The Macroeconomic Consequences of Export Subsidies *

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Abstract

We study the impact of export subsidies by exploiting major changes in China's export VAT rebates. Our causal estimates shows that export responses to export subsidies are: (1) highly dynamic, taking more than five years to fully materialize; and (2) these dynamics are driven by real frictions, since subsidies are immediately fully passed through to prices. We incorporate these dynamics into a two-country DSGE model, identifying key parameters to match our causal estimates, and estimate the remainder ones with Bayesian methods. We find that the macroeconomic consequences of export subsidies depend crucially on their persistence, cyclical design, and interaction with exchange rate regimes. We show that failing to account for export dynamics leads to substantial biases in trade policy evaluation.

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1 Introduction

Recent years have seen a resurgence of active trade policy across the globe, with both developed and developing countries increasingly employing measures to influence trade flows and domestic macroeconomic conditions, ranging from tariffs to export and domestic production subsidies. The rise in these policies which affect allocations across borders, particularly in the context of the US-China trade tensions, is gaining significant relevance for both research and policy implementation. As a consequence, significant attention has been placed on understanding the effect of tariffs on domestic and foreign markets (Fajgelbaum et al., 2020; Fajgelbaum and Khandelwal, 2022; Chen et al., 2022; Hoang and Mix, 2024). However, the macroeconomic effects of export subsidies, one of the main drivers of recent policy changes affecting trade Evenett et al. (2024), have received much less attention.

This paper addresses this gap by studying the macroeconomic effects of export subsidies. We achieve this by leveraging China's Value Added Tax Rebate on Exports (VAT-RX) policy changes between 2004 and 2017. Utilizing a granular dataset exhibiting considerable variation in these rebates across sectors and over time, we document new empirical facts regarding the use of VAT-RX in China, together with new causal estimates on its dynamic effects for export quantities and prices. Then, we integrate the empirical evidence into a dynamic stochastic general equilibrium (DSGE) model to analyze the policy's impact on trade, international prices, and the broader economy. Our analysis reveals the significant and often underestimated role of VAT-RX as a trade policy tool. Moreover, we find that VAT-RX has been used as a fiscal devaluation tool (Farhi et al., 2014) under China's managed exchange rate system.

There are several advantages of exploiting VAT-RX to isolate the effects of export subsidies on trade flows properly. First, VAT-RX is permitted under World Trade Organization rules and utilized by many countries. This alleviates any concern that the response of trade flows to export subsidies might be affected by expected anti-dumping or other trade measures taken by destination countries Rotunno and Ruta (2025), which naturally biases the estimates. Second, China's application of this policy stands out for its consistent and widespread implementation over time and across different products, which provides enough variation and episodes to isolate its effects.

We document several important empirical regularities concerning the use of VAT-RX in China across time, and provide new causal estimates regarding its impact on export and pricing dynamics. First, unlike the standard practice in most WTO member countries of maintaining a uniform and 100% VAT rebate on exports, we show that China has adjusted these rates across sectors and over time, providing a valuable setting to investigate the macroeconomic implications of actively using fiscal policy to influence international trade.

Second, we present evidence of a significant link between VAT-RX and sectoral export performance. To establish this, we exploit the heterogeneous changes in VAT-RX rates around the Global Financial Crisis (GFC), where some products experienced an increase in their VAT-RX while others did not. We find that products receiving an increase in their VAT-RX rate experienced a roughly 30 percentage point smaller reduction in export growth between 2005 and 2010. VAT-RX policy significantly mitigated the negative impact on sectoral exports arising from the GFC.

Third, we document a strong counter-cyclical pattern in China's VAT-RX policy. We find that increases in the aggregate VAT-RX rate occur after periods of lower real export and GDP growth, and before periods of stronger performance. This suggests a deliberate use of the policy to manage aggregate economic fluctuations. This result is important, as trade policies are generally studied in isolation, as shocks, instead of using them as endogenous responses to the underlying state of the economy, as we do in our DSGE model.

Having established these three simple observational facts, we proceed to causally estimate the effects of VAT-RX on export quantities and prices. For this, we exploit the recent advances in the econometric literature and make use of Local projection Diff-in-Diff methods as developed by Dube et al. (2025). This method is perfectly suited for studying VAT-RX policy, since these policy changes tend to be clear and sharp events, after which additional policy changes take time to place. Specifically, we exploit sudden and sharp reductions in the VAT-RX, which are stable for at least 40 quarters. Using our causal estimates, we document two main findings, with general implications beyond the study of VAT-RX and export subsidies implementations.

First, we find that the response of export quantities is highly dynamic and takes time to materialize after the changes in export subsidies. Following a VAT-RX reduction of approximately six percentage points, exports decline by nearly 10% in the first year and by around 60% forty quarters. Our results show the existence of a trade elasticity that is significantly larger in the long-run than in the short-run. Specifically, we estimate a short-run trade elasticity of around 1.3 during the first year after the policy change, and around 9.5 after forty quarters.

Our estimates are consistent with the recent literature estimating the trade elasticity over different horizons (Alessandria et al., 2025b; Boehm et al., 2023). The quantitative similarity with the findings by Alessandria et al. (2025a) is surprising, as they exploit tariff variations, whereas we exploit export subsidies through VAT-RX. Relative to the literature using tariff variation to estimate the dynamic trade elasticity, our estimations have two key advantages. First, we exploit clear and clean policy events, unlike those using tariff variations, which might generate measurement errors as shown in Teti (2024) and the dynamic problem given agents' expectations regarding future tariff changes (Khan and Khederlarian, 2021; Alessandria et al., 2025b). Second, we exploit these events in a methodology consistent with their nature of the changes in VAT-RX, which allows us to estimate the whole dynamic path of export and price responses and together with their anticipatory behavior.

Second, we show that the dynamic response of export quantities to these policy events is driven by real, not nominal, frictions. The existing literature has attributed the presence of a smaller short-run elasticity of trade to both real frictions (Alessandria and Choi, 2007; Ruhl and Willis, 2017; Fitzgerald et al., 2024; Kohn et al., 2016), and nominal frictions (Gopinath and Itskhoki, 2022, 2011; Amiti et al., 2019). Despite these two clear strands of literature, there is no clear consensus on each one's relevance. We find that prices immediately increase after changes in VAT-RX. We also find that forty quarters after the reform, the cumulative price change is not statistically different from that implied by full pass-through. Hence, at least for these policies, nominal rigidities play no role in explaining export dynamics.

Having established the facts about the nature and effects of export subsidies through VAT-RX, we turn to estimate their macroeconomic implications. For this, we develop and estimate a two-country Dynamic Stochastic General Equilibrium (DSGE) model that incorporates this policy. We extend the framework of Backus et al. (1994) by incorporating export dynamics driven by real frictions, VAT and VAT-RX policies, a rich set of shocks, and trade frictions. To quantify the impact of this policy instrument, we estimate the key parameters governing the export dynamics to match our causal estimates, while the remaining parameters are estimated using Bayesian methods. This approach allows us to infer the underlying historical sequences of the model's shocks that best match the observed data. By estimating the model and these shocks, we can then identify the specific contribution of China's VAT-RX policy to its macroeconomy and that to the rest of the world, conditional on the other shocks.

Using the estimated model, we conduct several counterfactual analyses. We start by examining the macroeconomic response to the GFC in the absence of China's increase in its VAT-RX rates. Our results suggest that the global trade collapse would have been more severe, with Chinese exports falling by an additional three percentage points. The policy also helped mitigate the decline in China's GDP growth by 0.3 percentage points, albeit at the cost of a similar reduction in consumption growth. Finally, this policy effectively acted as a quasi-fiscal devaluation, since it induced effects on allocations similar to those under an exchange rate devaluation. The increase in VAT-RX after the global financial crisis boosted Chinese exports, the trade balance, and GDP, while dampening consumption.

We also perform two additional counterfactuals. First, we estimate the impact for China if it were to implement a full 100% rebate as most countries do. Second, we estimate the impact of these counterfactual changes, absent the dynamic responses in the model. Our results suggest that both welfare and estimated impact on other macroeconomic variables differ substantially when allowing or not for dynamic trade elasticities, consistent with our findings.

From a policy perspective, our findings offer important lessons for governments seeking to enhance trade competitiveness and manage macroeconomic stability. While the WTO permits a uniform 100% VAT rebate on exports, China's experience highlights the potential for a more actively managed system to function as a quasi-fiscal devaluation. Our analysis provides valuable insights into the effectiveness of such policies in influencing not only export volumes but also international relative prices and broader economic activity. China's deviation from the standard approach provides a compelling case study for understanding the wider macroeconomic consequences of strategically employing fiscal tools to influence the macroeconomy beyond their direct effects on exports.

Literature. Our work contributes to the literature studying the impact of export subsidies in general (Desai and Hines Jr, 2008; De Meza, 1986; Collie, 1991; Itoh and Kiyono, 1987; Rotunno and Ruta, 2024) and the one studying the VAT-RX in particular. We contribute to this literature in several dimensions. First, we are the first to estimate the dynamic response of prices and export quantities after export subsidies are implemented, and to provide a clear estimate of the elasticity of export quantities to export subsidies. We are also the first paper studying the macroeconomic consequences of export subsidies within a DSGE model, with a dynamic trade elasticity. Most papers have focused on estimating the cross-sectional impact of these subsidies in the context of VAT-RX on sectoral exports, as in (Gourdon et al., 2022; Liu and Lu, 2015; Chandra and Long, 2013; Braakmann et al., 2020) or have been studied within the context of static trade models Bond et al. (2023). We also show that this policy has strong similarities to fiscal devaluations (Farhi et al., 2014; Erceg et al., 2023).

We also contribute to the literature by estimating the relevance and determinants of trade elasticity dynamics. First, estimate this elasticity using export subsidies, rather than tariffs which is the usual practice. The use of tariffs has been found to suffer from several caveats, including improper data Teti (2024) and biases due to tariff announcements and anticipation Khan and Khederlarian (2021). Our identification has the advantage of being based on a clean trade policy change, within a methodology that has not been previously used in the literature for this task, the Local Projection Diff-in-Diff estimation. Estimates of the dynamic trade elasticity in the literature ranges from 0.7 to above 1 for the short run, and from 2 to around 7 for the long run (Teti, 2024; Boehm et al., 2023; Alessandria et al., 2025a).[1] Our findings are slightly higher than the existing ones, being 1.29 in the short run and between 9 and 10 in the long-run.

We also contribute to the literature studying the determinants of the dynamic export response to changes in trade policy or to other macro shocks. While some work has focused on real frictions, where exporters slowly grow, face sunk costs of investment or accumulated customer (Fitzgerald et al., 2024; Steinberg, 2023; Ruhl and Willis, 2017); others have interpreted these dynamics as the result of pricing frictions that slowly adjust in different currencies (Gopinath and

[1] See Simonovska and Waugh (2014) for a survey on estimates of the trade elasticity in static models.

Itskhoki, 2010, 2022; Amiti et al., 2019). We present evidence that our observed export dynamics are unrelated to pricing dynamics, consistent with the work that emphasizes real frictions driving the dynamics. Specifically, our findings show that export prices adjust almost immediately to these export subsidy changes and are statistically indistinguishable from the full pass-through case.

We also show how allowing for trade dynamics is relevant for welfare, and the welfare consequences of assuming away these frictions, as was initially discussed in Alessandria et al. (2021b) and more recently by Boehm et al. (2024) for tariffs and import cost changes. We expand on the previous literature studying the welfare effects of export subsidies (Itoh and Kiyono, 1987; Collie, 1991; Delpeuch et al., 2021; Rotunno and Ruta, 2024). We show quantitatively that in the absence of these frictions, estimated models will load the model misspecifications in trade frictions. Lastly, we show that when these trade frictions are assumed away, the macro predictions of macro policies like foreign exchange rate interventions are predicted to have substantially different effects than when export dynamics are allowed in the model.

Layout. The rest of the paper is organized as follows. Section 3 describe the data we use. Section 4 present the observation regarding the use of VAT-RX in china. Section 5 describe our empirical strategy and results for the causal estimates of VAT-RX in exports quantities and prices. Section 6 shows how we embed our empirical findings in the model and present the partial equilibrium mapping between the model trade block and our causal estimates. Section 7 presents the full DSGE model, the estimation procedure and the quantitative results. Section

2 sec: conclusion

concludes.

