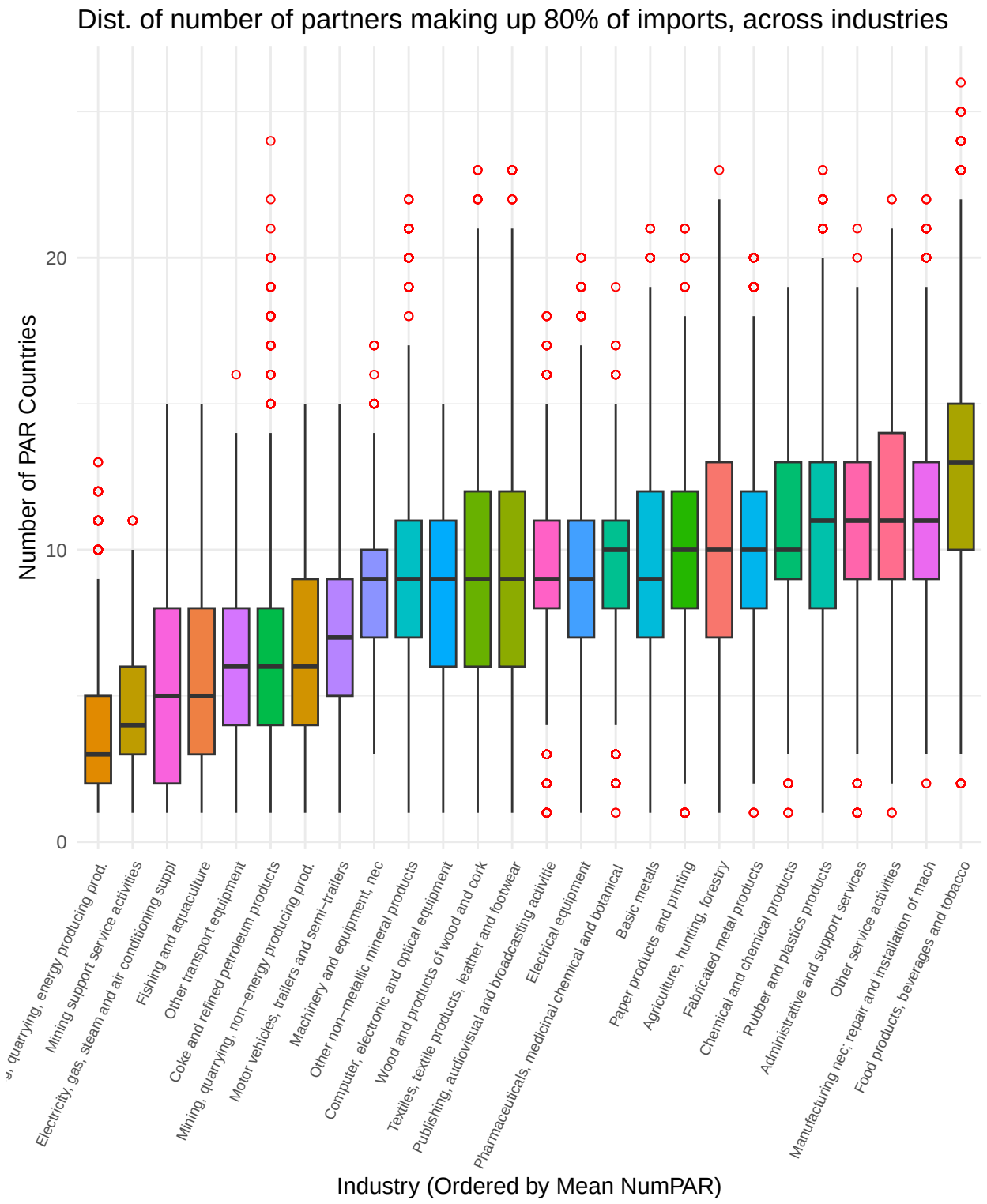

Figure 19: Plots showing variation in the extensive margin of trade across industry.

