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Imports of key capital goods and quality upgrading: Evidence from China's import subsidy policy[1]

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ABSTRACT

This paper examines the impact of capital goods imports on firms' export quality upgrading with a subsidy policy for advanced capital imports implemented in China since 2008. Using a matched dataset of firms' production and custom data, we employ a difference-in-differences strategy that exploits firms' differential pre-event exposures to the policy. We find that the subsidy policy increases firms' imports of subsidized products, and improves their export quality. Furthermore, export quality improvements due to capital goods imports are larger if (1) firms are more productive; (2) the exporting product is the firm's core product; (3) the product is a differentiated good; and (4) the destination market is larger and richer. Further analysis suggests that capital goods imports can also boost firms' total exports and the number of exporting destinations and products. The mechanism tests reveal that capital-skill complementarity can explain improved export product quality through capital goods imports. Capital goods imports also lead to increased skill management that can improve export quality as well.

1. Introduction

Capital goods imports from developed countries have long been deemed as a primary source of accessing advanced technologies and receiving knowledge spillovers for developing countries, which is crucial for productivity growth and industrial upgrading.[1] However, importing capital goods is often constrained by firms' internal and external financial resources. Gathering information from foreign markets, establishing relationships with foreign suppliers, and purchasing capital goods all incur substantial costs that prevent firms from accessing advanced foreign technologies (Fauceglia, 2015). At the beginning of 2008, the Chinese government announced an import subsidy policy for firms importing products from a specified product list consisting mainly of capital goods. This paper exploits this subsidy policy as a quasi-natural experiment and investigates how increased capital goods imports would influence firms'

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[1] See: Eaton and Kortum (2001); Lin and Zhang (2005); Acharya and Keller (2009); Mo et al. (2021).

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export product quality upgrading at the micro-level.

In September 2007, the "*Catalogue for the Guidance of Importing Technologies and Products*" (henceforth, the Catalogue) was published by the National Development and Reform Commission, the Ministry of Finance, and the Ministry of Commerce in China. The Catalogue specifies a list of advanced technologies, key machinery and parts that could promote technology upgrading and productivity growth. To encourage firms to import products on the Catalogue, at the beginning of 2008, China's central government implemented a subsidy policy that rebates part of the purchasing costs to firms importing products on the Catalogue.[2] This policy lowered the purchasing costs of the subsidized goods, which induced the import of products on the Catalogue, especially for firms that rely heavily on subsidized products in the production process. Given that China's tariff rates imposed on the listed goods have decreased substantially since the entry of the World Trade Organization (WTO), this import subsidy policy features an important trade policy that aims to promote economic upgrading through the import of advanced capital goods in China''s post-WTO period.

This subsidy policy provides a quasi-natural experiment setting that allows us to empirically investigate firms' production responses to a policy shock that lowers firms' cost of purchasing certain capital goods. In particular, we focus on a sample of firms that engage in importing and exporting simultaneously and investigate changes in their export product quality in response to the policy. Studying the determinants of export quality upgrading is of great economic importance. For many developing countries, including China, expansion of the exporting sector is a driving force for economic growth and structural transformation. Improvements in export product quality can boost export performance and further accelerate economic growth.

How can imports of capital goods promote the upgrading of export product quality? First, capital-embodied technology can directly improve firms' productivity and thus output performances. The literature in the field of neoclassical theory shows that improvements in technical progress are embodied in newly-introduced machinery and equipment, which are key to long-run productivity movements (Greenwood, Hercowitz, & Krusell, 1997; Hulten, 1992). The importance of imported capital goods on productivity growth has also been examined in previous literature (Caselli, 2018; Yasar, 2013). The second and indirect channel is through the complementarity between capital and skilled labor. Imports of capital goods could promote skill-biased technical changes, which could boost firms' demand for skills in production. Autor, Levy, and Murnane (2003) reveal that skill demands for jobs rise with the introduction of computers. Using employer-employee linked data from Hungaria, Koren and Csillag (2011) show that importing of capital goods is an important source of skill-biased technical change. Chen (2020) denotes that capital accumulation combined with capital-skill complementarity can explain around two-thirds of the gap in sectoral labor productivity growth. Most closely related to the current research, Bas and Paunov (2021) show that input quality upgrading due to trade liberalization results in an increase in demand for skilled labor, which may jointly boost firms' output quality. Therefore, both the direct productivity channel and the indirect capital-skill complementarity channel predict that increased capital goods imports would improve export product quality. In what follows, we give an outline for our empirical analysis to test the above prediction.

We start our empirical analysis by constructing a matched dataset using China's Annual Survey of Industrial Firms, which contains firm-level financial information, and customs data that documents transaction-level imports and exports information. In particular, we focus on the post-WTO period from 2002 to 2013 to avoid changes brought about by WTO entrance. From official documents, we can obtain the harmonized system (HS) code list for the subsidized capital goods. Using this information, we employ a difference-in-differences (DiD) strategy to compare firms' imports of subsidized and non-subsidized products in the pre- and post-policy periods. We find that in the post-policy years, the rise of subsidized goods import values is roughly 30% higher than that of non-subsidized goods. Especially, this effect is driven mainly by the increase in import quantity rather than import prices.

Second, we study responses in firms' export quality to the subsidy policy with export quality measures constructed following Amiti and Khandelwal (2013) and Fan, Li, and Yeaple (2015). We construct a time-invariant subsidy share measure that captures firms' share of imported subsidized capital goods over the total imported capital goods in the pre-policy period. This measure captures the degree to which a firm is affected by the policy in the post-policy period. Using this measure, we also implement a DiD strategy to study export quality responses at the firm-product-destination-year level. The empirical results reveal that firms more affected by the policy experience a larger increase in export quality. This result also holds when we include more controls and use alternative export quality measures.

The existence of endogeneity issues could potentially confound baseline findings. For instance, subsidized goods may differ systematically from non-subsidized goods, thus making the positive relationship between capital goods imports and export quality upgrading a spurious correlation, rather than the causal impact of the policy. Moreover, firms may anticipate the subsidy policy and adjust their import/export behaviors in the pre-policy periods. To test whether these factors confound the baseline results, we conduct an event study analysis for import and export quality outcomes, which suggests that pre-trends are of little concern in this study. In the robustness checks section, we also discuss and control for other contemporaneous shocks that may confound our baseline findings, including the high-tech firm certification policy, the Global Financial Crisis, banking sector changes, export tax rebate adjustment, and the corporate income tax adjustment policy. We find that the positive and significant effect of the import subsidy policy on export product quality still stands after controlling for these shocks.

After establishing the causal link between the subsidy policy and import/export outcomes, we continue to examine heterogeneous responses to the policy in terms of firms', products', and export destinations' characteristics. Several interesting patterns emerge. First, firms with larger initial sizes and higher initial productivity tend to import more subsidized capital goods, but only high-productivity firms can effectively use advanced capital goods to upgrade their export quality. The R&D investment, on the other hand, serves as a

[2] This policy is called "*jin kou tie xi* 进口贴息" in Chinese.

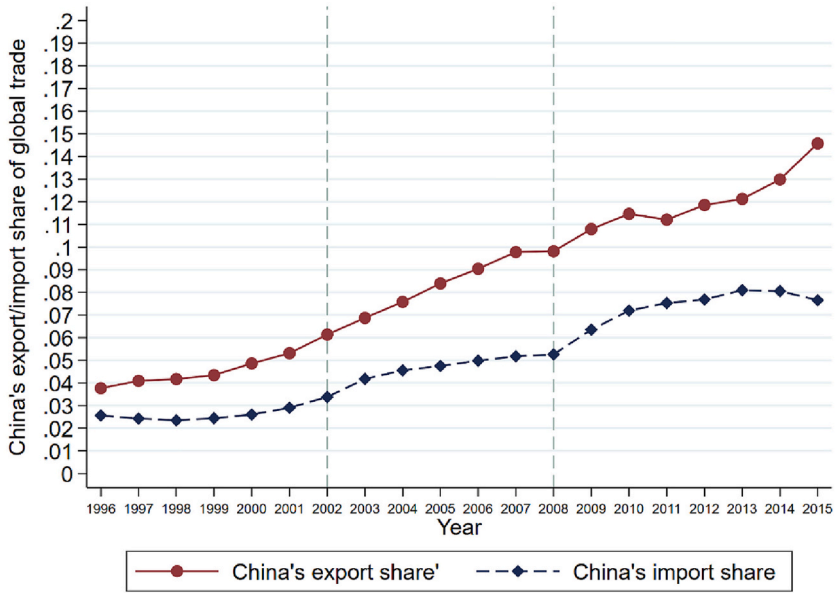

Fig. 1. Share of China's exports and imports over global trade.
Notes: This figure shows China's export and import share over global trade. The statistics are calculated from CEPII-BACI.

substitute for capital goods imports. Second, export product quality upgrading is differentially stronger for products exported to larger and richer destination markets. Third, quality upgrading is more pronounced for firms' core products and differentiated products. The last two patterns suggest that firms strategically employ capital goods to enhance their competitive advantages.

In addition to export quality upgrading, we examine other aspects of firms' export performance. We find that firms more affected by the policy would experience an increase in their total exports, the number of HS-6d products exported, and the number of destination countries they export to. These findings provide additional evidence that increases in capital goods imports improve firms' overall production capacity. Moreover, export sales tend to be more concentrated in key destination markets and products, following the subsidy policy.

Finally, we empirically test whether the indirect capital-skill complementary channel contributes to export product quality upgrading. By exploiting cross-regional variations in skilled-labor abundance, we find that firms located in skilled-labor-abundant cities can benefit more from the import subsidy policy, which offers suggestive evidence for quality upgrading through the *capital-skill complementarity* channel. Additionally, such complementarity also exists between the imports of advanced capital goods and skilled managers. We also exclude the possibility that firms may realize product upgrading through relaxed financial constraints following the subsidy policy.

Our paper contributes to the literature on the economic consequences of capital goods imports. As a key channel in global technology diffusion, the adoption of foreign advanced capital goods could help developing economies to catch up through technology spillovers. Previous empirical studies at the macro level have already documented that capital goods imports work as a crucial channel for importing advanced technology and consequently benefit domestic productivity growth (Burstein, Cravino, & Vogel, 2013; Eaton & Kortum, 2001; Parro, 2013; Raveh & Reshef, 2016; Verhoogen, 2008). Studies at the firm level have confirmed the productivity-promoting effects of capital goods imports (Lafortune, Lewis, & Tessada, 2019; Mo, Qiu, Zhang, & Dong, 2021; Mutreja, Ravikumar, & Sposi, 2018). However, few studies discuss the impact of capital goods imports on firms' export performance, in particular, export quality upgrading. We study this issue using China's import subsidy policy for capital goods imports as a quasi-natural experiment.