3 Data

We use three main data sources: aggregate quarterly macroeconomic time series, detailed product-level information on China's Value Added Tax (VAT) and rebates to export VAT, and exports at the HS-6 level from customs data, obtained from trade data monitor. The data in both cases spans from 2004 to 2019. The initial period is determined by data constraint in our VAT data, and the end by the end of COVID-19.

3.1 Aggregate Quarterly Data

For aggregate macroeconomic variables at the quarterly frequency, we rely on data from the International Monetary Fund (IMF), to obtain: Gross Domestic Product (GDP) for both China and the Rest of the World, real consumption, and real and nominal exports and imports, and real effective exchange rates (REER). To capture the dynamics of international relative prices, we utilize terms of trade data sourced from the World Bank. These aggregate series are the ones we will use to feed into out Bayesian estimation of our Dynamic Stochastic General Equilibrium (DSGE) model as we will describe later.

3.2 Value Added Tax Data and Export Rebates

The VAT system in China, implemented in 1994, features a standard VAT rate (which has remained constant over our study period) alongside a reduced rate for certain necessities. Importantly for our research, exported goods are theoretically subject to a zero VAT rate. However, in practice, China has historically applied a system of partial VAT refunds on exports, with the rebate rate varying significantly by sector and specific commodity. This incomplete rebate effectively implies an additional tax cost for exporters whose rebate rate is lower than the applicable VAT rate, a phenomenon akin to export taxation (Feldstein and Krugman, 1990). Indeed, over the period of 2002-2012, a significant majority of tariff lines in China featured a VAT rebate rate below the prevailing VAT rate (Liu and Lu, 2015).

The rationale behind China's use of variable and often incomplete VAT rebates on exports is multifaceted. These adjustments can serve various purposes, including the manipulation of the terms of trade, supporting food security, indirectly subsidizing higher value-added industries by limiting raw material exports, stabilizing domestic prices for export producers, managing trade surpluses, increasing government revenue, and guiding the growth of specific industries, particularly those in high-technology and value-added sectors while discouraging energy-intensive and polluting ones. Notably, significant adjustments to VAT refund rates were observed in response to growing trade surpluses in the 2000s and during the Global Financial Crisis, where rates were temporarily increased for many commodities to support export growth. On top if this we argue, that at a more aggregate level they have been use in counter cyclical fashion.

We use the data available on China's VAT system, sourced directly from the Chinese government. Our primary variable of interest is the the net VAT paid by exporters, computed as the domestic VAT rate applied to domestic sales products minus the VAT rebate rate exporters faced. In our dataset bot the domestic VAT and the rebates are specified at the Harmonized System (HS) 10-digit level. The dataset also provides the specific dates for when changes get in place, and when the rebates ar removed.

To construct the VAT and the exporter's Net VAT aggregate measures relevant for our analysis, including the overall VAT rebate, total VAT, and net VAT, we follow the following aggregation procedure. First, for each quarter, we calculate the simple average of the VAT and the rebate rates within each HS 6-digit category, aggregating across the HS 10-digit products within the corresponding HS-6 category. This step reduces the dimensionality of the data while preserving most of the product-level heterogeneity, and is due to our lack of exports at the HS 10-digit level.

Second, we weight these HS 6-digit average rates (VAT and rebates) by the export share of the corresponding HS 6-digit category in the previous quarter. Here we make use of the custom export data coming from the Trade Data Monitor. The lagged weighting scheme helps to mitigate potential bias issues where current policy changes might simultaneously affect both VAT rebates and export performance. Our underlying HS-10 digit VAT data spans from 2004 to December 2024, but in in this paper focuses on the period 2004-2019 to ensure consistency with our aggregate macroeconomic data, and avoid the COVID-19 period.

4 Stylized empirical observations

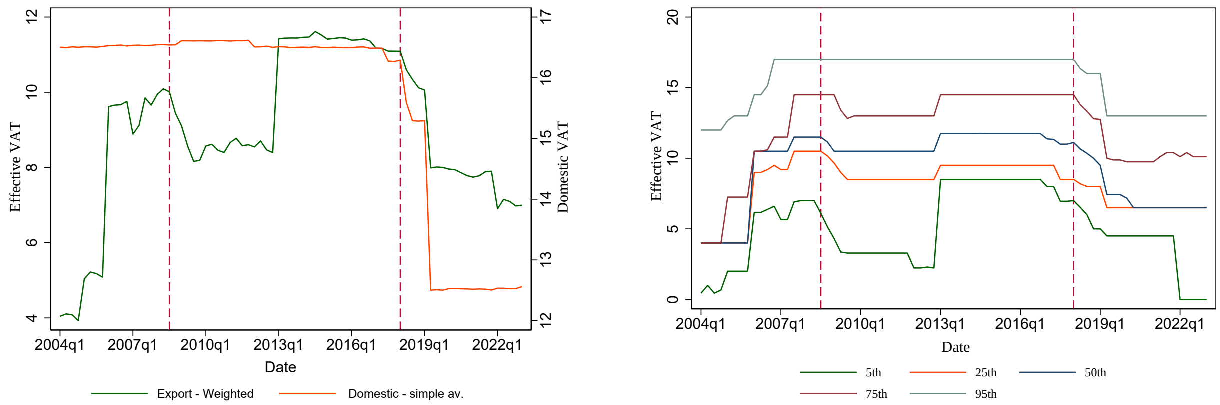
This section present three empirical observations of China's VAT-RX policy. These facts not only motivate our subsequent quantitative modeling but also provide tangible evidence of VAT-RX functioning as a quasi-fiscal devaluation tool. We present compelling evidence showing how VAT rebate policy to exports has been use as an active policy tool at the aggregate and product level in China. Then we show, how exports of products affected by a reduction in their exporter effective VAT within a year of the GFC saw a meaningful differences in their behavior. Lastly, we show how aggregate variables like exports, current account, the cyclical GDP and the fiscal balance, present dynamics correlation suggestive of the use of VAT policy as a counter-cyclical tool.

Stylized Observation 1: China's active use of VAT rebate policy. Figure 1 shows the evolution of the effective VAT to exports in China over time and products. While the VAT rate levied on domestic VAT has remained relatively stable between the first quarter of 2004 and the last quarter of 2018, the average net VAT burden on exporters has experienced considerable changes, influenced directly by the VAT rebate policy as shown in Panel (a). Specifically, it is clear that VAT rebate to export increases after the beginning of the GFC, as shown by the vertical dash line in Panel a of Figure 1, which lead to a sustained reduction on exporters effective VAT until the starts of 2013. The drop was of almost 2 p.p., which is significant change at the aggregate level if it is compare to the observe changes in effective tariffs around the world since the collapse of the Bretton Woods system.

Additionally, this aggregate changes mask a even more active role at the product level as display in Panel (b). This panel, shows the evolution over time of the different percentiles of the Net VAT to exports at the HS-6 digit level. The percentiles are computed for each given date. These time series shows the movements of VAT-RX policy, suggesting an active use of this policy.

Stylized Observation 2: VAT-RX improve export performance during GFC. VAT-RX has significant implications for exports performance in those sectors affected by the rebate as shown in Figure 2. Two pieces of evidence support our estimate. First, Panel 2a, plots the exports mean annualized export growth over HS-6 digits of two groups: those that saw a change in their

Figure 1: VAT rebate to exports: An active and time varying trade policy



(a) Average VAT Rates: Domestic vs. Exports

(b) Sectoral Export VAT Rate Dynamics

Note: Panel (a) illustrates the stable aggregate VAT rate applied to domestic sales (solid line) juxtaposed with the fluctuating aggregate net VAT rate faced by exporters (dashed line). Panel (b) provides a glimpse into the sectoral heterogeneity by showing the evolution of the VAT rate for an example sector, underscoring the targeted nature of the VAT-RX policy.

rebate at any point in time in our sample, and those that did not. It is clearly, how products non affected by the rebate present more volatile growth rate in exports, than those ever affected.

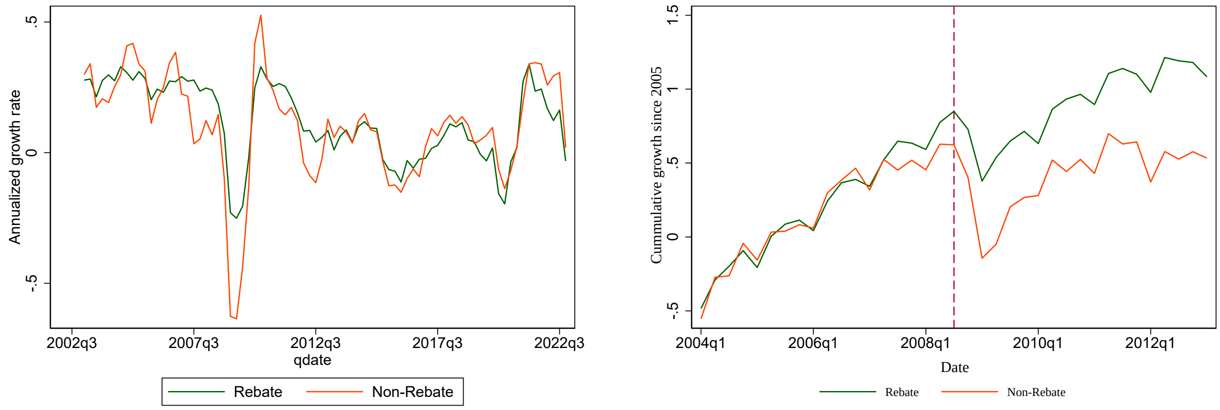
Second, we explore how export growth evolves after the global financial crises for those products affected by an export rebate within a year window of the GFC vs those products that were not affected by rebates increases. Panel 2b, presents the mean cumulative growth relative to the average exports in 2005 among products in each of these two groups. Relative to exports in the 2005 level, the drop of products affected by the rebate was almost 30 p.p. bigger than non-affected products.

Dynamic correlation of Net VAT with aggregate variables. Now we turn to focus on the dynamic correlation between aggregate variables and VAT movements. We focus on four time series: cyclical component of real exports, cyclical component of GDP, the current account over GDP, and the fiscal balance over GDP. For this purpose we the dynamic correlations between a given series x_t, and the VAT rebate$_t$ is given by [2]:

$$\textit{Dynamic correlation}_h = \mathrm{Corr}(x_{t+h}, \text{VAT rebate}_t)$$

[2] We only fucus on the VAT rebate, as already shown for the period between 2004 and 2018, most of the effective VAT to exports comes from movements in the VAT rebate.

Figure 2: VAT Rebates as a Shield: Protecting Export Growth in Treated Sectors



(a) Export growth with and without VAT Rebate Support

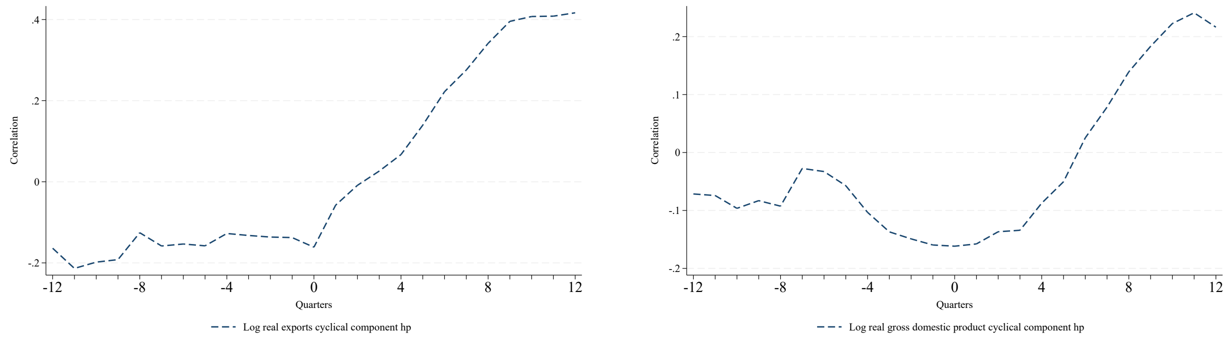
(b) Export growth with and without VAT Rebate Support after GFC

Note: Panel (a) shows exporters effective VAT in China. The average is computed using a weighted average of last quarters export shares over the effective VAT paid by each HS-6 digit product. Panel (b) presents the percentile of effective VAT over all the HS-6 digit products exported by china. The percentiles are computed in each quarter.