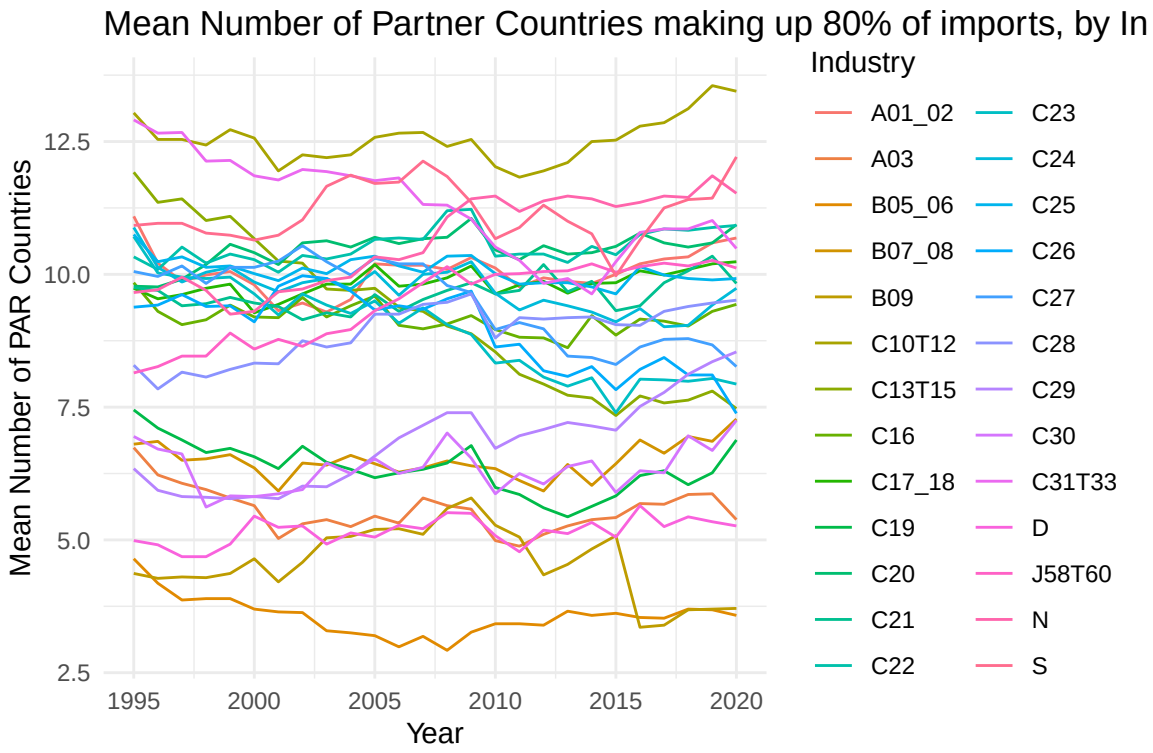

Figure 20: Plots showing variation in the extensive margin of trade over time by industry.

12 Appendix Items for Section 5: Changes Over Time

12.1 Time Series Clustering

Our preferred clustering algorithm does not endogenously determine the number of clusters. The specification shown in the main text uses three clusters. To demonstrate some robustness to the number of clusters requested, we produce in Figure 21 the bin scattered graphs for a range of numbers of clusters. In addition, we also produce a list of states which are associated with each cluster, to help readers assess the stability of cluster membership across specifications. Across all panels with three or more clusters, we can identify at least one cluster whose dependence is increasing, one whose dependence is decreasing, and one which follows the U shaped pattern.