This paper also closely relates to the vast literature studying the determinants of export product quality. Verhoogen (2021) classifies the determinants of firm-level upgrading into demand-side and supply-side factors. There exists literature confirming the strong link between the income levels of exporting destinations and firms' export quality (Bastos, Silva, & Verhoogen, 2018; Fajgelbaum, Grossman, & Helpman, 2011), which are demand-side determinants. On the supply side, Feng, Li, and Swenson (2016) find that decreases in import tariffs could expand firms' volume and scope of exports. Fan, Li, and Yeaple (2015) show that an increase in imported intermediates would improve export quality, and Fan, Li, and Yeaple (2018) further find that the impact is especially pronounced for initially low-productivity firms. Bas and Paunov (2021) emphasize the complementarity between high-quality imported inputs and skilled labor, which jointly improves output quality. However, most literature in this field ignores the different effects of intermediates imports and capital goods imports. Mo et al. (2021) fill this gap by studying the distinctive productivity-improving effects of intermediate imports and capital goods imports, and they find a substantially larger productivity effect caused by capital goods imports. Our paper puts a new spin on the previous findings by establishing the causal link between capital goods imports and export quality upgrading.

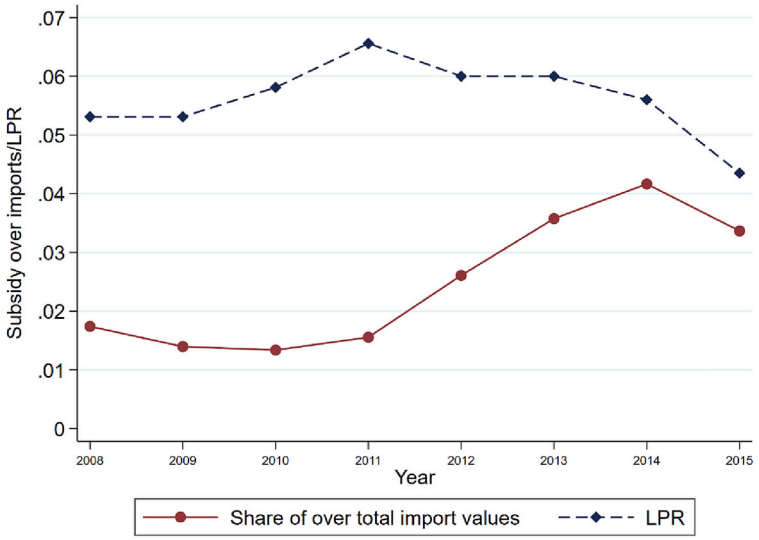

Fig. 2. The average share of subsidy over imports.
Notes: The solid line shows the average share of subsidy over imports of subsidized goods for a sample of firms that were granted the subsidy. The dotted line displays changes in benchmark 1-Yr LPR. Subsidy data comes from the Ministry of Commerce and LPR data comes from the website of Easymoney.

More broadly, this paper speaks to the literature studying the effectiveness of trade policies. Using cross-country data, some literature has examined how regional trade agreements have influenced economic integration (Baier, Bergstrand, & Clance, 2018; Baier, Yotov, & Zylkin, 2019). There is also literature focusing on trade policies implemented by a specific country. For instance, Akgündüz, Kal, and Torun (2018) find the substantial export-promoting impact of Turkey's export subsidy loan program in 2012 using firm-level data. Defever, Reyes, and Riano (2020) estimate the positive impact of Nepal's Cash Incentive Scheme for Exports program on targeted product-destination cells' extensive margins using customs transaction data. Chandra and Long (2013) use China's value-added tax (VAT) reform in 2004 as a quasi-natural policy experiment and find that VAT rebates exert significant effects on firms' export volumes. Nonetheless, many country-specific trade policies aim to promote exports, since exports play a larger role in increasing firms' international market size and providing more domestic job opportunities. This paper contributes to this strand of the literature by investigating the consequences of the subsidy policy for capital goods imports.

The remainder of this paper is organized as follows. Section 2 presents the background of the import subsidy policy. Section 3 introduces the measurement construction for the key variables and the empirical strategies. Section 4 describes the data used for empirical analysis. Section 5 presents and interprets our main results and Section 6 presents heterogeneous analysis. Section 7 further tests potential channels driving quality upgrading following the adoption of key capital goods and Section 8 concludes.

2. Institutional background for the import subsidy policy

China has played an increasingly important role in the global market since its entry into the WTO. As shown in Fig. 1, China's export share of global trade has increased from 4.86% to 9.78% from 2000 to 2007. During this period, the import share increased from 2.61% to 5.17%. Nevertheless, there existed challenges and risks in China's international trade market during this period. Firstly, the trade surplus increased substantially since its entry into WTO. In the first quarter of 2007, China's net export share peaked at 8.6%. This rise led to growing friction with trade partners that may slow down China's globalization process and economic growth rates. Secondly, China's overall economic comparative advantage has long been in labor-intensive industries, which are relatively low in value-added. To achieve high-quality growth, it is vital to realize industry upgrading and economic transformation, so that China's export can move up along the global value chain.

To tackle these issues, in September 2007, the central government of China promulgated the "*Catalogue for the Guidance of Importing Technologies and Products*", which specifies a list of advanced technologies, key capital goods and production parts, key industries, and important resources. The import of these technologies and products is encouraged since they are indispensable to the development of high-tech industries. In the meantime, the central government also announced a subsidy policy that allows firms to apply for a subsidy if they import products on the Catalogue. The requirements and application procedures are specified in the "*Interim Measures on the Administration of the Import Subsidy Fund*" (henceforth, the Interim Measures). This policy took effect on January 1, 2008.

According to the Interim Measures, a firm needs to meet two key requirements to be qualified for the subsidy. First, the applicant must have imported technologies or products on the catalogue via ordinary trade in the year before the application. Second, the applicant must have not violated the law or delayed payment to the government in recent three years. This policy does not discriminate against firms' ownership, industry, or location. As a result, applications for the subsidy have a high pass rate. In most cases, the reason

for an application to get rejected is that the imported products are not on the Catalogue, thus not qualify for a subsidy.

Applicants who are granted the subsidy can receive a subsidy amount that is no higher than the product of import values of goods on the catalogue. The subsidy rate is no higher than the benchmark loan prime rate (LPR) set by the People's Bank of China. From 2008 to 2015, the government also set an upper limit of 30 million yuan (roughly 4.32 million dollars) for the subsidy amount per firm per year. This upper limit has increased to 60 million yuan since 2016. If a firm is granted an import subsidy, it can receive the fund within two to three months.[3]

Since the implementation of the policy, many firms have benefited from the subsidy policy, receiving a non-negligible number of rebates. In Fig. 2, we compare the average share of subsidy over import values for a sample of firms that were granted the subsidy, with changes in the 1-Yr LPR from 2008 to 2015. The figure shows that the subsidy rate is always lower than the benchmark LPR; however, the gap is closing over time. In particular, from 2011 to 2014, the LPR was on a decreasing trend since the central bank aimed to boost the economy with a loose monetary policy; while the subsidy rate increased from 1.5% to 4.1%. This increase suggests that the government has tilted more financial resources to boost the imports of technologies and products on the Catalogue over time.

Some anecdotal evidence also shows the government's commitment to supporting capital goods imports with the help of the subsidy policy. For instance, the government of Guangdong Province, one of the most developed provinces in China, spent 0.75 billion yuan to subsidize firms importing goods on the catalogue from 2012 to 2014.[4] In addition to government financial support, China's import-export bank also offers discounted loans for firms importing listed technologies and capital goods to lower their cost of using external finances.

The most important piece of information we use for the identification is the product list from the Catalogue, which specifies the HS codes of imports that can receive subsidies. The Catalogue contains four parts. Part A details the advanced technologies that are encouraged to be introduced from aboard. Part B presents the list of key equipment. The eight-digit HS codes of the equipment are presented in this part as well. Part C shows a list of high-tech industries the government aims to support. In particular, technologies in Part A and key equipment in Part B are major inputs for industries listed in Part C. Part D contains a list of natural resources. As the goal of the current paper is to study the role of capital goods, we mainly focus on subsidized products in Part B of the Catalogue.

We use the Catalogue published in 2008 for empirical analysis.[5] Part B of the 2008 Catalogue listed 147 HS eight-digit products that are classified as the key equipment and can receive import subsidies.[6] Matching the HS codes with BEC classification, we find that only 6 items are classified as intermediates with the rest being capital goods.[7] In the empirical analysis, we exclude these intermediates and focus only on capital goods imports.

3. Empirical strategy

This section presents the empirical strategy we employ to identify the impacts of the import subsidy policy on firms' importing dynamics and export quality. Section 3.1 lays out the DiD framework used to estimate import outcomes. In Section 3.2.1 and Section 3.2.2, we describe the construction of the key outcome variable export quality and firm-level *subsidy_shr* measure in detail. Section 3.2.3 presents the regression specification used to estimate changes in the quality of exports in response to the import subsidy policy. Section 3.3 discusses potential endogeneity issues and the event study specification used to test the parallel trends.

3.1. Subsidy for imported capital goods and import growth

The direct purpose of the import subsidy policy is to promote the imports of subsidized goods. To check whether the policy goal is realized, we begin by estimating import changes in response to the policy implementation. In particular, we employ micro-level import data in a DiD framework that compares the imports of subsidized goods with imports of non-subsidized goods before and after the policy took place since 2008. The DiD specification is as follows:

$$Ln\_impval_{fpt} = \alpha_0 + \alpha_1 Subsidy_p \times Post08_t + \alpha_2 X_{pt} + \phi_{ft} + \chi_{fp} + \epsilon_{fpt} \quad (1)$$

The outcome variable Ln_impval_{fpt} is firm f's imports of HS6 product p in year t. $Subsidy_p$ is a dummy representing whether the product is on the list of subsidized goods. Since the policy was announced in the latter half of 2007, the $Post08_t$ dummy equals one for years later than 2008 (2008 included), and zero before 2008. The key coefficient α_1 is estimated by comparing the firm's imports of treated and non-treated products, before and after the policy was implemented. X_{pt} is time-varying product-level controls. We control

[3] Appendix Figure A1 presents an example of the application form, which includes the information the applicant needs to fill in to apply for the subsidy.

[4] Information from the website of Guangdong province's government.

[5] There are yearly adjustments in the subsidized goods list, but the adjustments are relatively minor before 2014. The Ministry of Finance and the Ministry of Commerce official issued the "*Measures for the Administration of Special Funds for Foreign Trade and Economic Development*" in the April of 2014, implying the repeal of the former "*Interim Measures on the Administration of the Import Subsidy Fund*". We thus focus on a period before 2014 in our empirical analysis.