Stylized Observation 3: Negative correlation between export VAT rebate with lags of GDP and exports, positive with leads. Figure 3 presents the dynamic correlation between exporters VAT rebate at a given time, and the cyclical components of exports (Panel 3a) and real GDP (Panel 3b) in different time windows. Both panels shows a similar pattern. Negative correlation between VAT rebates to exports with respect to lags of GDP and exports, and a positive correlation with the leads of the variables. This suggest that both GDP and export tend to be low before increases in the VAT rebate takes place (which works as a export subsidies increase), and both are cyclical high after the increases in the rebates.

Figure 3 unveils the dynamic relationship between the aggregate net VAT rate and China's external sector. Panel (a) suggests a systematic pattern: before a reduction in the net VAT burden on exporters (an increase in rebates, effectively making exports cheaper), export growth tends to lag its cyclical trend. Subsequently, following the VAT adjustment, exports appear to experience a rebound. Panel (b) presents a similar narrative for the current account balance, where a weakening often precedes a net VAT reduction, followed by an improvement. This evidence is suggestive of the VAT-RX policy being employed to influence China's net exports, a core mechanism through which fiscal devaluations are theorized to operate by shifting expenditure towards domestically produced goods and boosting exports.

Figure 3: The External Sector's Response to Net VAT Signals



(a) Cyclical exports

(b) Cyclical GDP

Note: Panel (a) illustrates the dynamic correlation of cyclical total exports around changes in the aggregate net VAT rate, suggesting a pattern of underperformance followed by a rebound after a net VAT decrease. Panel (b) depicts a similar dynamic for the current account balance, hinting at a link between net VAT adjustments and China's external balance.

In conclusion, the empirical evidence presented in this section suggest the use of VAT-RX as an active countercylically policy tool used in China. We documented a dynamic and sectorally differentiated VAT-RX policy, targeted support for export growth through VAT rebates, and suggestive dynamic correlations between aggregate net VAT rates and key macroeconomic variables, both external and domestic. These observations provide strong motivation for our subsequent quantitative analysis, where we will embed these empirical regularities at the aggregate level within a structural DSGE model estimated using Bayesian methods. This framework will allow us to more rigorously assess the macroeconomic consequences of China's VAT-RX policy and its role as a significant, and often overlooked, quasi-fiscal devaluation tool in the global economy.

5 Dynamic quantities and prices response to export subsidies.

As previously discussed, net VAT tend to proceed periods of low performance, while it precedes high exports periods. In this section we proceed to estimate the export subsidies causal impact on trade flows quantities and its prices. Estimating the partial equilibrium impacts of these policy changes is useful in two ways: (1) first it help us to understand the nature of the key trade frictions playing important roles for these policy; (2) the quantitative estimates are key to discipline the quantitative model parameters that will be developed in Section 7.

Estimation. We saw already in Figure 1 that net VAT changes across industries between 2004 and 2017 were mainly driven by changes in the net VAT rebate to exports. These changes have three main characteristics which allow us to use the methodology developed by Dube et al. (2025), the local projection difference in differences (LP-DiD henceforth) approach.[3] These three characteristics are: (i) changes in VAT-RX are usually followed by stable periods, (2) occurred in different periods, and (3) there are large variations across industries and products.

Specifically, let $E_{i,t}$ be a dummy variable for industry i at time t. That takes value $E_{i,t} = 1$ if industry i has been treated with a rebate decrease, and zero for those industries used as control, which we will detailed later. Having established a dummy variable, we estimate the following equations:

$$\Delta_h y_{i,t-1} = \gamma_t + \beta_h \Delta E_{i,t} + \beta \mathbb{X}_{i,t} + \epsilon_{i,t} \quad \text{for h=-10,...,-2,0,.,40} \tag{1}$$

Where $\Delta_h y_{i,t-h} = y_{i,t+h} - y_{i,t-1}$, γ_t denotes year fixed effects, and $\mathbb{X}_{i,t}$ denotes a vector of controls up to year t-1, before the events takes place. Specifically we control for up to the four year lagged rebate and level of VAT.

As we show in previous Figure 3, rebates are unlikely exogenous object. They are likely to respond to other policies, or the underlying state of the economy as we find to be the case when we estimate the full quantitative model, as we will explain later. Hence, by projecting total exports or prices against the VAT rebate to exports we will obtain downward bias estimates towards zeros, as rebates are more likely to apply to under-performing industries or sectors.

Treatment and control groups. We overcome this problem by comparing industries treated with significant rebates decreases, relative to those industries whose rebate is already at zero. The idea is as follows. When rebates are decreased there is a zero lower bound; VAT-RX can't be negative, even though these industries are performing relatively well there's not scope to change their rebates. Hence, by comparing the export performance between industries with large rebate decreases and those for which their rebate was at zero we can estimate a cleaner impact of these effects. Besides the strategy, there might still be cases that treated are performing relatively

[3]See the paper to a discussion of how this approach is preferable in cases of staggered events and how it solves the usual problems of negative weights for standard events studied staggered over time.

better than those that can't be treated. We test this by looking at that pre-event's exports growth, and we find no evidence to sustained this might be the case as we will show later. Nonetheless, if this is the case our results will be biased toward zero, and hence our estimates provide at least a lower bound for the estimated responses.[4] Our dummy variable $E_{I,t}$ is then constructed to ensure a set of clean set of controls. $E_{I,t}$ is given by the following equation:

$$E_{i,t} = \begin{cases} 1 & \text{if } E_{i,t-1} = 1; \text{ or } \Delta\text{rebate}_{i,t} < \Delta\text{rebate}^{q25} \\ 0 & \text{if } \max\{\text{rebate}_{i,t+h}, 0\} = 0 \ \forall\ h; \text{ or } \Delta\text{rebate}_{i,t+j} < 0 \ \forall\ 0 < j < 40 \end{cases} \tag{2}$$

The first conditions implies that once a industry is treat with a reduction on rebate below the first quartile value of all rebate reductions (denoted by $\Delta\text{rebate}^{q25}$), is assume to be treated forever. By focusing on large reduction in rebate we rule out small changes are potential events being driven by measurement error or due to average or compositional effects. The second conditions implies that non-treated industries are those that never had rebate to export, and those that have positive rebates, but will face a reduction in the future.

Our estimation then follows Dube et al. (2025) in which our estimations is performed over restricted sample of industries that are either:

$$\begin{cases} \text{newly treated: } \Delta E_{i,t} = 1 \\ \text{or clean control: } E_{i,t+h} = 0 \end{cases} \tag{3}$$

These sample restrictions ensure as that our estimated are obtained from a comparing between units entering treatment at time t and units that are not yet treated at $t + h$.

Value added Rebates. Figure 4 shows the estimated coefficients when using rebates as dependent. The coefficient show the percentage point change in export rebates between affected exporters relative to those not affected. It clearly show an immediate and permanent rebate reduction on average of 5.93 p.p. over 40 quarters. While by construction, we expected a reduction

[4]We focus on only those industries for which the quantities are reported in the same unit during all our sample, and that are reported in number of units or kilograms sold. This allows us to overcome any issue related to quantities or prices changes due to changes in the way quantities sold are reported.

in the estimated rebates across groups, the rebate dynamics was not imposed. Its immediate and permanent behavior facilitated our interpretation on the effects of the export subsidy changes in both changes in quantities and prices.

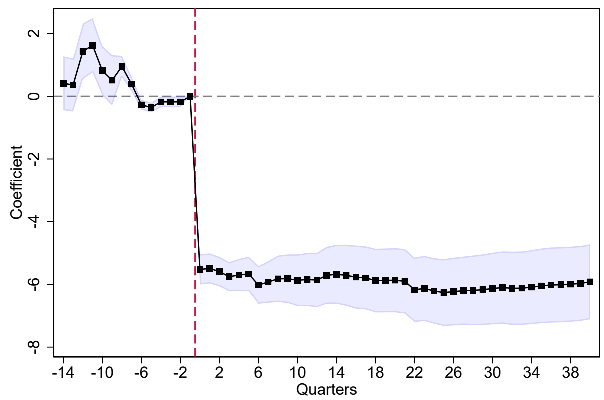


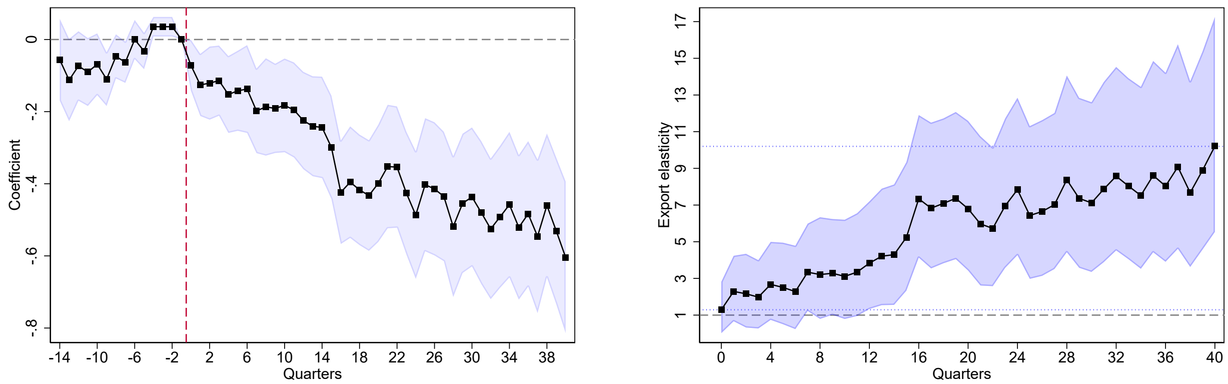
Figure 4: VAT rebate dynamics

Export dynamics. Panel (a) of Figure 5 shows the export quantity response of the affected industries relative to the control group. Despite the immediate and permanent change in export subsidies, exports take time to decline. In the first 4 quarters exports reduced by around 11% while by quarter 40 the reduction is about 60% in log points. This result has two important implications for our understanding of trade policy. First, it shows a clear dynamic response from exports to permanent changes in trade policy, in this case, export subsidies. There has been a large body of work suggesting that trade dynamics are likely dynamics Alessandria et al. (2021a); Fitzgerald et al. (2024); Boehm et al. (2024); Alessandria et al. (2021b, 2025b), but obtaining clear causal identification has been elusive, mainly driven by trade policy unstable and risky nature Alessandria et al. (2025b) and data limitations Teti (2024). Our episode is clean, and overcame these limitations, allowing us to provide such causal evidence.

Second, by comparing Figure 4 and panel (a) of Figure 5 we can back up the implicit trade elasticities over different time horizons. We use the point estimates to backed up the trade elasticity as follows

$$\textit{export-rebate elasticity} = \frac{\hat{\beta}^{exports} \times 100}{\hat{\beta}^{rebate}},$$

Panel (b) of Figure 5 shows the estimated trade elasticities at each time horizon. In the short run the estimated elasticity is around 1.29 while after 40 quarters reaches between 9 an 10. Later on, we show how these moments directly relate to key parameters in our model. While some trade elasticity estimates are found to be smaller than one specially for the short run, Boehm et al. (2023); Teti (2024), we recover trade elasticity values above 1 for all horizons, meaning that increases in Net VAT rebate subsidies tend to decrease nominal trade flows both in the short and long run. Our estimates are closer to those obtained by Alessandria et al. (2025a,b) for both the short and long run elasticity.



Export response

Trade elasticity

Figure 5: Export Dynamics and Trade Elasticity

The underlying causes of the dynamic responses for trade are important. Welfare gains estimating from slow trade responses due to real frictions, or pricing frictions might be different. For example, literature has taken different stands to understand what drives the export dynamics. While some work has focused on real frictions, where exporters slowly growth, face sunk costs of investment or accumulated customer Kohn et al. (2016); Fitzgerald et al. (2024); Steinberg (2023); Ruhl and Willis (2017); Alessandria and Choi (2007); Roberts and Tybout (1997), others have interpreted these dynamics as the result of pricing frictions that slowly adjust in different currencies Gopinath and Itskhoki (2011, 2022); Amiti et al. (2019).