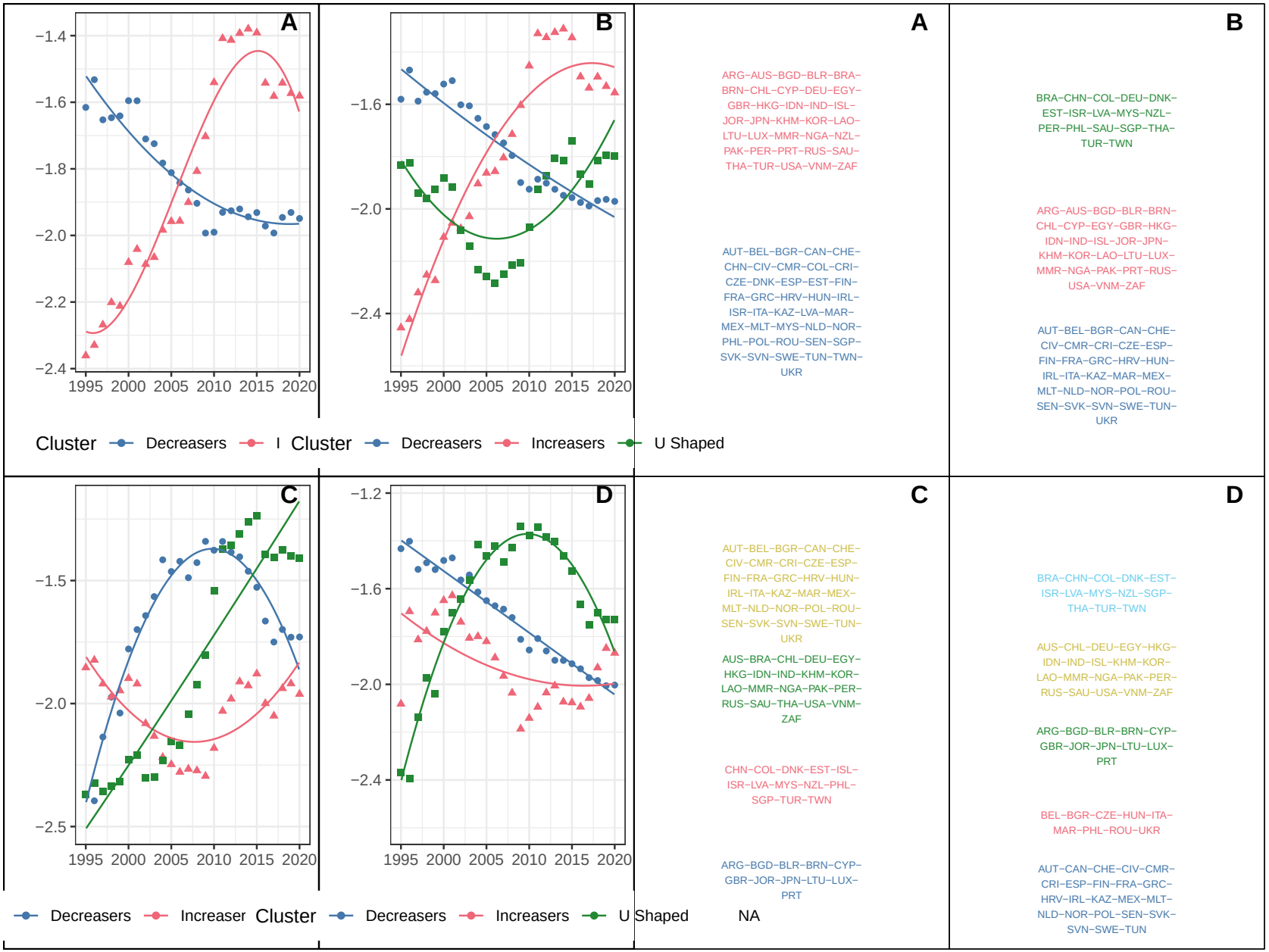

Figure 21: Robustness of the clustering procedure to the number of clusters. The ISO codes for cluster members are produced alongside their trends. Labels in the upper right hand corner of each panel indicate the specification.

12.2 "Max" measure robustness

In the main manuscript, Figure 3 showed trends in our measure over time. It showed each country's maximum value of a particular measure. Figure 22 shows the same thing, only it is based on each country's 5 most dependent relationships, instead of the maximally dependent relationship.