[6] In comparison, part D of the catalogue is much shorter, with only 12 8-digit HS resources.

[7] The six products classified as intermediates are: Parts of gas turbines (84119990), Parts of industrial or laboratory furnaces ovens (841790), Parts and accessories for surveying (90159000), (84871000), Ships' or boats' propellers and blades (85372090), Other power control apparatus or distribution (85371090)

for product level import tariff, the interaction between the $Post08_t$ dummy and product-level contract intensity, capital intensity, skill intensity, and firm's initial import share of the product respectively.

Since $Subsidy_p \times Post08_t$ varies in the product-year dimension, we can control for firm-year fixed effects ϕ_{ft}, which could account for firms' overall changes in their import compositions. Another fixed effect we consider is firm-product FE χ_{fp} which allows us to identify treatment effects using within firm-product variations before and after policy implementation. Standard errors are two-way clustered at the firm and product levels.

3.2. Import subsidy for imported capital goods and export quality upgrading

The main purpose of this study is to evaluate how import subsidies for capital goods can affect export quality. Before introducing the empirical specification, we describe the construction of the outcome variable and key independent variable of interest.

3.2.1. Export quality

The outcome of interest in this study is export product quality. The Customs Database provides information on transaction-level export information at the HS-8-digit level. We aggregate the export values and quantities at the firm-destination-HS6-year level. Export quality is not directly observable, and can only be inferred from the prices and demand for each product. The quality of exports is estimated following Khandelwal, Schott, and Wei (2013), Fan, Lai, and Li (2015), and Fan et al. (2018). We assume a quality-adjusted constant elasticity of substitution (CES) utility function for a representative consumer. The demand function for CES utilities would lead to the following quality estimating equation:

$$Ln\_q_{fpdt} + \sigma Ln\_p_{fpdt} = \zeta_p + \zeta_{dt} + \epsilon_{fpdt}$$

where Ln_q_{fpdt} denotes the natural log of the quantity exported of product p by firm f into country d in year t. Ln_p_{fpdt} is the price, and σ is the elasticity of demand for the product. The residuals from the regression above proxy for product quality levels. Previous trade literature suggests that the gravity-based elasticity of substitution varies between 5 and 10 (Anderson & Van Wincoop, 2004). We use product-specific estimates of σ from Broda and Weinstein (2006) to estimate the export quality. We also use $\sigma = 5$ in the robustness checks. Additionally, we follow Piveteau and Smagghue (2019) and estimate product quality using an IV approach to perform robustness checks.

3.2.2. Construction of the subsidy share measure

Firms differ in their reliance on subsidized capital goods. Firms that employ subsidized capital goods heavily in the production process are more likely to import capital goods following the policy implementation. These firms can be considered as the "treated" firms that are the main targets of the policy. Firms using little subsidized capital goods for production are less affected by the policy, and they can be considered as the "control" group. Since there is no comprehensive data on firms' use of each type of capital goods, we obtain information on firms' reliance on subsidized capital goods using import data from the Customs Dataset. If a large share of a firm's capital goods imports is on the subsidized list, then the firm can benefit more from the policy. To relieve endogenous concerns that firms' import structures may adjust in response to the policy, we use import information from the pre-policy period from 2005 to 2007 to construct a time-invariant *Subsidy_shr* measure to quantify firms' exposure to the policy. For each year from 2005 to 2007, we construct the *Subsidy_shr* as follows:

$$Subsidy\_shr_f = \sum_p \frac{D_p \times Imp_{fp}}{\sum_{p=1}^{P_{cap,f}} Imp_{fp}}$$

where D_p is a dummy indicating whether product p is one of the subsidized capital goods or not. Imp_{fp} is firm f's import value of product p. $\sum_{p=1}^{P_{cap,f}} Imp_{fp}$ represents firm f's imports of all types of capital goods. Then the average value of $Subsidy\_shr_f$ from 2005 to 2007 is taken to measure the average pre-policy share of the firm f's capital goods imports that would be affected by the policy. It is a continuous treatment measure with a larger value indicating a higher likelihood to be affected by the policy.

In the construction of $Subsidy\_shr_f$, we use imports of capital goods rather than total imports as the denominator. Capital goods and intermediates are both crucial inputs in the production process, but they serve different purposes and thus influence firm outcomes in different ways. Intermediates include materials and parts that are consumed in the process of production. Capital goods, such as machineries, equipment and industrial robots, are not consumed entirely in production and can be used repeatedly. Therefore, removing intermediates from the denominator of $Subsidy\_shr_f$ can capture firm-level policy shocks more accurately.[8]

As the subsidized capital goods are not one-off consumables and can be used for more than one accounting period, firms may import subsidized goods in one period and not in subsequent periods. Therefore, one may concern whether pre-policy $Subsidy\_shr_f$ can precisely capture firms' demand for subsidized capital goods. We can address this issue by examining how well past imports of capital goods and especially imports of subsidized capital goods can predict their future imports. We aggregate firms' capital goods imports, and subsidized capital goods to the firm-year level, and then regress the current year's imports on the previous year's imports. The scatter plots, linear fit lines, regression coefficients and standard errors are presented in Fig. 3. It is clear from the figure that current

[8] For firms importing only intermediates or consumption goods, we treat their *Subsidy shr*$_f$ as zero.

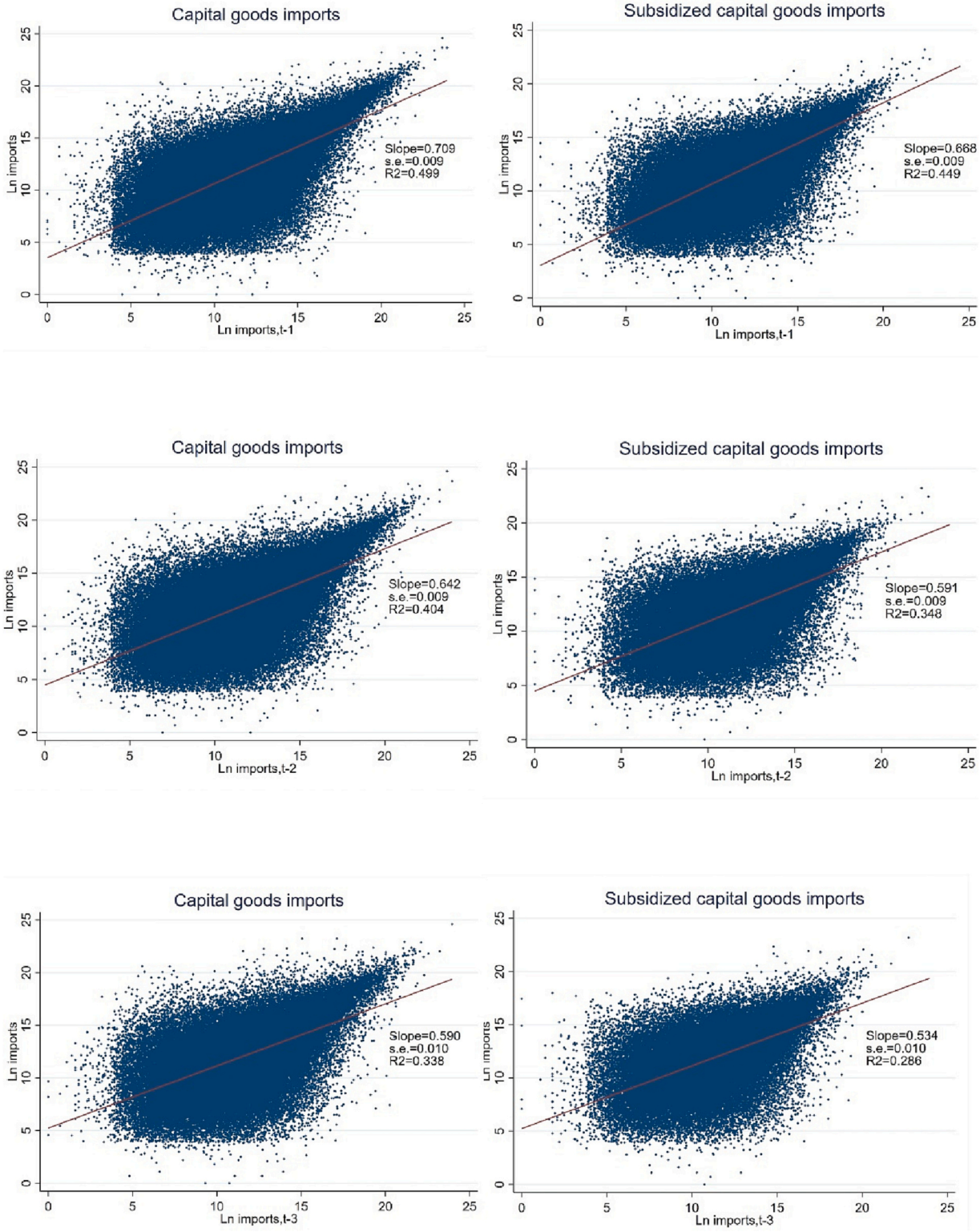

Fig. 3. Persistence of capital imports.
Notes: This figure shows the correlation between firms' past imports and current imports for capital goods and subsidized capital goods respectively.

capital goods imports strongly correlate with past capital goods imports. For instance, when current-year capital imports are regressed on past-year imports, the coefficient on past year imports is 0.709, and the R^2 is close to 0.5. The predictive power of the previous year's subsidized capital goods is strong as well, with the regression coefficient being 0.668 and the R^2 being 0.449. We also find similar patterns when using import in $t-2$ and $t-3$ as explanatory variables. Therefore, past imports of capital goods and subsidized capital goods can be considered as a good predictor for future imports, validating the construction of our subsidy share measure.

3.2.3. Regression specification

We adopt a DiD framework to study the impact of the subsidy policy on export goods quality as well. We identify the impact by comparing pre- and post-policy export quality changes for firms more exposed to the subsidy policy and firms less exposed to the policy. The regression specification is as follows:

$$Quality\_Exp_{fpdt} = \beta_0 + \beta_1 Subsidy\ shr_f \times Post08_t + \gamma X_{ft} + \xi_{fpd} + \lambda_{pdt} + \epsilon_{fpdt} \tag{2}$$

where $Quality\_Exp_{fpdt}$ is the product quality of firm f's export of product p into destination d in year t. $Subsidy\ shr_f \times Post08_t$ is our regressor of interest and β_1 measures the direction and magnitude of the policy. We expect the estimate $\hat{\beta_1}$ to be positive, which indicates that firms using more subsidized capital goods would benefit more from the import subsidy policy and upgrade the quality of their exports.