Price dynamics. Figure 6 shows the price responses to this shock. The black line shows our estimated coefficients when using unit values in the dependent variable, the blue area shows the 95 percent confidence intervals. The red dotted line denotes the value that would imply full

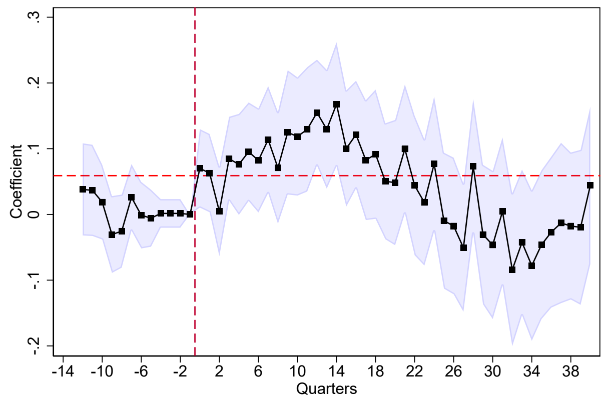


Figure 6: Price dynamics

price pass-through given the change in the rebate as previously shown. The takeaway is clear, price friction seems not to play any in exports underlying dynamics, as we cannot rule out the existence of full pass through. Furthermore, the relevance of pricing frictions seems not to play any role even in the short run horizon as on impact prices increases are indistinguishable to those that of what we would expect for full pass-through case.

Having established the export dynamic response to this export subsidies policy, and how is driven by non-pricing frictions, next we proceed to map these estimated to our model. We start by focusing on the partial equilibrium version of the model that we will extend to general equilibrium in the next section.

6 Partial Equilibrium Model

In this section we derive the partial equilibrium (PE) problem of monopolistic firms producing an intermediate good when seeling to a domestic and foreign retailer. The retailer uses domestic and imported intermediate goods and features habits in its demand. Specifically we show how to identify the dynamic trade elasticity estimated in the data in previous Section. We show that there is a one-to-one mapping between our previous causal estimates and our model parameters, allowing us to discipline our core mechanism. We then embed this mechanism in a full quantitative model to estimate the general equilibrium effects of VAT-RX on the economy in Section

7.

6.1 Intermediate Firms

Consider firms in China in Sector j producing a differentiated good using a vector of inputs $\mathcal{I}$ under monopolistic competition. We assume that all firms in this market are identical within their sector so that we omit their subscript f_j. There is no roundabout production, so that the production of the intermediate firm equals its value added. The firm can sell its output in the domestic and foreign markets. The production function and the resource constraint are

$$X_{j,ch,t} = \mathcal{F}(\mathcal{I}_{j,ch,t}) \quad \text{, and} \quad Y_{j,ch,t} = X_{j,ch,ch,t} + X_{j,ch,row,t}$$

where $Y_{j,ch,t}$ is the total production, $X_{j,ch,ch,t}$ the quantities sell to domestic market, and $X_{j,ch,row,t}$ the quantities exported to the rest of the world (ROW). Chinese firms are subject to domestic and export value added taxes, so their profits are given by,

$$\Pi_{j,ch,t} = P_{j,ch,ch,t} X_{j,ch,ch,t} \left[1 - \tau\right] + \mathcal{E}_t P_{j,ch,row,t} X_{j,ch,row,t} \left[1 - \left(\tau - \zeta_{j,t}\right)\right] - \mathcal{C}_{j,ch,t} \mathcal{I}_{j,ch,t}$$

where $P_{j,ch,ch,t}$ is the price of goods sold domestically, $P_{j,ch,row,t}$ the price of goods sold in the foreign market, $\mathcal{E}_t$ the nominal exchange rate, τ the domestic value added tax, $\zeta_{j,t}$ the VAT-RX, and $\mathcal{C}_{j,ch,t}$ a vector of factor prices. The effective value added tax on exports is then $\tau - \zeta_{j,t}$.[5]

The solution to the problem of the intermediate firm implies a demand for inputs of production and optimal prices,

$$\mathcal{C}_{j,ch,t} = \frac{\nabla F(\mathcal{I}_{j,ch,t})}{\nabla \mathcal{I}_{j,ch,t}}$$

$$P_{j,ch,ch,t} = \frac{\theta}{\theta - 1} \times \frac{MC_{j,ch,t}}{[1 - \tau]}$$

$$\mathcal{E} P_{j,ch,row,t} = \frac{\theta}{\theta - 1} \times \frac{MC_{j,ch,t}}{\left[1 - \left(\tau - \zeta_{j,t}\right)\right]} \tag{4}$$

where θ is the elasticity of substitution in the CES aggregator of Chinese varieties in the ROW,

[5]The value added tax coincides with a sales tax in this setting due to the absence of roundabout production.

and $MC_{j,ch,t}$ the marginal cost of production.

6.2 Retailer

There is a retailer in the ROW aggregating bundles of domestic and imported Chinese intermediate goods. The retailer faces difficult to adjust inputs immediately, which we model as habits in the use of domestic and imported bundles of intermediate goods. This is similar to Ravn et al. (2012), except that habits are formed at the level of the bundles of intermediate goods rather than at the variety level (i.e. deep habits).[6]

The bundles of intermediate goods are given by,

$$X_{j,row,row,t} = \left(\int_0^1 X_{j,row,row,t}(f_j)^{\frac{\theta-1}{\theta}} df_j \right)^{\frac{\theta}{\theta-1}} \quad \text{, and} \quad X_{j,ch,row,t} = \left(\int_0^1 X_{j,ch,row,t}(f_j)^{\frac{\theta-1}{\theta}} df_j \right)^{\frac{\theta}{\theta-1}}$$

where $X_{j,row,row,t}$ is the bundle of ROW intermediate goods, and $X_{j,ch,row,t}$ is the bundle of Chinese intermediate goods. The CES aggregator of the retailer is,

$$X_{j,row,t} = \left[(1-\omega_j)^{\frac{1}{\gamma}} \left(\frac{X_{j,row,row,t}}{\left(\frac{X_{j,row,v,t-1}}{X_{j,row,t}} \right)^{\frac{-\delta}{\gamma(1-\delta)-1}}} \right)^{\frac{\gamma(1-\delta)-1}{\gamma(1-\delta)}} + \left(\omega_j\right)^{\frac{1}{\gamma}} \left(\frac{X_{j,ch,row,t}}{\left(\frac{X_{j,ch,row,t-1}}{X_{j,row,t}} \right)^{\frac{-\delta}{\gamma(1-\delta)-1}}} \right)^{\frac{\gamma(1-\delta)-1}{\gamma(1-\delta)}} \right]^{\frac{\gamma(1-\delta)}{\gamma(1-\delta)-1}}$$

where $X_{j,row,t}$ is total demand, $(1-\omega_j)$ is the home bias in the ROW, γ the Armington elasticity between domestic and imported composite goods, and δ the degree of habits. When $\delta = 0$ then we are back to the standard CES aggregator. Total expenditure is,

$$P_{j,row,t}X_{j,row,t} = P_{j,row,row,t}X_{j,row,row,t} + P_{j,ch,row,t}X_{j,ch,row,t}$$

where $P_{j,row,row,t}$ and $P_{j,ch,row,t}$ are the prices of the ROW and (imported) Chinese goods, respectively, and $P_{j,row,t}$ the price of the sector good. We assume the habits are external as in Ravn et al.

[6] The presence of habits at the bundle level triggers a dynamic trade elasticity as opposed to deviations from the law of one price, as is the case with deep habits.

(2012). The solution to the problem of the ROW retailer is a pair of demand functions

$$X_{j,ch,row,t} = \left[\omega_j \left(\frac{P_{j,ch,row,t}}{P_{j,row,t}}\right)^{-\gamma}\right]^{1-\delta} \left(\frac{X_{j,ch,row,t-1}}{X_{j,row,t}}\right)^{\delta} X_{j,row,t} \tag{5}$$

$$X_{j,row,row,t} = \left[\left(1-\omega_j\right) \left(\frac{P_{j,row,row,t}}{P_{j,row,t}}\right)^{-\gamma}\right]^{1-\delta} \left(\frac{X_{j,row,row,t-1}}{X_{j,row,t}}\right)^{\delta} X_{j,row,t} \tag{6}$$

The presence of habits induces a lagged response of the demand for Chinese imports to changes in the state of the economy, resulting in a dynamic elasticity of trade flows to prices. Consequently, changes in the VAT-RX will induce a dynamic effect on Chinese exports through the lagged response of the demand of Chinese intermediate goods by the ROW retailer. The following proposition summarizes the dynamic trade elasticity induced by a permanent change in the VAT-RX in China.

Proposition 1 (Dynamic Trade Elasticity). *Consider a permanent shock to the VAT-RX in China in Sector* 1, ζ_1. *From the ROW demand of Chinese intermediate goods in equation* (20) *and the expression for the export price in equation* (4), *we can derive the time-t elasticity of Chinese exports of firm* f *to a permanent change in the VAT-RX,*

$$\frac{\partial \hat{X}_{1,ch,row,t}}{\partial \hat{\zeta}} = \gamma(1-\delta)\left(\sum_{j=0}^{t} \delta^j\right)$$

where $\hat{X}^*_{ch,row,t}$ *and* $\hat{\zeta}$ *are log-deviations from the steady state Chinese exports and the VAT-RX, respectively. The habit,* δ, *governs the dynamic trade elasticity, which eventually converges to* γ.

Proposition 1 is useful because we can use it to pin down the habits degree δ using the estimated elasticity from Section 5. We estimate the elasticity in the model using the simulated method of moments. We target horizons 0 to 39 of the estimated coefficient of the trade elasticity from the data, where each moment is weighted by the inverse of its variance, constructed from the confidence intervals. Let $\boldsymbol{\Psi}(\delta)$ the mapping from δ to the model trade elasticity moments, and $\hat{\boldsymbol{\Psi}}$ the corresponding empirical estimates. Then the estimator $\hat{\delta}$ is the solution to

$$J = \min_{\delta} [\hat{\boldsymbol{\Psi}} - \boldsymbol{\Psi}(\delta)]' \mathbf{V}^{-1} [\hat{\boldsymbol{\Psi}} - \boldsymbol{\Psi}(\delta)]$$

where $\mathbf{V}$ is diagonal matrix with sample variances of $\hat{\Psi}$'s along the diagonal. We estimate a value of habits, $\hat{\delta}$, of 0.9279. Figure 7 presents the dynamic trade elasticity in the model and data, where it can be seen that the model closely tracks its data counterpart. In the next section we build a quantitative model that generates the same partial equilibrium dynamic trade elasticity, since it nests the model displayed in this section.

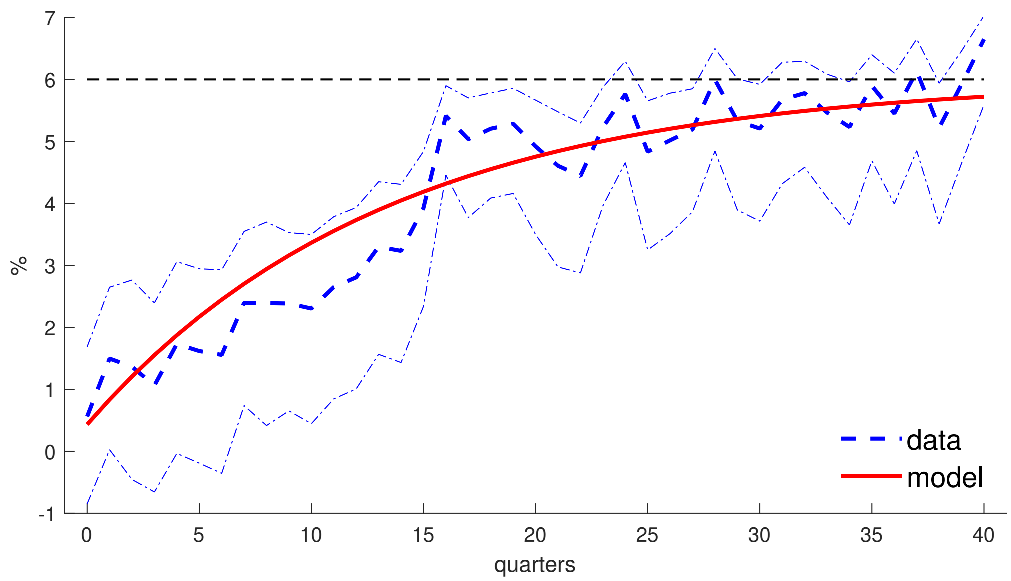


Figure 7: Partial Equilibrium Dynamic Trade Elasticity: Data and Model

7 Quantitative Model

In this section, we build a quantitative two-country-two-sector DSGE model to evaluate the macroeconomic consequences of VAT-RX policy. the quantitative model nests the partial equilibrium model from Section 6. Consequently, the dynamic trade elasticity is pinned down by Proposition 1. The quantitative model incorporates VAT and VAT-RX policy dynamics, a rich structure of shocks, capital accumulation, and pricing-to-market frictions. We study the international transmission of VAT-RX policy in China, focusing on the level and cyclicality effects of this policy.