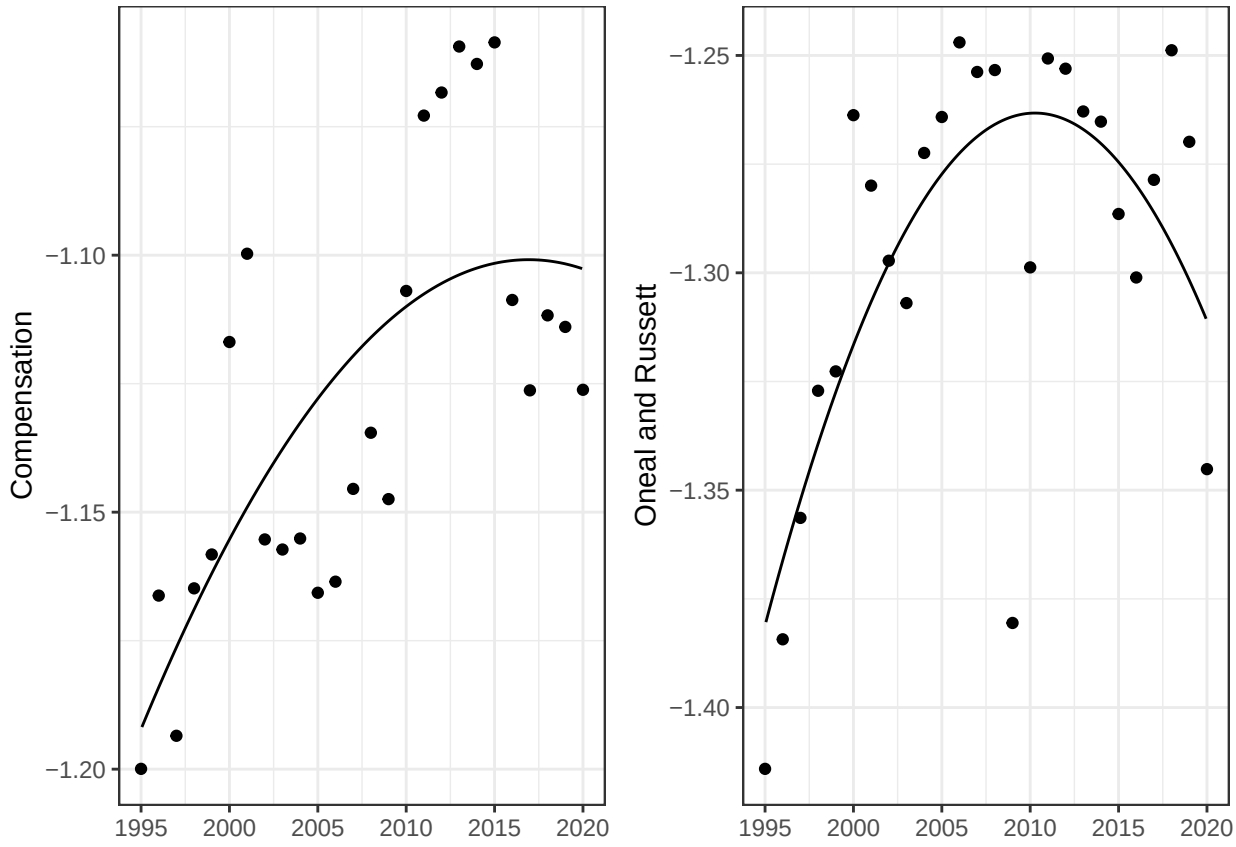

Figure 22: Bin scatters of the top 5 of each measure after taking the natural logarithm. Both variables are normalized to the unit interval before taking logs to equalize their support and facillitate comparison.

13 Appendix Items for Section 7: Chinese Foreign Assistance

13.1 Effect on Chinese dependence, OR measure

13.2 Alternative estimators

In the main manuscript, we showed treatment effects estimated from Callaway and Sant'Anna (2021) with a particular set of control variables and definition of the control group. The table below shows the aggregate treatment effects for a wide variety of variations on assumptions about control variables and control group. It also shows estimates from a two-way fixed effects model. The estimates for the effect of assistance on dependence are very consistent in size and significance.