We control for two fixed effects ξ_{fpd} and λ_{pdt}. ξ_{fpd} is a firm-product-destination fixed effect that captures unobserved factors specific to firm-product-destination pairs. The inclusion of ξ_{fpd} also suggests that the impact is identified by exploiting over-time variations before and after the policy within firm-product-destination cells. λ_{pdt} is the product-destination-year fixed effect that can control for the destination's supply- and demand-side changes in product d over time. For instance, it captures the technological advancement in product p in country d over time. It can also absorb the country d's tariff barriers for product p. Additionally, it takes into account consumers' preference changes for the product over time. All these factors could potentially influence firm f's decision to improve product quality in the destination market. In all the regressions, the standard errors are two-way clustered at the firm and product levels.

3.3. Endogeneity issues

To obtain an unbiased estimate for β_1, the error terms cannot be substantially correlated with the interaction between $Subsidy\_shr_f$ and the $Post08_t$ dummy. Even though the subsidy share is constructed with pre-policy import shares to minimize endogeneity issues, three remaining concerns may weaken the causal interpretation for β_1.

First, the policy aims to promote imports of key capital goods that can foster technology spillovers and boost productivity growth, and thus the chosen subsidized goods may differ systematically from non-subsidized capital goods. Consequently, firms importing a large share of subsidized capital goods in the pre-policy period may adopt different quality upgrading strategies from other firms even without the import subsidy policy. If this is the case, a positive and significant estimate of α_1 in Eq. (1) and β_1 in Eq. (2) simply reflect firm-specific trends rather than the causal impact of the policy.

Second, there might exist anticipation effects. If firms expect the subsidy policy to be implemented in the pre-policy period, they may refrain from importing them until the policy is announced to save purchasing costs. If this is the case, then we would overestimate the true impact of the import subsidy policy.

To test the existence of pre-trends caused by firms' systematic differences and anticipation effects, we conduct an event study analysis for Eq. (1) and Eq. (2) respectively using the following two specifications:

$$Ln\_impval_{fpt} = \sum_{\substack{\tau=2002 \\ \tau \neq 2007}}^{\tau=2013} \left(\alpha_\tau D\{t=\tau\} \times Subsidy_p\right) + \alpha_2 X_{ft} + \phi_{ft} + \chi_{fp} + \epsilon_{fpt} \tag{3}$$

$$Quality\_Exp_{fpdt} = \sum_{\substack{\tau=2002 \\ \tau \neq 2007}}^{\tau=2013} \left(\beta_\tau D\{t=\tau\} \times Subsidy\_shr_f\right) + \gamma X_{ft} + \xi_{fpd} + \lambda_{pdt} + \epsilon_{fpdt} \tag{4}$$

The two event study specifications above include the same set of controls and fixed effects as in Eq. (1) and Eq. (2). We drop the dummy variable for the year 2007, one year before the policy took effect, to circumvent the multi-collinearity issue. The specifications above allow us to test for the existence of pre-trends and thus further establish causal impacts of the policy. Moreover, we can better capture dynamic patterns of the policy with the event study designs.

Third, there might exist other contemporaneous macroeconomic and policy shocks that could influence export product quality. If the measure for the subsidy share picks up other policy shocks, the estimate for β_1 would be biased as well. For instance, the Chinese government implemented a High-Tech enterprise certification policy in 2008 that gives certified high-tech firms tax breaks and other supports, which may subsequently promote innovation and improve product quality. In addition, the global financial crisis that occurred in 2008 also coincided with the import subsidy policy that could contaminate baseline findings. In Section 5.3.1, we provide a more detailed discussion of several major contemporaneous shocks and check the robustness of the baseline results after controlling for

Table 1
Summary statistics: comparison among different groups of firms.

Firm variables	Two-way traders (Sample firms)	Only Exporters	Only Importers	Non-traders
Employment (Number of employees)	529.78	208.0639	280.4101	159.2406
	(1628.952)	(457.3859)	(923.1687)	(641.9657)
Total output (in million RMB)	261,895.5	70,429.86	179,299.1	65,233.27
	(1706879)	(424,130.7)	(1067790)	(619602)
Total sales (in million RMB)	256,949.9	68,802.28	175,880.3	63,876.14
	(1682566)	(423,932.6)	(1065963)	(613,272.3)
Value added (in million RMB)	64,271.18	18,968.18	47,516.02	18,146.17
	(400,040.6)	(131,345.4)	(285,478.9)	(187,233.6)
Total asset (in million RMB)	214,069.4	52,017.71	165,044.1	47,933.61
	(1300078)	(358,669.9)	(943,755.7)	(610,161.6)
Net fixed asset (in million RMB)	64,747.96	15,975.33	52,523.58	15,960.88
	(495,572.7)	(143,510.7)	(332,038.3)	(232,270.6)
Average wage (in RMB)	22,533.26	15,470.55	21,530.35	15,031.71
	(29,857.92)	(10,849.98)	(35,808.62)	(13,784.08)
RD values (in million RMB)	1681.715	169.8806	1103.375	169.9931
	(38,042.05)	(3435.009)	(25,200.74)	(7504.284)

Notes: This table presents mean and standard deviations (in parenthesis) of several key financial variables for four types of firms. Data is from Annual Survey of Industrial Firms and averaged from 2005 to 2007.

these confounding factors.

4. Data and summary statistics

4.1. Data sources

To understand how the import subsidy policy affects firms' import values and quality upgrading in firms' exports, we bring together two datasets: (1) the Chinese Customs Dataset maintained by China's General Administration of Customs; and (2) the Annual Survey of Industry Firms maintained by the National Bureau of Statistics of China (NBC). Our sample covers the post-WTO period from 2002 to 2013, to alleviate changes in imports and exports due to China's entry into entry WTO.

4.1.1. Customs data

The Chinese Customs Dataset covers the universe of imports and exports transactions since 2000. The dataset includes detailed information on each transaction, including the name and firm identifier of the exporter/importer, the 8-digit HS product code, trade regimes (ordinary or processing trade), trade value and quantities, and sourcing or destination countries. We utilize the information above to construct our major dependent and independent variables as in Section 3.2.1 and Section 3.2.2.

4.1.2. Annual Survey of Industrial Firms (ASIF) data

The ASIF data provides comprehensive information on China's manufacturing firms, including firm's name, industry, location, and production and financial information such as employment, wages, output, use of intermediate inputs, and net fixed assets. It covers all state-owned manufacturing enterprises and non-SOEs with annual sales of over five million yuan before 2011 and those with annual sales of over twenty million yuan after 2011. The data are cleaned following Cai and Liu (2009) and the general accounting procedure. Since industry classification is different before and after 2002, we convert industry codes before 2002, namely GB/T 4754-1994 into GB/T 4754–2002. Inconsistencies also exist in prefecture codes, which we all convert to 2003 prefecture codes.

4.2. Sample construction

We match firms in the ASIF dataset and customs dataset to construct the sample for regression analysis. Even though these two datasets have different firm identifiers, detailed contact information such as the firm's name, zip code, and contact person is provided in both datasets. We merge these two datasets using this information, thereby restricting our sample to manufacturing firms that engage in trade activities.

To estimate Eq. (1), we use a sample of firms in the ASIF dataset that engaged in importing through ordinary trade from 2002 to 2013. There are in total 121,313 firms that satisfy this requirement. Since our identification exploits within firm-product variation before and after the policy, we need firm-product observations that appeared in both the pre- and post-policy periods. This restricts the sample to 51,887 firms.

The sample we use to estimate Eq. (2) differs from the importing firm sample described above. Firms involved in trade activities can be categorized into only importers, only exporters, and two-way traders. For only importers, there are no available datasets offering their product-level outputs, making it impossible to examine their output quality. Only exporters, on the other hand, are not directly affected by the import subsidy policy. Therefore, two-way traders are of particular interest in the estimation of Eq. (2).

Therefore, the firms in the sample must satisfy three requirements. First, since the construction of firm-level subsidy share measure

Table 2
Summary statistics.

Variables	Observations	Mean	SD	Min	P25	P50	P75	Max
Quality	2,835,086	0.336	2.775	−7.291	−1.495	0.457	2.284	6.739
Quality5	2,835,086	0.479	4.941	−40.048	−2.315	0.463	3.183	55.453
Quality SFS	2,199,939	0.421	3.273	−47.775	−1.382	0.472	2.258	56.993
Subsidy Shr	2,835,086	0.214	0.329	0	0	0	0.365	1
Firm's export shares	2,835,086	0.064	0.148	0	0.001	0.007	0.043	1
Lnemployment	2,835,086	6.106	1.254	0	5.303	6.047	6.858	12.201
Ln Exchange rates,import wgt.	2,835,086	0.135	0.297	0	0	0.011	0.116	3.047
Ln input tariff	2,835,086	0.06	0.041	0	0.033	0.063	0.083	0.519
HHI employment	2,835,086	0	0	0	0	0	0	0.002
EG index	2,835,086	0.036	0.057	−0.22	0.017	0.024	0.043	4.996

Notes: This table reports summary statistics for the regression sample. The sample includes firms that engaged in importing activities between 2005 and 2007 and export before and after the policy was implemented.

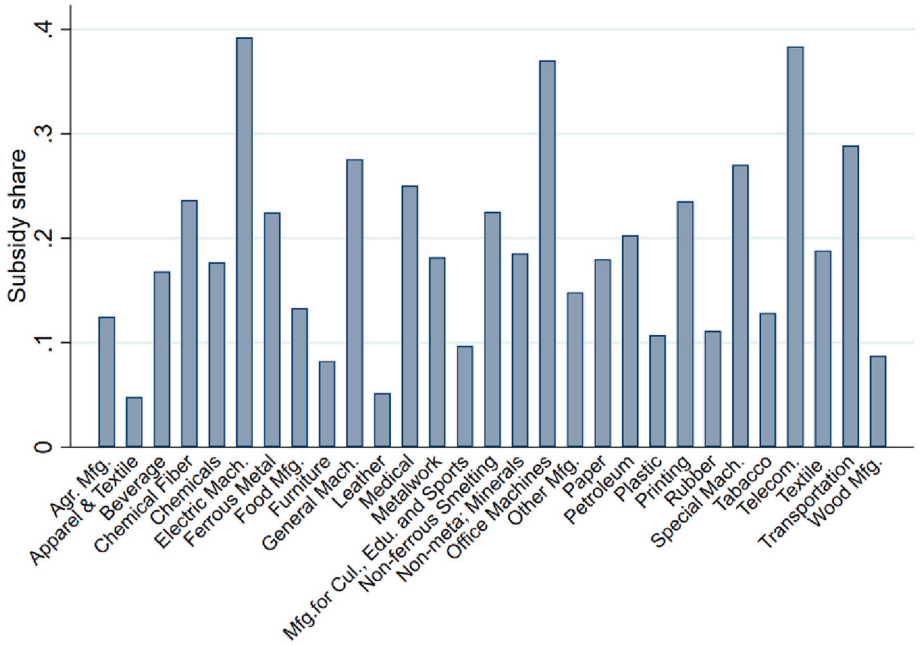

Fig. 4. Subsidy share averaged at CIC-2d levels.
Notes: This figure shows the average subsidy share for each CIC 2-digit industry.

requires firms' pre-policy import information, our sample consists of firms with imports in the pre-policy period from 2005 to 2007. Second, as we exploit firm-product-destination variations to estimate the effect, and thus the sample firms need to engage in exporting activities before and after 2008. Third, the empirical analysis will focus on the export quality of ordinary exports due to large differences between the sourcing choices of processing and ordinary exporters.[9]

In total, the sample used to estimate Eq. (2) consists of 53,676 firms. These firms are from 219 CIC-3d manufacturing industries and are located in 296 prefectures.[10] During the 2002–2013 period we study, there are in total 121,313 firms in the ASIF dataset ever engaged in importing through ordinary trade; while there are 174,359 firms engaging in ordinary exporting.[11] Our sample thus accounts for a little less than half of importing firms, and more than one-fourth of the exporting firms.