7.1 Two-Country-Two-Sector DSGE Model

There are two countries, China and the ROW, denoted by $i \in \{ch, row\}$, which differ in their size, and two sectors denoted by $j \in \{1, 2\}$. Intermediate firms produce differentiated goods under monopolistic competition, using capital and labor and are subject to TFP shocks. Firms sell they goods in domestic and foreign markets, and are subject to a stochastic iceberg trade cost on exports. Firms in China are also subject to taxes on domestic and export value added. Chinese firms in Sector 1 and 2 differ in the value added tax and export rebates they pay to the government.

In each sector there is a retailer aggregating bundles of domestic and imported intermediates to produced the output of each sector which is non-tradable. These retailers are also subject to external habits and home bias shocks. The output of each sector is then aggregated by a retailer to produce the final non-traded good, which is used for consumption and investment.

The representative household chooses consumption, labor, investment, and a risk free bond traded with the foreign household, denominated in ROW currency. The Chinese household is subject to a financial shock that induces deviations from the uncovered interest parity. Investment is sector specific and subject to adjustment costs. Households are also subject to discount factor shocks.

Finally, the Chinese government follows a balanced budget, collecting domestic and export value added taxes on intermediate firms which are given back lump-sum to the household. The value added tax and the export rebates are sector specific, and follow a stochastic process. There is no government in the ROW.

There are two sources of asymmetry in the model: the size of the countries, and the absence of a government in the ROW. We present the model from the point of view of Chinese agents.

7.2 Intermediate Firms

Since all firms within each sector $j \in \{1, 2\}$ are identical we omit their subscript f_j. Total production of firm j in China is given by,

$$Y_{j,ch,t} = e^{z_{j,ch,t}} K_{j,ch,t}^{\alpha} L_{j,ch,t}^{1-\alpha}$$

where $z_{j,ch,t}$ is a TFP shock, and α the share of capital in income in Sector j. Firms can sell their output in the domestic and foreign market, with the resource constraint being

$$Y_{j,ch,t} = X_{j,ch,ch,t} + X_{j,ch,row,t}^{*} e^{\xi_{j,ch,row,t}}$$

where $X_{j,ch,ch,t}$ are the quantities sold in domestic markets, $X_{j,ch,row,t}^{*}$ the quantities exported, and $\xi_{j,ch,row,t}$ is an iceberg trade cost of exporting to the ROW.

Chinese firms are subject to domestic and export value added taxes, so their profits are given by,

$$\Pi_{j,ch,t} = P_{j,ch,ch,t} X_{j,ch,ch,t} \left[1 - \tau_{j,ch,t}\right] + \mathcal{E}_t P_{j,ch,row,t} X_{j,ch,row,t} \left[1 - \left(\tau_{j,t} - \zeta_{j,t}\right)\right] - W_{j,ch,t} L_{j,ch,t} - R_{j,ch,t}^{k} K_{j,ch,t}$$

where $P_{j,ch,ch,t}$ is the price of goods sold domestically, $P_{j,ch,row,t}^{*}$ the price of goods sold in the foreign market, $\tau_{j,t}$ the domestic value added tax, and $\zeta_{j,t}$ the rebate on the export value added tax. Hence, the effective value added tax on exports is given by $\tau_{j,t} - \zeta_{j,t}$.[7]

The solution to the problem of the intermediate firm in sector j is a pair of demand functions,

$$R_{j,ch,t}^{K} K_{j,t} = \alpha Y_{j,ch,t} MC_{j,ch,t}$$

$$W_{j,ch,t} L_{j,ch,t} = (1-\alpha) Y_{j,ch,t} MC_{j,ch,t}$$

[7]The value added tax coincides with a sales tax in this setting due to the absence of roundabout production.

where the marginal cost of production is given by,

$$MC_{j,ch,t} = \frac{1}{\varpi}\left[e^{-z_{j,ch,t}}\left(R^k_{j,ch,t}\right)^{\alpha}\left(W_{j,ch,t}\right)^{1-\alpha}\right] \quad \text{and} \quad \varpi \equiv \left[\alpha^{\alpha}(1-\alpha)^{1-\alpha}\right].$$

and a pair of optimal prices,

$$P_{j,ch,ch,t} = \frac{\theta}{\theta-1} \times \frac{MC_{j,ch,t}}{\left[1-\tau_{j,t}\right]}$$

$$\mathcal{E}_t P_{j,ch,row,t} = e^{\xi_{j,ch,row,t}}\frac{\theta_{ch,t}}{\theta_{ch,t}-1} \times \frac{MC_{j,ch,t}}{\left[1-\left(\tau_{j,t}-\zeta_{j,t}\right)\right]} \tag{7}$$

where $\theta_{ch,t} = \theta \mathcal{Q}_t^{-\Lambda}$ is the elasticity of substitution in the CES aggregator of Chinese varieties in the US, which depends on the real exchange rate, $\mathcal{Q}$, and a parameter $\Lambda > 0$. This formulation captures pricing-to-market frictions in reduced form that generates an incomplete pass-through of exchange rates to prices, as in Alessandria and Choi (2021).

The aggregators of domestic and exported varieties in sector j are,

$$X_{j,ch,ch,t} = \left(\int_0^1 X_{j,ch,ch,t}(f_j)^{\frac{\theta-1}{\theta}} df_j\right)^{\frac{\theta}{\theta-1}}, \text{ and } \quad X_{j,ch,row,t} = \left(\int_0^1 X_{j,ch,row,t}(f_j)^{\frac{\theta_{ch,t}-1}{\theta_{ch,t}}} df_j\right)^{\frac{\theta_{ch,t}}{\theta_{ch,t}-1}}, \text{ for } j \in \{1,2\}$$

7.3 Sector Output

Output at the sector level is produced by a retailer that aggregates bundles of domestic and imported intermediates from its sector. These retailers face difficulties in adjusting its inputs immediately, which we model as external habits in the use of bundles of intermediate goods from each sector. The aggregator for the output in Sector j is,

$$X_{j,ch,t} = \left[(1-\omega_j)^{\frac{1}{\gamma}}\left(e^{-\omega_j \vartheta_{j,ch,t}}\right)^{\frac{1}{\gamma}}\left(\frac{X_{j,ch,ch,t}}{\left(\frac{X_{j,ch,ch,t-1}}{X_{j,ch,t}}\right)^{\frac{-\delta}{\gamma(1-\delta)-1}}}\right)^{\frac{\gamma(1-\delta)-1}{\gamma(1-\delta)}} + (\omega_j)^{\frac{1}{\gamma}}\left(e^{(1-\omega_j)\vartheta_{j,ch,t}}\right)^{\frac{1}{\gamma}}\left(\frac{X_{j,row,ch,t}}{\left(\frac{X_{j,row,ch,t-1}}{X_{j,ch,t}}\right)^{\frac{-\delta}{\gamma(1-\delta)-1}}}\right)^{\frac{\gamma(1-\delta)-1}{\gamma(1-\delta)}}\right]^{\frac{\gamma(1-\delta)}{\gamma(1-\delta)-1}}$$

where $1-\omega_j$ is the home bias of sector j, $\vartheta_{j,ch,t}$ is a stochastic process for the home bias, γ the elasticity of substitution between the bundle of domestic and imported intermediate goods, and δ the habits.

The problem of the retailer is to minimize expenditure,

$$P_{j,ch,t}X_{j,ch,t} = \left(P_{j,ch,ch,t}X_{j,ch,ch,t} + P_{j,row,ch,t}X_{j,row,ch,t}\right)$$

subject to the CES aggregator. The solution to this problem is a pair of demand functions,

$$X_{j,ch,ch,t} = \left[\left(1-\omega_j\right) e^{-\omega_j \vartheta_{j,ch,t}} \left(\frac{P_{j,ch,ch,t}}{P_{j,ch,t}}\right)^{-\gamma}\right]^{1-\delta} \left(\frac{X_{j,ch,ch,t-1}}{X_{j,ch,t}}\right)^{\delta} X_{j,ch,t} \tag{8}$$

$$X_{j,row,ch,t} = \left[\left(1-\omega_j\right) e^{\left(1-\omega_j\right)\vartheta_{j,ch,t}} \left(\frac{P_{j,row,ch,t}}{P_{j,ch,t}}\right)^{-\gamma}\right]^{1-\delta} \left(\frac{X_{j,row,ch,t-1}}{X_{j,ch,t}}\right)^{\delta} X_{j,ch,t} \tag{9}$$

The price index of sector j output is given by,

$$P_{j,ch,t} = \left[\omega_j^{1-\gamma} e^{-\omega_j \vartheta_{j,ch,t}(1-\gamma)} \left(P_{j,ch,ch,t}\right)^{1-\gamma(1-\delta)} \left(\frac{X_{j,ch,ch,t-1}}{X_{j,ch,t}}\right)^{\delta} + \left(1-\omega_j\right)^{1-\gamma} e^{(1-\omega_j)\vartheta_{j,ch,t}(1-\gamma)} \left(P_{j,row,ch,t}\right)^{1-\gamma(1-\delta)} \left(\frac{X_{j,row,ch,t-1}}{X_{j,ch,t}}\right)^{\delta}\right]^{\frac{1}{1-\gamma(1-\delta)}}$$

As in the partial equilibrium model, the presence of habits generate a dynamic elasticity of trade flows to prices. Since in partial equilibrium aggregate variables are constant, then Proposition 1 holds in this model.

7.4 Final Retailer

The final retailer in China aggregates the output of each sector j. The final good is used for consumption and investment,

$$C_t + I_t = \left[(1-\omega)^{\frac{1}{\gamma^F}} \left(X_{1,ch,t}\right)^{\frac{\gamma^F-1}{\gamma^F}} + (\omega)^{\frac{1}{\gamma^F}} \left(X_{2,ch,t}\right)^{\frac{\gamma^F-1}{\gamma^F}}\right]^{\frac{\gamma^F}{\gamma^F-1}}$$

where ω is the size of sector 2 and γ^F the elasticity of substitution across sectors. Total expenditure is,

$$P_t\left(C_t + I_t\right) = P_{1,ch,t}X_{1,ch,t} + P_{2,ch,t}X_{2,ch,t}$$

where P_t is the price index of the final good in China. The solution to the problem of the Chinese final retailer is a pair of demand functions

$$X_{1,ch,t} = \omega \left(\frac{P_{1,ch,t}}{P_t} \right)^{-\gamma^F} (C_t + I_t) \tag{10}$$

$$X_{2,ch,t} = (1 - \omega) \left(\frac{P_{2,ch,t}}{P_t} \right)^{-\gamma^F} (C_t + I_t) \tag{11}$$

The price index of final output in China is given by,

$$P_{ch,t} = \left[\omega \left(P_{1,ch,t} \right)^{1-\gamma^F} + (1 - \omega) \left(P_{2,ch,t} \right)^{1-\gamma^F} \right]^{\frac{1}{1-\gamma^F}}$$