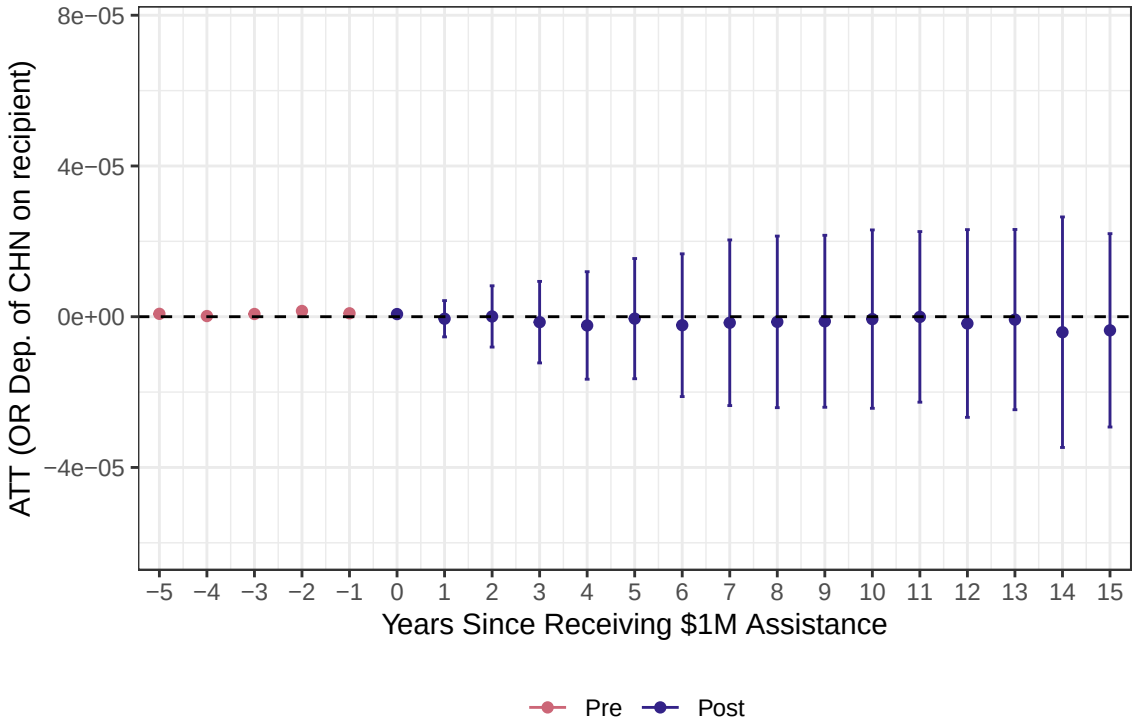

Figure 23: Effect of Chinese assistance on China's dependence on the recipient. The OR dependence measure is the outcome variable.

estimate	se	p.value	type	controls	control_group	indepvar
0.1164	0.0367	0.0015	CS	~1	nevertreated	event_year_did
0.1123	0.0389	0.0039	CS	~1	notyettreated	event_year_did
0.1374	0.0380	0.0003	CS	~TotalTrade_log	nevertreated	event_year_did
0.1447	0.0377	0.0001	CS	~gdp_COU_log	nevertreated	event_year_did
0.0809	0.0373	0.0302	CS	~vdem_electCOU	nevertreated	event_year_did
0.0978	0.0364	0.0072	CS	~TotalTrade_log + gdp_COU_log + vdem_electCOU	nevertreated	event_year_did
0.0956	0.0367	0.0091	CS	~TotalTrade_log + gdp_COU_log + vdem_libdemCOU	nevertreated	event_year_did
0.0889	0.0318	0.0052	CS	~TotalTrade_log + gdp_COU_log + vdem_libdemCOU	nevertreated	event_year_zero_did
0.0957	0.0319	0.0027	CS	~TotalTrade_log + gdp_COU_log + vdem_libdemCOU	nevertreated	event_year_half_did
0.1240	0.0479	0.0096	CS	~TotalTrade_log + gdp_COU_log + vdem_libdemCOU	nevertreated	event_year_five_did
0.0981	0.0260	0.0009	Two Way FE	+ TotalTrade_log + gdp_COU_log + vdem_electCOU		event_indTRUE

Figure 24 shows the estimated effects of Chinese assistance using the original specification, but broken down by calendar year instead of year of treatment.