Using ASIF data from 2005 to 2007, we show in Table 1 that firms in the sample are larger than only-importers, only-exporters, and non-traders. The imports of subsidized capital goods by firms in the sample account for >75% of subsidized capital goods by all firms in the ASIF dataset.[12] This suggests that firms in the sample are major importers of subsidized capital goods and studying their export

[9] See: Manova and Zhang (2012); Manova and Yu (2016); Feng et al. (2016).
[10] There are in total 219 manufacturing industries at CIC-3d level, and 340 prefectures across China.
[11] We classify a firm as engaging in ordinary importing/exporting if it imported/exported through ordinary trade at least once during the 2002 to 2013 period.
[12] The share is calculated with Customs data.

performance can give us a general picture of the economic implications of the subsidy policy.

4.3. Summary statistics

Table 2 presents summary statistics for outcome variables, explanatory variables and controls. It shows that the mean of *Subsidy_shr* is 0.214, with a standard deviation of 0.329. The median of the *Subsidy_shr* is 0, suggesting that more than half of importers imports either no capital goods on the subsidized list or imports no capital goods at all.[13] This is not surprising since the subsidized list only covers a small fraction of capital goods.

Fig. 4 displays the industry-level average for $Subsidy\_shr_f$, which shows stark cross-industry differences in the use of subsidized capital goods. Subsidized capital goods play a small role in the production of low-tech consumption goods for final use, such as clothes, furs, and furniture. They serve as important capital inputs in the production of electrical machinery, high-tech communication equipment, and office products, which are relatively high-tech and capital-intensive products. Especially, some outputs in these industries are located upstream in the production chain, and they further serve as inputs in the production of other downstream products. This observation suggests that the imports of the subsidized advanced capital goods could have rippling effects on domestic production networks.

5. Empirical results

This and the next two sections present major empirical results. We start by estimating Eq. (1) to test the impact of key capital goods subsidizing policy on import outcomes. Then we present baseline results that estimate the impact of the policy on export quality. We continue to perform a variety of robustness checks and add extensions to the baseline results. Finally, we discuss potential channels driving our results.

5.1. The impact of the policy on import growth

The results for estimating Eq. (1) are presented in Table 3. Column (1) to (3) use the imports of all goods as the sample. In column (1), we use the natural log of import values at the firm-HS6-year level as the outcome variable. We observe a positive and significant coefficient on the interaction term between the subsidy dummy and the *Post08* dummy, suggesting that firms would import more of the subsidized products. Compared to non-subsidized products, the imports of subsidized capital goods would increase by around 25.2%.

When some of the key capital goods are subsidized, firms may choose to purchase capital goods with higher unit prices, or they may simply import subsidized capital goods in greater quantities. Both can lead to boosts in import values. To disentangle the price and quantity channels, we rerun Eq. (1) using the natural log of price and quantity as the outcome variables in columns (2) and (3) of Table 3. The results suggest that the policy has an insignificant effect on unit import price, while import quantity positively and significantly responds to the subsidy policy. This suggests that the rise in total import value following the policy is mainly driven by the rise in import quantity.

Results in column (1) to (3) use non-subsidized capital goods, intermediates and final consumption goods as the control group products. In column (4) to (6), we exclude final consumption goods from the estimation sample to see whether the results still stand. In column (7) to (9), we only include capital goods imports in the regression sample. We observe similar patterns in the restricted samples, all indicating the significant role of import quantity growth following the subsidy policy.

We also test for the policy effect at the extensive margin by exploring how the import subsidy policy affects firms' entry into and exit from importing the targeted product in Appendix Table A1. We construct an entry dummy that takes on value 1 if firm imports a product in year t but not in year $t-1$. We also construct an exit dummy that takes on value 1 if firm imports a product in year t but year t but not $t+1$. As shown in column (1) and column (3) of Appendix Table A1, the subsidy policy increases firms' probability of starting to import the affected products, if we use all imports or capital goods and intermediates as the regression sample. Column (5) suggests that firms' entry into importing targeted capital goods is not significant when use other capital goods as the control group. On the other hand, the import subsidy policy has less insignificant effect on firms' exit from the importing the affected products. Overall, the table suggests that the policy has an impact at the extensive margin as well. But the effect is more pronounced at the intensive margin.

5.1.1. Test for pre-trends

To ensure that the impact is causal, we perform an event study analysis for import outcomes following Eq. (3) using all products in the sample. Fig. 5 plots the point estimates and 95% significance intervals for the interaction between the treated dummy and each year's dummies. It is clear from the figure that the differences between treated goods imports and non-treated goods imports are insignificant before the policy took effect. Imports of treated goods have become significantly larger in comparison since 2008. This provides further evidence that the import subsidy policy has a causal effect on the import growth of subsidized capital goods. Fig. 5 also shows that the import jump is large at the beginning of the policy implementation, and remains relatively stable in the following years. This implies that the import response to the policy is immediate and long-lasting.

We also perform an event study analysis using import prices and quantities as outcomes respectively. The left panel of Fig. 6 shows

[13] Around 40% firms in the sample imported subsidized goods between 2005 and 2007. Among firms with positive *subsidy_shr*, the mean and median of *subsidy_shr* are 0.545 and 0.551 respectively.

Table 3
Treatment effects of the policy.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All imports			Capital goods+Intermediates			Capital goods		
	Ln import value	Ln import price	Ln import quantity	Ln import value	Ln import price	Ln import quantity	Ln import value	Ln import price	Ln import quantity
Affected HS6 products×Post08	0.252***	−0.016	0.270***	0.246***	−0.018	0.265***	0.253***	0.002	0.254***
	(0.073)	(0.065)	(0.087)	(0.072)	(0.065)	(0.086)	(0.084)	(0.066)	(0.081)
Contract intensity×Post08	−0.054	−0.045	−0.023	−0.025	−0.043	0.003	−0.142	0.006	−0.161
	(0.145)	(0.081)	(0.183)	(0.147)	(0.084)	(0.187)	(0.375)	(0.313)	(0.592)
Capital intensity×Post08	0.070***	−0.021***	0.090***	0.071***	−0.022***	0.092***	0.108**	−0.047***	0.155***
	(0.015)	(0.008)	(0.018)	(0.015)	(0.008)	(0.018)	(0.048)	(0.014)	(0.048)
Skill intensity×Post08	0.010	0.066	−0.059	0.006	0.065	−0.061	−0.012	0.082	−0.096
	(0.055)	(0.044)	(0.055)	(0.056)	(0.045)	(0.056)	(0.070)	(0.060)	(0.071)
Initial import share×Post08	−2.038***	−0.120***	−1.907***	−2.034***	−0.118***	−1.907***	−2.250***	−0.333***	−1.917***
	(0.068)	(0.034)	(0.059)	(0.069)	(0.034)	(0.060)	(0.240)	(0.098)	(0.208)
Ln tariff	−0.113	−0.844*	0.645	−0.137	−0.535	0.318	0.947	−1.915	2.806*
	(0.391)	(0.489)	(0.649)	(0.422)	(0.422)	(0.588)	(0.770)	(1.270)	(1.432)
Firm-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-Product FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Product-Linear trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,122,860	4,082,938	4,082,938	3,971,769	3,933,232	3,933,232	1,083,539	1,078,789	1,078,789
R-squared	0.795	0.917	0.879	0.795	0.917	0.879	0.805	0.939	0.912

Notes: This table reports results that estimate the impact of the subsidy policy on import values, import price and import quantities. The dependent variable in column (1), (4) and (7) is the natural log of import values. The dependent variable in column (2), (5) and (8) is the natural log of import price. The dependent variable in column (3), (6) and (9) is the natural log of import quantity. Column (1) to (3) use all imports as the sample. Column (4) to (6) use the imports of capital goods and intermediates as the sample. Column (7) to (9) use imports of intermediates as the regression sample. Standard errors are two-way clustered at firm and product levels; ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

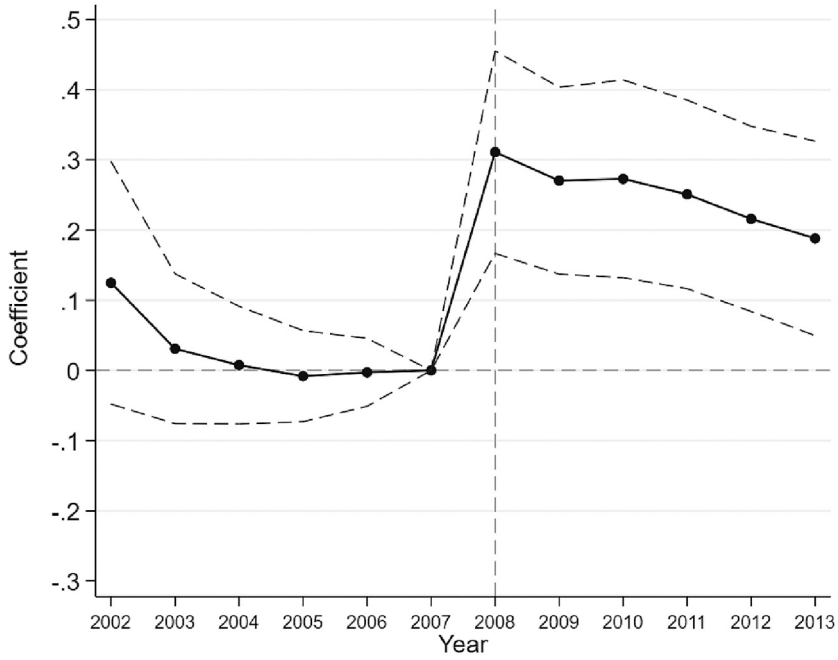

Fig. 5. Dynamic impact of the import subsidy policy on import values.
Notes: This figure plots estimates for the dynamic impact of the subsidy policy on import values, with 2007 (1 year prior to the policy) treated as the benchmark. 95% confidence intervals are presented.