7.5 Consumer

The Chinese representative household maximizes the discounted expected utility

$$\max_{\{C_t, L_t I_t, K_{t+1}, B_{t+1}\}_{t=0}^{\infty}} \mathbb{E}_t \sum_{t=0}^{\infty} \Theta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{\eta_{ch} \left(\varrho L_{1,t} + (1-\varrho) L_{2,t} \right)^{1+\frac{1}{\nu}}}{1 + \frac{1}{\nu}} \right)$$

where C_t is consumption, L_t is labor, $1/\sigma$ the intertemporal elasticity of substitution, η_{ch} the weight on labor in China, ϱ governs the preference for working in sector 1, and ν the Frisch elasticity of labor supply, and Θ_t the discount factor at t. The flow budget constraint is,

$$P_t \left(C_t + \sum_{j \in \{1,2\}} \left(I_{j,t} \right) \right) + \frac{\mathcal{E}_t B_{t+1}}{R_t^* e^{\psi_t}} + \frac{\chi}{2} \left(\frac{\mathcal{E}_t B_{t+1}}{R_t^*} - \frac{\bar{\mathcal{E}} \bar{B}}{\bar{R}^*} \right)^2 = \sum_{j \in \{1,2\}} \left(W_{j,t} L_{j,t} + R_{j,t}^k K_{j,t} + \Pi_{j,t} \right) + \mathcal{E}_t B_t + T_t$$

where P_t is the price index, $I_{j,t}$ is investment in Sector j, B_{t+1} the quantity of bonds traded internationally, R_t^* the risk-free interest rate on the bond, $\mathcal{E}_t$ is the nominal exchange rate, $W_{j,t}$, $R_{j,t}^k$, $K_{j,t}$ and $\Pi_{j,t}$ are the wage bill, return on capital, capital stock and profits of firms in Sector j, respectively. T_t are lump-sum transfers from the government. The parameter χ governs the adjustment cost of internationally traded bonds and $\bar{B}$ its long-run level, included to induce stationarity to the model, and ψ_t is a financial shock only faced by the Chinese household which generates a wedge relative to the return faced by the ROW household. The stock of capital in Sector j follows the law of motion,

$$K_{j,t+1} = (1-\delta^k)K_{j,t} + I_{j,t} \times \left[1 - \frac{\kappa}{2}\left(\frac{I_{j,t}}{I_{j,t-1}} - 1\right)^2\right]$$

where κ governs the adjustment cost of investment following Christiano et al. (2005). Finally, the cumulative discount factor evolves as

$$\ln(\Theta_{t+1}/\Theta_t) = \ln\beta_t = (1-\rho_b)\ln\bar{\beta} + \rho_b \ln\beta_{t-1} - \nu\ln\left(\tilde{C}_t/\bar{C}\right) + \varepsilon_{\beta,t}$$

where $\bar{\beta}$ is the steady state β, $\bar{C}$ is the steady state C, and $\tilde{C}_t$ is the average (aggregate) consumption in the economy, and ε_β is a shock. The discount factor β_t is external.

The solution to the Chinese household problem can be characterized by the labor supply condition and the Euler equations for the international traded bond and for capital. The stochastic discount factor between t and $t+1$ is given by,

$$\Omega_{t,t+1} \equiv \beta_t \mathbb{E}_t \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}$$

7.6 Chinese Government

The Chinese government follows a balanced budget,

$$T_{ch,t} = \sum_{j=\{1,2\}} \left\{ P_{j,ch,ch,t} X_{j,ch,ch,t} \left[1 - \tau_{j,t}\right] + \mathcal{E}_t P_{j,ch,row,t} X_{j,ch,row,t} \left[1 - \left(\tau_{j,t} - \zeta_{j,t}\right)\right] \right\}$$

The evolution of the value added tax and the export rebate are governed by the following rules,

$$\tau_{j,t} = \mu_{j,\tau}\left(1 - \rho_{j,\tau}\right) + \rho_{j,\tau}\tau_{j,t-1} + \sigma_{j,\tau}\epsilon_{j,\tau,t}$$

$$\zeta_{j,,t} = \mu_{j,\zeta}\left(1 - \rho_{j,\zeta}\right) + \rho_{j,\zeta}\zeta_{j,t-1} + \sigma_{j,\zeta}\epsilon_{j,\zeta,t}$$

7.7 Shock Processes

There are 18 shocks in the model: TFP shocks in each sector j (4), discount factor shocks (2), home bias shocks (2), trade cost shocks (4), a financial shock (1), valued added tax shock and the export rebate shock in each sector j (4). It remains to define the processes for TFP, home bias, trade costs, and the financial shock,

$$
\begin{aligned}
z_{j,t} =& \mu_z(1-\rho_z) + \rho_z z_{t-1} + \sigma_{j,z}\varepsilon_{j,z,t} \quad \text{, and} \quad z^*_{j,t} = \mu^*_z(1-\rho^*_z) + \rho^*_z z^*_{t-1} + \sigma^*_{j,z}\varepsilon^*_{j,z,t} \\
\xi_{j,t} =& \rho_{j,\xi}\xi_{t-1} + \sigma_{j,\xi}\varepsilon_{j,\xi,t} \quad \text{, and} \quad \xi^*_{j,t} = \rho^*_{j,\xi}\xi^*_{j,t-1} + \sigma^*_{j,\xi}\varepsilon^*_{j,\xi,t} \\
\psi_t =& -\phi_\psi(B_{t+1} - B_t) + \rho_\psi \psi_{t-1} + \sigma_\psi \varepsilon_{\psi,t}
\end{aligned}
$$

where variables with * denote ROW variables. The term ϕ_ψ captures capital controls by the Chinese government in reduced form.

7.8 Market Clearing

Market clearing for foreign bonds: $\mathcal{E}_t B_{ch,t+1} + B_{row,t+1} = 0$

Country budget constraint,

$$
\mathcal{E}_t \frac{B_{t+1}}{R_t} - B_{t+1} = NX_t - \frac{\chi}{2}\left(\frac{\mathcal{E}_t B_{t+1}}{R_t} - \bar{B}\right)^2
$$

where

$$
NX_t \equiv \sum_{j\in\{1,2\}} \left(\mathcal{E}_t P_{j,ch,row,t} X_{j,ch,row,t} - P_{j,row,ch,t} X_{j,row,ch,t}\right)
$$

7.9 Bayesian Estimation

We estimate the model using Bayesian methods, and perform counterfactual analysis to study the effect of the level of the VAT-RX and use the Global Financial Crisis as a case study to evaluate the countercyclical use of VAT-RX. We explain the estimation strategy, and then discuss the main results.

Table 1 presents the parameters that are externally set, with its target moment or source. We normalize the steady state TFP in the ROW to one, and then set the mean of China's TFP process to match China's share in global GDP of 10%. We set the home bias in China to match the average real trade share over GDP of 50% in the sample period. Given this, we set the home bias in the ROW such that net trade is zero in the steady state. Finally, we set the habit parameter, δ, to match the partial equilibrium dynamic trade elasticity to changes in the VAT-RX, following proposition 1. As in Section 6, this gives a value of 0.9279 when estimated with the simulated method of moments.

Table 1: Calibrated Parameters

Parameter		Value	Target Moment or Source
Discount factor	β	0.99	Annual interest rate of 4%
Risk aversion	σ	2	Intertemporal elasticity of substitution of 0.5
Weight on consumption in China	η_C	0.53	Hours worked of 1/3
Weight on consumption in ROW	η_R	0.53	Hours worked of 1/3
Macro Frisch Elasticity	ν	1	Frisch Elasticity
Capital share of income	α	0.40	Bai et al. (2018)
Elasticity of substitution across varieties	θ	4	Producer markup of 33%
Armington Elasticity	ρ	6	Estimated long-run elasticity of VAT export rebates
Depreciation rate of capital	δ^k	0.025	standard
Average TFP in ROW	μ_z^*	1	Normalization
Average TFP in China	μ_z	0.067	China's GDP in world GDP
Home bias in China	γ^C	0.25	Trade-to-GDP ratio of 50% in China
Home bias in ROW	γ^R	0.025	zero net exports in steady state
Bond adjustment cost	χ	0.001	stationarity of NFA
Steady state NFA	$\bar{B}$	0	Steady state NFA of zero
Pricing-to-market friction	Λ	1.20	50% exchange rate pass-though to prices (Gopinath and Itskhoki, 2010)
Habits in CES aggregator	δ	0.9279	PE dynamic trade elasticity

We have 18 shocks and feed 15 time series in the Bayesian estimation, displayed in Figure 8 present the time series used for the estimation. We feed the value added tax and the export rebates in China in both sectors, the growth rate of nominal exports and imports in each sector in China, aggregate real exports and imports in China, the real GDP and investment in China, the growth rate of nominal GDP in the ROW, the real exchange rate, and the terms of trade.[8] The estimated parameters are displayed in Table 2.[9]

[8] The terms of trade are defined as the ratio of import to export prices.

[9] The log data density is 1198.23.

Table 2: Estimated Parameters

Parameter	Prior Distribution	Post. Mean	90% Interval	Prior	Post. dev.
ρ_z	0.499	0.7195	(0.7123 , 0.7253)	unif	0.2884
σ_{z_1}	1.000	0.3759	(0.3556 , 0.4030)	unif	0.5774
σ_{z_2}	1.000	0.4538	(0.4411 , 0.4624)	unif	0.5774
ρ_{z^*}	0.499	0.9858	(0.9827 , 0.9894)	unif	0.2884
$\sigma_{z_1^*}$	1.000	0.2431	(0.2336 , 0.2530)	unif	0.5774
$\sigma_{z_2^*}$	1.000	0.5707	(0.5536 , 0.5852)	unif	0.5774
ρ_{ξ_1}	0.499	0.7068	(0.6987 , 0.7146)	unif	0.2884
σ_{ξ_1}	1.000	0.5383	(0.5213 , 0.5549)	unif	0.5774
ρ_{ξ_2}	0.499	0.8492	(0.8325 , 0.8641)	unif	0.2884
σ_{ξ_2}	1.000	0.5154	(0.4942 , 0.5349)	unif	0.5774
$\rho_{\xi_1^*}$	0.499	0.7491	(0.7443 , 0.7518)	unif	0.2884
$\sigma_{\xi_1^*}$	1.000	0.3361	(0.3194 , 0.3502)	unif	0.5774
$\rho_{\xi_2^*}$	0.499	0.9784	(0.9739 , 0.9816)	unif	0.2884
$\sigma_{\xi_2^*}$	1.000	0.4268	(0.4202 , 0.4340)	unif	0.5774
ρ_β	0.499	0.5001	(0.4875 , 0.5113)	unif	0.2884
σ_β	0.250	0.0287	(0.0281 , 0.0296)	unif	0.1443
ρ_{β^*}	0.499	0.8775	(0.8623 , 0.8897)	unif	0.2884
σ_{β^*}	0.250	0.0018	(0.0009 , 0.0028)	unif	0.1443
ρ_ψ	0.499	0.9839	(0.9682 , 0.9990)	unif	0.2884
σ_ψ	1.000	0.0205	(0.0196 , 0.0213)	unif	0.5774
ϕ_ψ	0.250	0.0137	(0.0126 , 0.0149)	unif	0.1443
ρ_ϑ	0.750	0.5115	(0.5023 , 0.5229)	unif	0.1440
σ_{ϑ_1}	1.000	0.4186	(0.3920 , 0.4576)	unif	0.5774
σ_{ϑ_2}	1.000	1.9589	(1.9458 , 1.9717)	unif	0.5774
ρ_{τ_1}	0.495	0.4908	(0.4840 , 0.5031)	unif	0.2858
ρ_{τ_2}	0.495	0.5259	(0.5139 , 0.5334)	unif	0.2858
σ_{τ_1}	0.250	0.0028	(0.0027 , 0.0029)	unif	0.1443
σ_{τ_2}	0.250	0.0021	(0.0021 , 0.0021)	unif	0.1443
σ_{ζ_1}	0.250	0.0055	(0.0052 , 0.0058)	unif	0.1443
σ_{ζ_2}	0.250	0.0069	(0.0065 , 0.0072)	unif	0.1443
ν	0.010	0.0198	(0.0197 , 0.0199)	unif	0.0058
χ	0.100	0.0127	(0.0126, 0.0127)	unif	0.0577