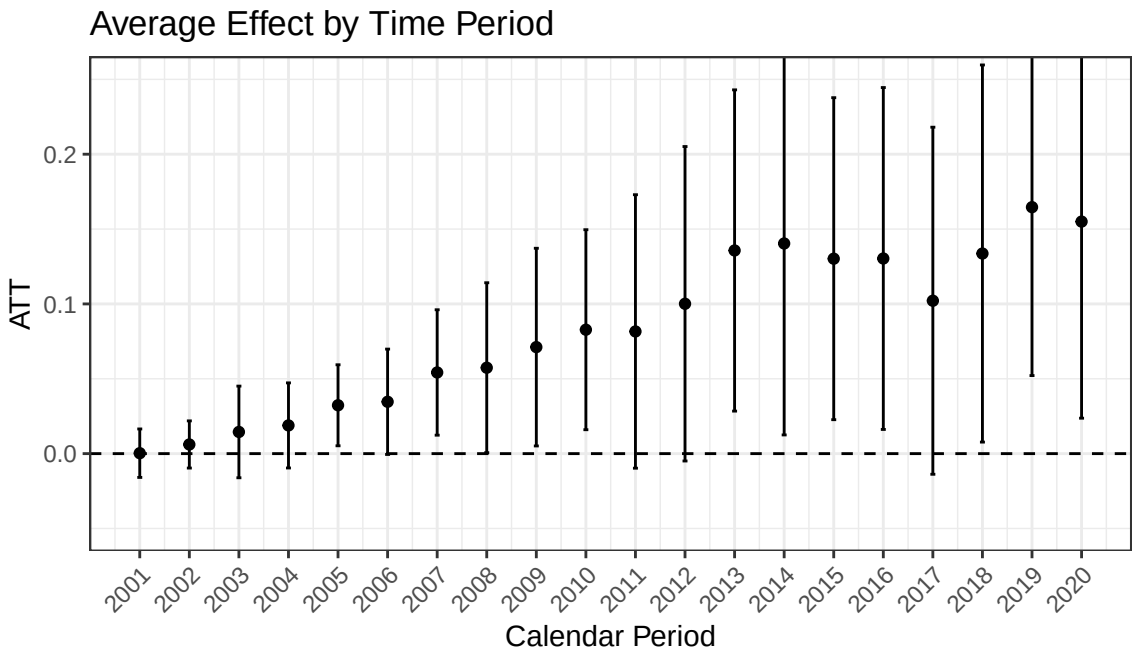

Figure 24: Estimates of Chinese assistance effect by calendar year.

treated	untreated	weight	estimate	type
2000		0.2057	0.1329	Treated vs Untreated
2005		0.0995	0.0230	Treated vs Untreated
2002		0.0757	0.1796	Treated vs Untreated
2007		0.0699	0.1176	Treated vs Untreated
2004		0.0611	0.0764	Treated vs Untreated
2015		0.0509	0.1460	Treated vs Untreated
2001		0.0486	0.0937	Treated vs Untreated
2009		0.0370	0.2259	Treated vs Untreated
2011		0.0340	0.0220	Treated vs Untreated
2006		0.0337	0.0241	Treated vs Untreated
2010		0.0323	0.4159	Treated vs Untreated
2003		0.0279	0.1585	Treated vs Untreated
2017		0.0180	0.2176	Treated vs Untreated
2000	2015	0.0170	0.0609	Both Treated
2000	2005	0.0170	-0.0863	Both Treated
2000	2007	0.0151	-0.0270	Both Treated
2000	2011	0.0097	-0.0541	Both Treated
2000	2009	0.0097	0.0601	Both Treated
2000	2004	0.0095	-0.0577	Both Treated
2000	2010	0.0087	0.1576	Both Treated

Table 1: Top 20 weights produced by the Goodman-Bacon decomposition. The weights indicate each comparison's influence on a two way fixed effects estimate of a difference-in-differences model. The overall estimate is 0.1 and the estimate after excluding the highest weighted comparison is 0.092.

COU	treated_year
BGD	2000
CIV	2000
KAZ	2000
KHM	2000
LAO	2000
MAR	2000
MMR	2000
PAK	2000
PHL	2000
VNM	2000
CMR	2001
IND	2001
EGY	2002
NGA	2002
PER	2002
JOR	2003
IDN	2004
TUN	2004
BLR	2005
SEN	2005
THA	2005
UKR	2006
CRI	2007
ZAF	2007
MEX	2009
CHL	2010
TUR	2011
ARG	2015
MYS	2015
COL	2017

Table 2: All treated units by treatment year.

14 Appendix Items: US-China bilateral dependence