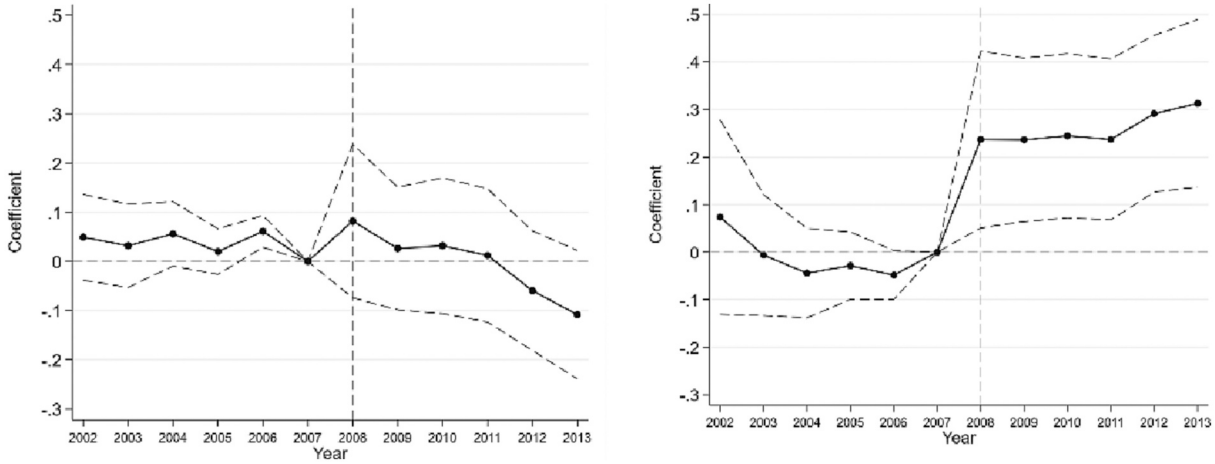

Fig. 6. Dynamic impact of the policy on import prices and quantities.
Notes: This figure plots estimates for the dynamic impact of the subsidy policy on import prices (the left panel) and quantities (the right panel), with 2007 (1 year prior to the policy) treated as the benchmark. 95% confidence intervals are presented.

plots for import price estimates, and the right panel presents plots for import quantity estimates. In both panels, the interaction estimates are insignificant before the policy took place. The difference in interaction estimates remains insignificant after 2008 for the unit import price outcome variable. However, the policy has significantly boosted the import quantity of the affected products, as shown in the right panel of Fig. 6. The dynamic patterns in Fig. 6 offer us further evidence that the import subsidy policy promotes firms' imports of subsidized goods through its impact on import quantity growth. In Fig. A2, we plot event study estimates for regressions using the capital goods and intermediates goods sample, as well as the capital goods sample, which shows a similar pattern to that in Fig. 6.

Table 4
Baseline regressions.

Variables	(1)	(2)	(3)	(4)	(5)
	Product quality	Product quality	Product quality	Product quality	Product quality
Subsidy shares×Post08	0.154***	0.163***	0.179***	0.165***	0.159***
	(0.019)	(0.018)	(0.020)	(0.025)	(0.027)
Firm's export shares				6.861***	6.955***
				(0.038)	(0.042)
Firm's employment				0.058***	0.057***
				(0.004)	(0.004)
Exchange rates,import wgt.				0.042***	0.044***
				(0.006)	(0.007)
Input tariff				0.182***	0.202***
				(0.070)	(0.071)
HHI index					17.262
					(40.550)
EG index					−0.045
					(0.031)
Firm-Country-Product FE	Yes	Yes	Yes	Yes	Yes
Product-Year FE	Yes	Yes	No	No	No
Country-Year FE	No	Yes	No	No	No
Country-Product-Year FE	No	No	Yes	Yes	Yes
Observations	3,964,496	3,964,495	3,625,945	3,163,856	2,835,086
R-squared	0.718	0.723	0.759	0.793	0.795

Notes: This table reports results that estimate the impact of the subsidy policy on export product quality. The dependent variable is estimated export product quality. Bootstrapped standard errors are two-way clustered at firm and product levels; ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

5.2. *Baseline results: The impact of the subsidy policy on export quality*

We estimate the impact of the import subsidy policy for key capital goods imports on export quality using Eq. (2). The results are presented in Table 4. In column (1) of Table 4, we control for firm-country-product fixed effects and product-year fixed effects, which gives us a positive estimate for the interaction term between the subsidy share and the *Post08* dummy that is significant at 1% level. However, the specification in column (1) fails to take into account time-varying destination country factors. We take this into account in column (2) with an additional country-year fixed effect. The estimate on the interaction term is similar to that in column (1). In column (3), we replace product-year and country-year fixed effects with the country-product-year fixed effects which can take into account time-varying and country-specific product factors, from both demand and supply sides. The inclusion of this high-dimension fixed effects reduces the number of observations by approximately 10%, but the results remain positive and significant at the 1% level.

Column (4) further includes several firm-level controls. First, the estimated quality may correlate with firms' market shares in the destination market. We use customs data to calculate firms' market shares among all Chinese exporters in destination-product cells. Second, we control for changes in firms' size with employment information from the ASIF dataset. Third, the subsidy policy boosts firms' imports by lowering their importing costs. Besides this policy, changes in exchange rates and tariff rates can influence firms' input costs. To rule out the influence of these contemporaneous factors, we use pre-policy import compositions as weights to construct time-varying firm-specific exchange rates and tariff rates.[14] The inclusion of those firm-level controls slightly brings down the magnitude of the coefficient but doesn't change its significance. Column (5) further includes two time-varying industry controls: (1) the industry's HHI index which measures its concentration in terms of employment, and (2) the industry's Ellison-Glaeser (EG) index which captures the industry's geographic concentration. The estimate on the interaction term in column (5) remains similar to that in previous columns.

We use the estimates on β_1 in column (5) to quantify the magnitude of the policy impact. Given other things unchanged, if a firm's $Subsidy\_shr_f$ jumps from the 25th to the 75th percentile (0 vs. 0.365), its export product quality increase from pre-policy to post-policy period would be 0.058 higher. This represents a 17.3% increase relative to the mean export quality, which is an economically important increase. This is in line with previous findings that input trade liberalization could promote export quality upgrading (Fan, Li, and Yeaple, 2015; Bas & Paunov, 2021), and also expands our knowledge of the importance of capital inputs in quality upgrading.

5.2.1. *Test for pre-trends*

We test for the existence of pre-trends using the event study design in Eq. (4). Fig. 7 plots the estimated coefficients and their 95%

[14] Time varying exchange rates and tariff rates for each firm f are constructed as: $Imp\_EXR_{ft} = \sum_{c=1}^{C^f} \frac{Imp_{fc}^{05-07}}{\sum_{c=1}^{C^f} Imp_{fc}^{05-07}} EXR_{ct}$ and $Imp\_Tariff_{ft} = \sum_{p=1}^{P^f} \frac{Imp_{fp}^{05-07}}{\sum_{p=1}^{P^f} Imp_{fp}^{05-07}} Tariff_{pt}$ Where c represents firm f's sourcing countries and p represents firm f's importing products.

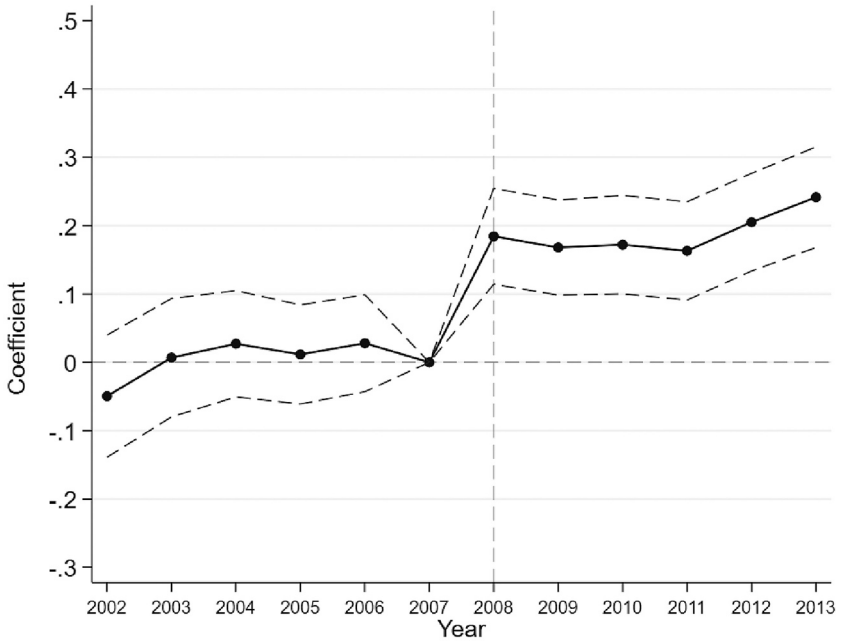

Fig. 7. Dynamic impact of the policy on export quality.
Notes: This figure plots estimates for the dynamic impact of the subsidy policy on product's export quality, with 2007 (1 year prior to the policy) treated as the benchmark. 95% confidence intervals are presented.

confidence intervals. We can observe from the figure that the estimates in pre-policy periods are not significantly different from zero. The export quality jumps for firms more affected by the subsidy policy since 2008, which offers further support for the causal impact of the subsidy policy on export quality improvement. The dynamic pattern for export quality in Fig. 7 is similar to that in Fig. 5 and Fig. 6. This is intuitive, as increases in advanced key capital goods could directly improve production capacity, promote technology spillovers, and thus output quality.

5.3. Robustness checks

5.3.1. Contemporaneous economic and policy shocks

While we have established with pre-trend tests that the choice for subsidized goods is not endogenous, and the anticipation effect is of little concern, estimates on β_1 could be biased if the constructed subsidy share measure picks up other contemporaneous economic and policy shocks. In what follows, we discuss several potential confounding factors and check the robustness of the baseline results after controlling these factors.

5.3.1.1. The high-tech enterprise certification policy. The purpose of the import subsidy policy is to lower firms' cost of importing high-tech machineries and to realize industrial upgrading. The improvement in the quality of economic growth has long been a major policy goal for the Chinese government, and other relevant policies may differentially benefit firms with higher subsidy shares and improve their export quality as well. The most relevant policy is the High-tech enterprise certification policy implemented since 2008. In the early 1990s, the State Council made policies to offer tax deductions and financial support for firms that are classified as "high-tech" enterprises. However, there is no official criteria for the classifications of high-tech firms in 1990s. In 2008, an administrative regulation was promulgated by the Ministry of Technology, the Ministry of Finance and the State Tax Administration, which laid out details for criteria and procedures for firms to be classified as high-tech enterprises. This administrative regulation was further amended in 2016 to encourage the development of small- and medium-sized enterprises (SMEs) and startups.