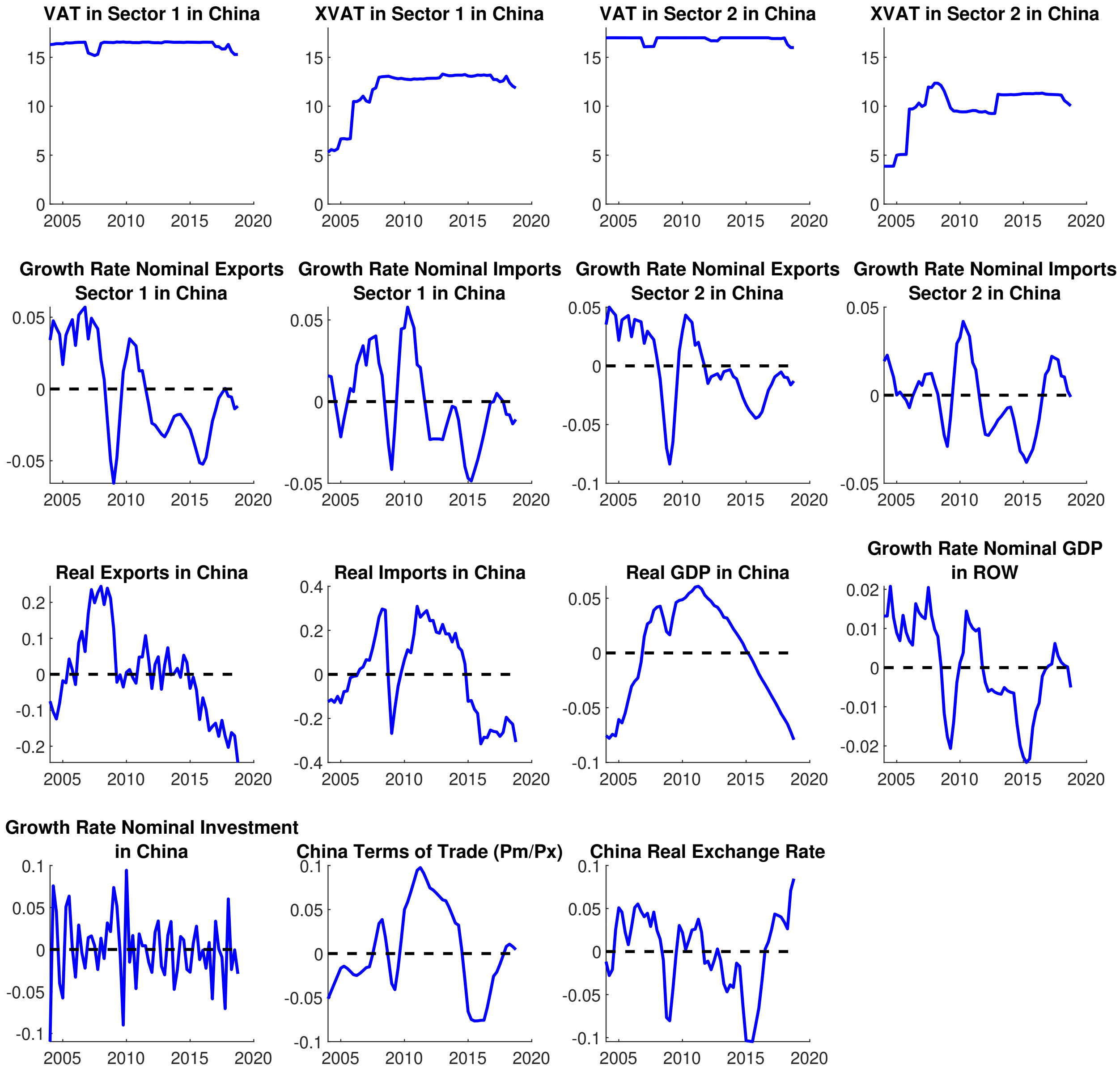


Figure 8: Data for Bayesian Estimation

7.9.1 The Level Effects of VAT-RX Policy

China's use of VAT-RX is an anomaly. In general, countries have a 100% export rebate of VAT. We study the implications of deviating from the standard practice of the 100% export rebate, by constructing a counterfactual case where China followed the standard practice.

Figure 9 present these results. The black solid line shows the time series of the Benchmark model, and the red-dashed lines the counterfactual where China followed a 100% rebate on export

VAT for the whole period under consideration. Panel (a), shows the dynamics of the effective VAT on exports, which is zero in the counterfactual 100% export rebate.

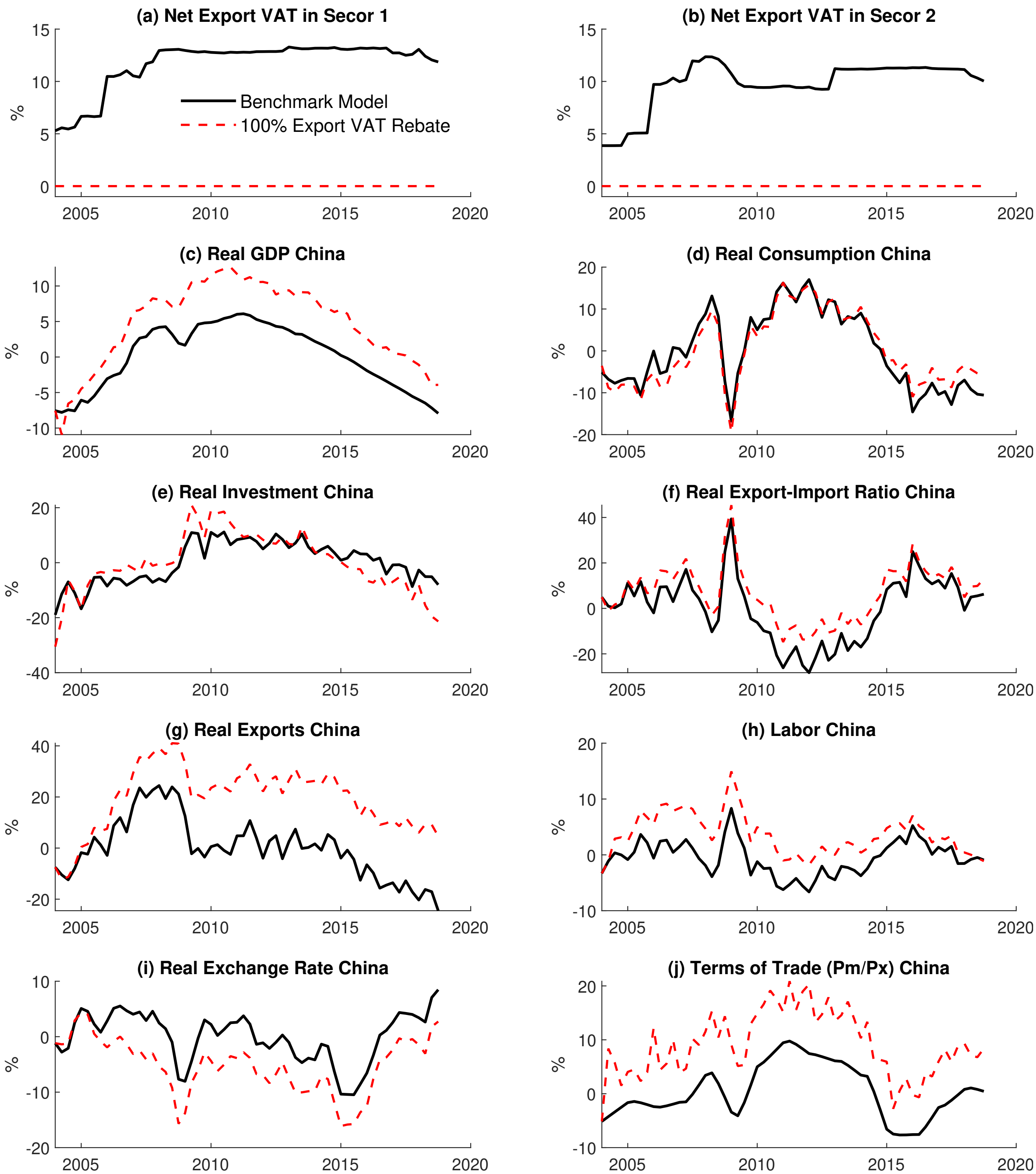


Figure 9: The level effects of VAT-RX policy

If China would have followed a constant 100% export rebate policy, real GDP in Chian would have been around 5p.p. higher. A 100% export rebate would have encouraged firms to export more (Panel g), which would have raised labor demand (Panel h). The export subsidy would have lowered the price of exports in equilibrium leading to a deterioration of the terms of trade (Panel j). Shifting the trade in intermediate goods from the domestic market to the export market, would have lowered the supply of final goods in China, triggering an increase in the price level which appreciates the RER in China (Panel i).

7.9.2 Quantifying the importance of Countercyclical VAT-RX Policy During the Global Financial Crisis

We use the global financial crisis between 2008 and 2012 as a case study for the countercyclical role of VAT-RX policy in China. Panel (b) in Figure 8 shows the path of the effective VAT on exports. Between the third quarter of 2008 and 2009 there was a reduction of the tax of around 187 basis points, since it fell from a a tax rate of 10.58% to 8.71%. After the third quarter of 2009 the tax rate remained almost unchanged. We study a counterfactual where the VAT rebate on exports did not change after the third quarter of 2008, so that the effective VAT on exports coincides with the domestic VAT. We interpret this case as 'shutting down' the countercyclical variation in the VAT rebate on exports.

Figure 10, presents the dynamics of key variables in the benchmark model which replicates the data and the counterfactual. Panel (a) shows the dynamics of the effective VAT on exports in both cases. Panel (b) shows that the VAT-RX policy followed by the government depreciated the effective real exchange rate on exports relative to the counterfactual. The increase in the VAT-RX rate on exports stimulated real exports. This can be seen in Panel (g), where we estimate that the increase in the VAT-RX raised exports on average by 300 basis points, during the global financial crisis. Consequently, Panel (c) shows that this policy was expansionary as it raised real GDP, which was raised on average by 170 basis points. The mechanism operated through an improvement in China's terms of trade (Panel j), due to the fall of the price of exports. Finally, China's real exchange rate appreciated in response to the policy (Panel i). This is similar to a fiscal devaluation (Farhi et al., 2014), for which we adopted the term quasi-fiscal devaluation.

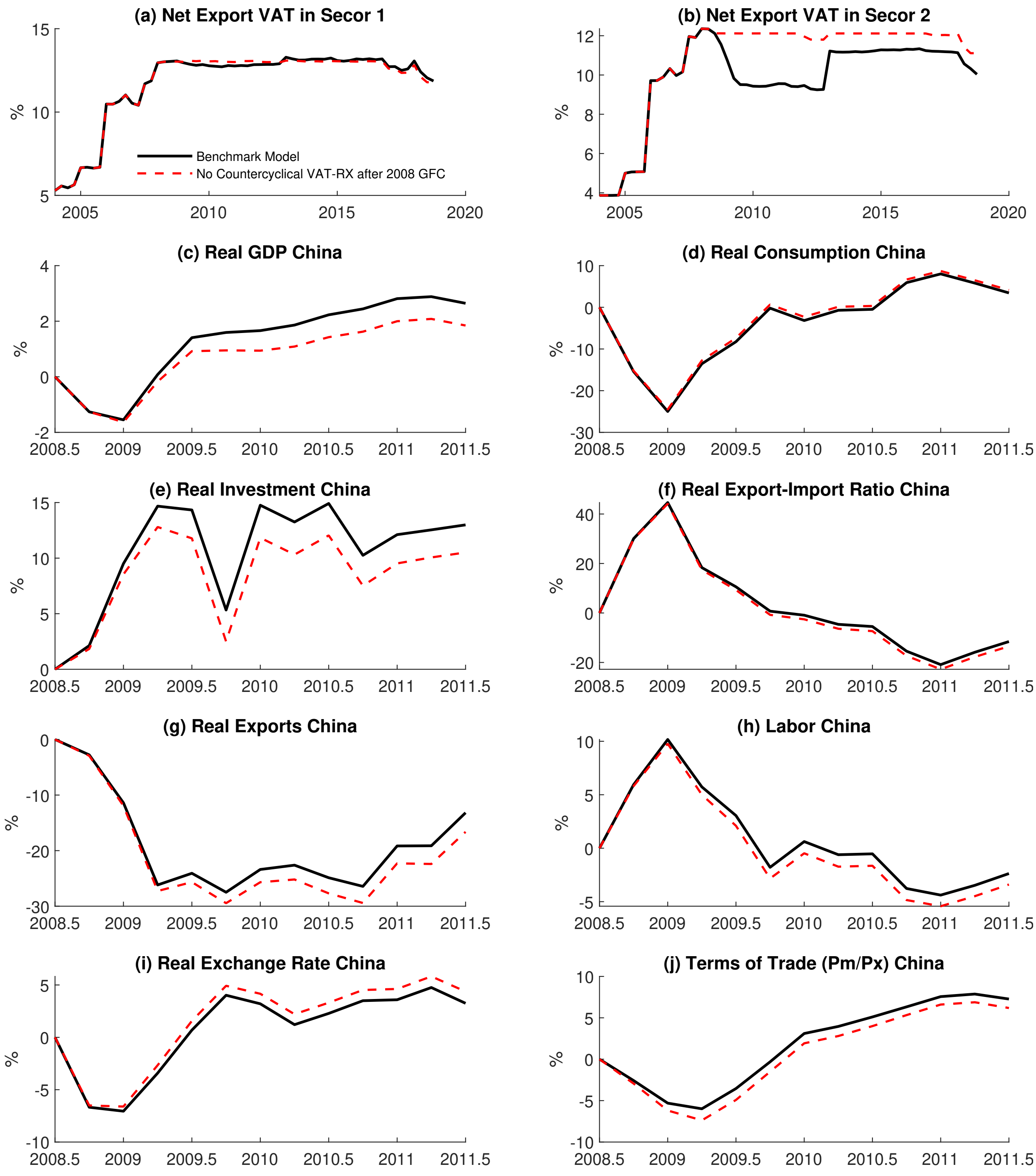


Figure 10: Global Financial Crisis: The importance of VAT-RX policy

8 Conclusion

This paper demonstrates the significant macroeconomic role of export subsidies. We exploit China's VAT-RX policy changes between 2004 and 2017. We provide causal estimates showing that export subsidies trigger important quantity dynamics, presenting low trade elasticity and high long-run elasticities, which are driven by real frictions.

Once we embed our partial equilibrium estimates into a full DESGE model, we find that in the context of China, VAT-RX works as a quasi-fiscal devaluation tool, particularly evident during the Global Financial Crisis. Our findings establish the relevance of considering fiscal instruments like VAT rebates alongside traditional monetary and exchange rate policies for macroeconomic stabilization and trade management. Specifically, absent the VAT-RX policy during the global financial crisis, aggregate exports and GDP in China would have been 3.7 and 0.3 percentage points lower.

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Appendix

A Proofs

We estimate a panel data local projection difference-in-differences (LP-DiD) specification

$$y_{i,t+h} - y_{i,t-1} = \Phi_t + \beta_h \Delta s_{i,t} + X_{i,t}\gamma_h + \nu_{i,t+h}$$

where Φ_t are time fixed effects, $s_{i,t} = 1$ are the treated units, defined as those firms that have a decrease in the rebate at t, where we assume the new state is an absorbing state. Hence, $\Delta s_{i,t} = 1$ are the newly treated. Finally, $X_{i,t}$ are a set of control variables, and $\nu_{i,t}$ the error term.

Taking logs of the ROW demand for Chinese intermediates in sector j,

$$x_{j,ch,row,t} = (1-\delta)\ln\left(1-\omega_j\right) + (1-\delta)\left(1-\omega_j\right)\vartheta_{row,t} - \gamma(1-\delta)\left(p_{j,ch,row,t} - p_{j,row,t}\right) + \delta\left[x_{j,ch,row,t-1} - x_{j,row,t-1}\right] + x_{j,row,t} \tag{12}$$

where lower case variables are logs.

Now define $\Delta_h y_t := y_{t+h-1} - y_{t-1}$ we get:

$$\Delta_h x_{j,ch,row,t} = (1-\delta)\left(1-\omega_j\right)\Delta_h\vartheta_{row,t} - \gamma(1-\delta)\left(\Delta_h p_{j,ch,row,t} - \Delta_h p_{j,row,t}\right) + \delta\left[\Delta_h x_{j,ch,row,t-1} - \Delta_h x_{j,row,t-1}\right] + \Delta_h x_{j,row,t} \tag{13}$$

Define $\bar{y}_{i,t} = \sum_i^N y_{i,t}\frac{1}{N}$. Denote then the variable $\Delta_h\bar{y}_{i,t} = \bar{y}_{i,t+h} - \bar{y}_{i,t-1}$. Note that $\bar{\Delta}x_t = \Delta x_t - \sum_{i=1}^N \frac{1}{N}\Delta x_t = 0$. Hence after including year FE we get that:

$$\bar{\Delta}_h X^*_{R,t} = (1-\delta)(-\rho)\bar{\Delta}_h {P^*}_{R,t} + \delta\bar{\Delta}_h\{X^*_{R,t-1}\} \tag{14}$$

Let for $r_1 \in R$, be the case that $\Delta s_{r_1 t^*} = 1$, where $\zeta_{r_1 t^*} - \zeta_{r_1 t^*-1} = a > 0$ is the change in the rebate at time t^*, and $\Delta\zeta_{r_1 t^*} = 0 \; \forall t > t^* \;\&\; t < t^*$. To simplify notation denote $t = t^*$.

We get that:

$$
\begin{aligned}
\bar{\Delta}_1 X^*_{r_1,t} &= (1-\delta)(-\rho)\bar{\Delta}_1 {P^*}_{r_1,t} + \delta \underbrace{\bar{\Delta}_1\{X^*_{r_1,t-1}\}}_{=0} \\
&= (1-\delta)(-\rho)\{ln(1-\tau_t+\zeta_t) - ln(1-\tau_{t-1}+\zeta_{t-1}) \\
&\approx (1-\delta)(-\rho)(-a)
\end{aligned}
\tag{15}
$$

Now for $t+2$:

$$
\begin{aligned}
\bar{\Delta}_2 X^*_{r_1,t} &= (1-\delta)(-\rho)\bar{\Delta}_2 {P^*}_{r_1,t} + \rho\bar{\Delta}_2\{X^*_{r_1,t-1}\} \\
&= (1-\delta)(-\rho)\{ln(1-\tau_{t+1}+\zeta_{t+1}) - ln(1-\tau_{t-1}+\zeta_{t-1}) + \delta\{\underbrace{X^*_{r_1,t} - X^*_{r_1,t-2}}_{=X^*_{r_1,t}-X^*_{r_1,t-1}=\bar{\Delta}_1 X^*_{r_1,t}}\} \\
&\approx (1-\delta)(-\rho)(-a) + \delta((1-\delta)(-\rho)(-a)) = (-a)(1-\delta)[-1-\delta]
\end{aligned}
\tag{16}
$$

Now for $t+3$:

$$
\begin{aligned}
\bar{\Delta}_3 X^*_{r_1,t} &= (1-\delta)(-\rho)\bar{\Delta}_3 {P^*}_{r_1,t} + \rho\bar{\Delta}_3\{X^*_{r_1,t-1}\} \\
&= (1-\delta)(-\rho)\{ln(1-\tau_{t+2}+\zeta_{t+2}) - ln(1-\tau_{t-1}+\zeta_{t-1}) + \delta\underbrace{\{X^*_{r_1,t+1} - X^*_{r_1,t-2}\}}_{=\bar{\Delta}_2 X^*_{r_1,t}} \\
&\approx (1-\delta)(-\rho)(-a) + (-\rho)(-a)(1-\delta)\delta[-1-\delta] = (1-\delta)(-\rho)(-a)[-1-\delta-\delta^2]
\end{aligned}
\tag{17}
$$

Hence we conclude that:

$$
\bar{\Delta}_h X^*_{r_1,t} = a(-\rho)(1-\delta)[\sum_{j=0}^{h} \delta^j] \tag{18}
$$

Which write in terms of elasticity is equal to:

$$
\frac{\bar{\Delta}_h X^*_{r_1,t}}{\zeta_{r_1,t} - \zeta_{r_1,t-1}} = (1-\delta)(-\rho)\left[\sum_{j=0}^{h} \delta^j\right] \tag{19}
$$

Now generalize and assume that we have a subset of treated units r_1 relative to $r \neq r_1 \in R$.

The treated units are in a subset defined $R_1 \in R$. We estimate the following equation where δ_t are the time FE. First assume that:

$$X^*_{R,t} = \left[\left(1-\gamma^R\right)\left(P^*_{R,t}\right)^{-\rho}\right]^{1-\delta}\left(\frac{X^*_{R,t-1}}{D^*_{t-1}}\right)^{\delta} D^*_t e^{v_{R,t}} \tag{20}$$

where $v_{r,t}$ is i.i.d with mean zero.

$$\Delta X_{r,t-1} = \delta_t + \beta_h \Delta s_{r,t} + v_{i,t+h}$$

Which is as estimating by ols:

$$\bar{\Delta} X_{r,t-1} = \beta_h \bar{\Delta} s_{r,t} + \bar{v}_{i,t+h}$$

The ols estimator is given by:

$$\hat{\beta} = \frac{1}{\sum \Delta s_{r,t}} \sum \bar{\Delta} X_{r,t-1} \Delta s_{r,t} - \frac{1}{\sum(1-\Delta s_{r,t})} \sum \bar{\Delta} X_{r,t-1}(1-\Delta s_{r,t})$$

Denote $\Delta s_{r,t} = I$ If $X^*_{R,t-1} = 1$

$$\begin{aligned}
\hat{\beta}_h &= \frac{1}{\sum I} \sum_r (a(-\rho)(1-\delta)[\sum_{j=0}^{h} \delta^j] + v_{i,t+h})\mathbf{I} - \frac{1}{\sum(1-\Delta s_{r,t})} \sum 0(1-\Delta s_{r,t}) \\
&= (a(-\rho)(1-\delta)[\sum_{j=0}^{h} \delta^j]) + \frac{1}{\sum I} \sum_r v_{i,t+h}\mathbf{I}
\end{aligned}$$

Hence:

$$\mathbf{E}\{\hat{\beta}_h\} = (a(-\rho)(1-\delta)[\sum_{j=0}^{h} \delta^j])$$

Now assume that $X^*_{R,t-1} = b$

$$\bar{\Delta}_h X^*_{r_1,t} = \{(1-\delta)(-\rho)a + \delta b_{r1}\}\left[\sum_{j=0}^{h} \delta^j\right] + \Delta_v v_{r,t} \tag{21}$$

While for not treated we have $r \in R$:

$$\bar{\Delta}_h X^*_{r_1,t} = \{\delta b_r\} \left[\sum_{j=0}^{h} \delta^j \right] + \Delta_v v_{r,t} \tag{22}$$

Hence:

$$\mathbf{E}\{\hat{\beta}_h\} = \{(1-\delta)(-\rho)a + \delta b_{r1}\} \left[\sum_{j=0}^{h} \delta^j \right] - \{\delta b_r\} \left[\sum_{j=0}^{h} \delta^j \right]$$

Now, assuming same pre trend we have that for $t < t^*$:

$$E\{\bar{\Delta}_{-h} X^*_{r_1,t}\} = E\{\bar{\Delta}_{-h} X^*_{r,t}\} \; \forall h > 1$$

Which implies that:

$$E\{\bar{\Delta}_{-h} X^*_{r_1,t}\} = b_{r1} = b_r = E\{\bar{\Delta}_{-h} X^*_{r,t}\}$$

Hence we get that under these assumption that:

$$\mathbf{E}\{\hat{\beta}_h\} = \{(1-\delta)(-\rho)a\} \left[\sum_{j=0}^{h} \delta^j \right]$$

Hence, we get that:

$$\mathbf{E}\{\bar{\Delta}_h X_{r1,t-1}\} = \mathbf{E}\{\beta_h \Delta s_{r,t}\} = \sum_{r \in R_1} \omega_{r1,h} \beta_h$$

Where $\omega_{r1,h}$ is some weight schedule. Assume $\omega_{r1,h} = \frac{1}{N_{R_1}}$. Hence we get that estimated

$\hat{\beta}_h = a(-\delta)(1-\delta) \left(\sum_{j=0}^{h} \delta^j \right)$ Start by identifying δ.

$\hat{\beta}^h = a(-\rho)(1-\delta) \left(\sum_{j=1}^{h} \delta^j \right)$

Use that

$$\sum_{j=1}^{\infty} \delta^j = \sum_{j=1}^{40} \delta^j + \sum_{j=41}^{\infty} \delta^j = \sum_{j=1}^{40} \delta^j + \frac{\delta^{40}}{1-\delta}$$

Using that $\sum_{j=1}^{\infty} \delta^j = \frac{1}{1-\delta}$. We get that:

$$\sum_{j=1}^{40} \delta^j = \frac{\delta}{1-\delta} - \frac{\delta^{40}}{1-\delta} = \frac{(1-\delta^{39})}{1-\delta}$$

Hence δ is given by the following condition:

$$\hat{\beta}^{40} = -\rho a(1-\delta^{39})$$

$$\rho = \frac{\hat{\beta}^{40}}{a(1-\delta^{39})}$$