From a government website, we can obtain the list of "high-tech" enterprises that are given preferential tax and financial treatments and the specific years they are classified as "high-tech" enterprises.[15] Based on this information, we construct a dummy variable that takes on value one for firm-year observations with the high-tech enterprise treatment and zero otherwise. We include this dummy in the baseline regression in column (1) of Table 5. The estimate for β_1 barely changes after controlling for the high-tech firm certification policy, and the estimates on the high-tech firm dummy is positive yet insignificant. Since this policy may differentially influence firms investing more in R&D, and firms that are more productive, we include the interaction between firms' R&D-to-sales ratio from 2005 to 2007 and the *Post08* dummy as well as TFP averaged from 2005 to 2007 and the *Post08* dummy in column (2) to see how they influence

[15] The URL for the website is http://www.innocom.gov.cn/

Table 5
Contemporaneous economic and policy shocks.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	High-tech policies	High-tech policies	GFC	Bank sector	Bank sector	Rebate	Tax adjustment	All
Subsidy shares×Post08	0.158***	0.158***	0.157***	0.152***	0.159***	0.160***	0.133***	0.132***
	(0.024)	(0.027)	(0.024)	(0.024)	(0.024)	(0.027)	(0.022)	(0.024)
Certified high tech firms dummy	0.008							0.031
	(0.015)							(0.017)
TFP, Pre × Post08		−0.085***						−0.073***
		(0.01)						(0.009)
RD to sales×Post08		−1.066**						−0.535
		(0.513)						(0.686)
Expshr to the US, Pre × Post08			0.127***					0.072
			(0.046)					(0.047)
Short debt over asset×Post08				−0.200***				−0.087 ***
				(0.031)				(0.026)
Long debt over asset×Post08				0.013				0.029
				(0.061)				(0.100)
SOE dummy×Post08				−0.015				0.035
				(0.076)				(0.086)
Ln 5 km banks					0.005			0.004
					(0.007)			(0.007)
Ln 10 km banks					0.017			0.012
					(0.012)			(0.010)
Ln 20 km banks					−0.024**			−0.016
					(0.011)			(0.010)
Rebate dummy, core×Post08						0.033		0.019
						(0.02)		(0.018)
Foreign firm dummy×Post08							0.245***	0.256***
							(0.013)	(0.018)
Firm-Country-Product FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Product-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,835,086	2,474,780	2,835,086	2,555,102	2,835,086	2,835,086	2,835,086	2,434,310
R-squared	0.795	0.792	0.795	0.793	0.795	0.795	0.796	0.792

Notes: This table reports robustness checks for baseline results after taking into account contemporaneous policies. The dependent variable is estimated export product quality. Baseline controls include firms' employment, input tariff rates and import-weighted exchange rates, the industry-level HHI index and EG index. Bootstrapped standard errors are two-way clustered at firm and product levels; ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

the baseline results. Results in column (2) suggest that the inclusion of the two additional interaction controls does not change the baseline findings.

5.3.1.2. The global financial crisis. Another important contemporaneous change was the global financial crisis that originated in the US since 2007 and spread worldwide in 2008. In addition to its negative shocks on the financial sector, economies worldwide have slowed down as well due to tightened credit supply and shrinking international trade (Chor & Manova, 2012). If export revenues dropped due to the GFC, then firms' ability to improve export product quality would deteriorate. Since the GFC originated in the US, we hypothesize that firms with a higher exporting share to the US in the pre-GFC period would be more affected by the GFC. Therefore, we use the average of firms' US exports share from 2005 to 2007 to proxy for firms' exposure to the GFC. It is then interacted with the *Post08* dummy and included as a control in column (3) of Table 5. We can observe from column (3) that the inclusion of the interaction term does not change the baseline findings, suggesting that the GFC factor does not confound our results.

5.3.1.3. Changes in the banking sector. In addition to the import subsidy policy, firms can also increase their imports of key capital goods by accessing external funds from banks. China's banking sector went through some major changes in the 2000s, which may influence firms' external finance conditions and correlate with the import subsidy policy. Following the GFC, the central government announced a *four-trillion economic stimulus plan* which aimed to boost domestic demand and offer more credit to the market. The changes in credit supply are mostly likely to influence firms that have a larger leverage. Therefore, we use firms' pre-policy short-term debt to asset ratio and long-term debt to asset ratio to interact with the *Post08* dummy, and add them to the baseline regressions. Moreover, state-owned banks play an important role in China's banking system, and they have stronger ties with state-owned

enterprises. We thus also include the interaction term between the SOE dummy and the *Post08* dummy to account for differential access to credit based on firms' ownership structure. We present the results that include the three additional interaction terms in column (4) of Table 5, and the baseline findings still hold.

Another notable change of China's banking sector in the 2000s is the expansion of city commercial banks. Before 2006, city commercial banks were not allowed to run business in other regions. In 2006, the China Banking Regulatory Commission announced a policy that allows above-scale city commercial banks to establish subsidiaries and branches in other regions. This policy intensified banking sector competition and offered firms more choices for external finance. To account for this change, we use the bank location data offered by the China Banking Regulatory Commission to calculate the number of banks locating within firms' 5 km, 10 km and 15 km distance for each year. We include the time-varying log number of banks at 5/10/15 km distance in column (5) of Table 5, which shows that the baseline results still stand.

5.3.1.4. Changes in export VAT rebate. In addition to the *four-trillion economic stimulus plan*, the central government also increased export tax rebate rate in industries using labor intensively to help maintain employment in the exporting sector. Firms affected by the export VAT rebate policy may perform better financially, and may become more capable of upgrading the quality of their exporting products. To account for this policy, we use firms' exporting structure information from the Customs database and construct a dummy indicating whether the firm's core exporting product is affected by export rebate adjustments. It is then interacted with the *Post08* dummy and included as a control in column (6) of Table 5. We can observe from column (6) that the export VAT rebate adjustment doesn't confound our baseline findings.

5.3.1.5. Corporate income tax adjustments. We further consider another confounding factor, namely the tax adjustment policy announced in 2007 that aimed to unify corporate income taxes for foreign-owned and domestic enterprises. To attract inward FDI, foreign-owned firms were given preferential treatment in corporate income taxes in the 1990s and the early 2000s in some regions. The corporate income tax rate for domestic firms was 33% before 2007, and for foreign-owned firms, the tax rate was 24% or 15% in some provinces. To facilitate fair competition, the corporate income tax rates were adjusted to 25% for all firms in 2007. This tax adjustment may change firms' financial capacity and subsequently their purchase of imported capital goods as well. To relieve this concern, we construct a dummy indicating whether a firm is foreign-invested or HK/Macau/Taiwan-invested. It is then interacted with the *Post08* dummy and included as a control in column (7). We can observe that the estimate on the key interaction term remains positive and significant at the 1% level, suggesting that adjustment in corporate income tax doesn't drive the baseline findings. In Appendix Table A2, we further split the sample into domestic firms and foreign firms and replicate the baseline regression on two subsamples. The estimates on the *Subsidy_shr*×*Post08* are positive and significantly at the 1% level for both subsamples, with the effect being larger for the foreign firm subsample.

In column (8) of Table 5, we control for all the policies mentioned above. The inclusion of all policies at the same time also doesn't alter the baseline findings, which offers us further evidence that the effect of the subsidy policy on export quality upgrading is causal, rather than driven by other contemporaneous policies and macroeconomic shocks.

5.3.2. More restrictive specifications

Firms also display heterogeneity across different industries and regions, which may confound the baseline results as well. Additionally, there may exist other contemporaneous industry-specific or region-specific policies influencing firms' adoption of the subsidized key capital goods and thus their product quality. Since the variable of interest varies at the firm-year level, we can control for industry-year and prefecture-year fixed effects to absorb these macro-level confounders. We present the results with additional fixed effects in column (1) of Table 6. The magnitude of the key estimate remains similar to that of the baseline after controlling for two additional fixed effects.

To further relieve the concern that the baseline results are driven by systematic differences between treated firms and control firms, we include an additional firm-specific linear trend in column (2) of Table 6. We can observe that the inclusion of the firm linear trends brings down the magnitude of the estimate, but the interaction term remains positive and statistically significant. In column (3), we replace the firm-specific linear trend with firm-destination-product-specific linear trend, which gives a similar result to that in the baseline.

5.3.3. Alternative quality measures

The baseline results use product-specific σ from Broda and Weinstein (2006) to estimate export quality at the destination-product-year levels. To check the robustness of our results, we use alternative σ and alternative methods to estimate export quality. In column (4) of Table 6, we use export quality estimated with $\sigma = 5$ as outcome variable. In column (5), we also estimate export quality following Piveteau and Smagghue (2019), which could further alleviate endogeneity concerns in the quality measure.[16] The coefficient on the interaction terms remains similar in magnitude in columns (4) compared with that in the baseline. Using quality estimates with Piveteau and Smagghue (2019)'s method leads to a drop in the magnitude of the interaction coefficient as shown in column (5); however, the estimate remains positive and significant at the 1% level.

[16] Piveteau and Smagghue (2019) exploit variations in real exchange rates and import shares from different source countries to construct instruments for export prices. Then quality estimates are identified from residual export variations after controlling for prices.

Table 6
Robustness checks.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Alt. specification	Alt. specification	Alt. specification	$\sigma = 5$	SFS	List adjustment	Industry exposure	Exclude large cities
Subsidy shares×Post08	0.151***	0.121***	0.161***	0.158***	0.078***		0.107***	0.141***
	(0.019)	(0.027)	(0.054)	(0.028)	(0.027)		(0.021)	(0.023)
Subsidy shares,t - 1						0.051*** (0.014)		
Firm-Country-Product FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Product-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City-Year FE	Yes	No	No	No	No	No	No	No
Industry-Year FE	Yes	No	No	No	No	No	No	No
Firm Linear trend	No	Yes	No	No	No	No	No	No
Firm-product Linear trend	No	No	Yes	No	No	No	No	No
Observations	2,415,068	2,415,320	2,835,072	2,450,970	1,913,283	2,415,320	3,657,038	1,876,209
R-squared	0.773	0.788	0.917	0.790	0.847	0.772	0.781	0.777

Notes: This table reports robustness checks for baseline results. The dependent variable is estimated export product quality. Baseline controls include firms' employment, input tariff rates and import-weighted exchange rates, the industry-level HHI index and EG index. Bootstrapped standard errors are two-way clustered at firm and product levels; ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

5.3.4. *Adjustments in subsidized capital products*

We adopt a DiD specification that uses a list of subsidized goods in the initial year to construct the subsidy share measure. However, there are minor adjustments in the list of subsidized capital goods over the years. To take this into account, we construct time-varying subsidy shares using subsidy lists in $t-1$ year.[17] The estimate on the time-varying subsidy share in column (6) of Table 6 is still significantly positive.

5.3.5. *Accounting for non-importers in the pre-policy period*

As the key variable subsidy share is constructed with the firm-level pre-policy import structure, our baseline sample consists of two-way traders that simultaneously engage in importing and exporting activities. However, incumbent importers only represent part of the *treated firms*, as non-importers in the initial period may start to import following the policy. The policy effect on the initial-non-importers could be either larger or smaller than the always-importers. On the one hand, the initial non-importers are smaller in sizes, asset values and R&D investments, as shown in Table 1. Therefore, initial non-importers have a larger room for quality improvement and the treatment effect of foreign capital goods imports could be greater on them. On the other hand, two-way traders are likely to be more capable of absorbing and integrating foreign technology because of their rich experience in using foreign capital goods. Thus, it is difficult to determine the relative magnitude of the treatment effect for two types of firms.

Estimating the policy effect on initial non-importers is more challenging because there is no information on their use of different types of capital. We exploit the fact that firms classified in the same industry produce similar products and may use similar inputs for production. We average the time-invariant subsidy share at the cic-4d industry level and use it to proxy the subsidy share measure for non-importers before 2008. In column (7) of Table 6, we include both always-importers and initial-non-importers in the sample, which also shows a positive and significant effect of the import subsidy policy on export quality. The magnitude of the coefficient is approximately 29.1% smaller compared to the baseline, suggesting that two-way traders can better utilize subsidized capital goods to improve product quality because of their rich experience with foreign capital goods.

5.3.6. *Excluding major prefectures*

There exist large cross-prefecture differences in the openness to trade in China. Firms in large prefectures have more information and connection on foreign markets and they tend to engage in international trade more actively. To ensure that the baseline findings are not driven by firms located in several largest prefectures, we perform a subsample analysis by excluding the "Tier-1" prefectures, namely, Beijing, Shanghai, Shenzhen and Guangzhou. The results are presented in column (8) of Table 6, which are consistent with the baseline findings.

[17] We use import shares of 2005 to 2007 as weights to construct time-varying subsidy shares to avoid endogenous changes in weights.

Table 7
The impact of the subsidy policy on imports and export quality: the role of firm characteristics.

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Import values						
Subsidy dummy×Post08× Ln initial output	0.092***					
	(0.026)					
Subsidy dummy×Post08× Ln initial total asset		0.075***				
		(0.028)				
Subsidy dummy×Post08× Ln initial fixed assets			0.063**			
			(0.028)			
Subsidy dummy×Post08× Initial TFP				0.068***		
				(0.025)		
Subsidy dummy×Post08× Ln initial RD over sales					−0.011	
					(0.009)	
Subsidy dummy×Post08× SOE dummy						−0.037
						(0.078)
Subsidy dummy×Post08× Foreign-owned dummy						0.137**
						(0.056)
Firm-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm-HS6 FE	Yes	Yes	Yes	Yes	Yes	Yes
Product linear trends	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,198,843	3,201,742	3,201,559	2,992,693	3,114,158	4,100,305
R^2	0.787	0.787	0.787	0.785	0.785	0.796
Panel B: Export quality						
Subsidy shares ×Post08 × Ln output, pre	0.020					
	(0.017)					
Subsidy shares ×Post08× Ln total asset, pre		−0.002				
		(0.016)				
Subsidy shares ×Post08 × Ln fixed assets, pre			−0.011			
			(0.016)			
Subsidy shares ×Post08× TFP, pre				0.084***		
				(0.024)		
Subsidy shares ×Post08× Ln RD over sales, pre					−0.024***	
					(0.008)	
Subsidy shares ×Post08 × SOE dummy						0.222**
						(0.110)
Subsidy shares ×Post08 × Foreign-owned dummy						0.051
						(0.055)
Firm-Country-Product FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Product-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Baseline Controls	Yes	Yes	Yes	Yes	Yes	Yes
Interaction Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,595,609	2,595,600	2,595,517	2,474,780	2,594,067	2,835,086
R-squared	0.793	0.793	0.793	0.792	0.793	0.796

Notes: This table reports results that estimate the heterogeneous effects of the subsidy policy on firms' imports and export product quality. The dependent variable in panel A is natural log of import values and the dependent variable in panel B is estimated export product quality. Controls in Panel A include product-year level import tariff, the post08 dummy interacted with product-level skill intensity, capital intensity, contract intensity, and initial import share respectively. Baseline controls in Panel B include firms' employment, input tariff rates and import-weighted exchange rates, industry-level HHI index and EG index. Bootstrapped standard errors are two-way clustered at firm and product levels; ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

6. Extensions

6.1. Firm heterogeneity, imports, and export quality

Having established the causal impacts of the capital goods subsidy policy on export quality upgrading, we further explore how this effect varies for firms with different initial conditions. This could provide further insights into the effectiveness of the policy. Panel A of Table 7 presents the results for import values and panel B presents results for the export quality.

First, we investigate whether the size of firm matters for policy effectiveness by considering three proxies for firm size: total output,

Table 8
Subsidy policy and export quality: the role of destination countries' income and product characteristics.

Variables	(1)	(2)	(3)	(4)	(5)
	Export quality	Export quality	Export quality	Export quality	Export quality
Subsidy shares ×Post08× Ln destination's GDP,t - 1	0.037**				
	(0.017)				
Subsidy shares ×Post08× Ln destination's GDP per capita,t - 1		0.088***			
		(0.023)			
Subsidy shares ×Post08× Ln destination's imports by product, t - 1			0.032***		
			(0.012)		
Subsidy shares ×Post08× Core product dummy				0.117***	
				(0.045)	
Subsidy shares ×Post08× Dummy for differentiated products					0.134**
					(0.061)
Firm-Country-Product FE	Yes	Yes	Yes	Yes	Yes
Country-Product-Year FE	Yes	Yes	Yes	Yes	Yes
Baseline Controls	Yes	Yes	Yes	Yes	Yes
Interaction Controls	Yes	Yes	Yes	Yes	Yes
Observations	2,835,086	2,835,086	2,751,966	2,574,722	2,820,755
R-squared	0.795	0.795	0.794	0.792	0.795

Notes: This table reports results that estimate how the effects of the subsidy policy on export product quality vary across products and exporting destinations. The dependent variable is estimated export product quality. Baseline controls include firms' employment, input tariff rates and import-weighted exchange rates, the industry-level HHI index and EG index. Bootstrapped standard errors are two-way clustered at firm and product levels; ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

total asset, and total fixed asset. In columns (1) to (3) of Table 7, we interact three size proxies with the subsidy share and *Post08* dummy interaction terms. Results in panel A suggest that larger firms with an initially higher subsidy share measure would import more subsidized capital goods in the post-policy period, which is consistent with intuition. However, the triple interaction coefficients in panel B are statistically insignificant. This implies that the effectiveness of the policy in promoting export quality upgrading is not influenced by firm sizes.

Second, we examine the role of firm productivity. Following Olley and Pakes (1996), we estimate firms' TFP from 2000 to 2007 and take the average for 2005 to 2007 to proxy for firms' initial productivity. Column (4) of panel A shows that more productive firms tend to import more subsidized goods following the policy. A possible explanation is that productive firms are more capable of utilizing capital goods more efficiently, and thus more imports of subsidized goods can help improve their revenues. The estimated coefficient on the triple interaction term in panel B of column (4) is also positive and significant, suggesting complementarity between productivity and advanced capital goods. Together, the estimates in columns (1) to column (4) indicate that a firm's productivity rather than size could help firms to better absorb foreign technology and upgrade product quality.

We further study the importance of firms' R&D investments using triple interactions with the initial R&D investment over sales. Column (5) of panel A suggests that the policy effects on high and low R&D firms are not significantly different. The estimate on the triple interaction term in panel B is negative and significant at the 5% level, suggesting that export quality upgrading effect of the subsidy policy is more pronounced for firms with low initial R&D investment. A possible explanation for this pattern is that there exists substitution between in-house R&D and technology adoption through capital goods imports. This echoes finding in Liu and Qiu (2016), which demonstrate that decreased tariffs for intermediate goods lead to worse innovative outcomes because it offers firms cheaper access to foreign technology. Firms investing less in R&D initially are more reliant on foreign technology spillovers. The key capital goods subsidy policy offers them an opportunity to upgrade their technology and product quality so that they can better compete with high R&D firms in both domestic and foreign markets.

Finally, we take a look at heterogeneity across firms of different ownerships. We construct a dummy indicating whether a firm is state-owned, and another dummy indicating whether the firm is foreign-owned. The results in column (6) of panel A suggest that foreign-owned firms are more responsive to the policy change and import more subsidized capital goods following the policy. This result is intuitive, as foreign firms may use the subsidy to import capital goods from their origin countries. Panel B further shows that SOEs are better at utilizing imported capital goods to upgrade their export product quality. In comparison, foreign-owned firms show no significant better export quality following the policy.

6.2. Destination heterogeneity and export quality

Quality upgrading subsequent to the imports of capital goods may vary along different margins. For instance, many firms in the sample export to multiple destinations, and it has been established in previous literature that high-income countries import more high-quality goods at higher prices. Therefore, heterogeneities in quality upgrading may exist not only across firms but also within firms

Table 9
Extension: export performances in other dimensions.

	Total exports	No. Prod.	No. Ctys	Theil HS	Theil Cty
	(1)	(2)	(3)	(4)	(5)
Subsidy shares ×Post08	0.560***	0.098***	0.109***	0.079***	0.082***
	(0.112)	(0.014)	(0.018)	(0.008)	(0.011)
ln employment	0.717***	0.108***	0.134***	0.063***	0.059***
	(0.052)	(0.009)	(0.010)	(0.005)	(0.004)
Exchange rates,import wgt.	1.074***	0.125***	0.152***	0.021***	0.029***
	(0.063)	(0.012)	(0.008)	(0.004)	(0.004)
Input tariff	6.667***	0.924***	1.080***	0.226***	0.241***
	(0.616)	(0.128)	(0.095)	(0.048)	(0.040)
Firm FE	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes
City-Year FE	Yes	Yes	Yes	Yes	Yes
Observations	472,621	472,621	472,621	327,576	327,576
R^2	0.597	0.678	0.695	0.668	0.641

Notes: This table reports results that estimate the impact of the subsidy policy on other dimensions of export performances. The dependent variables in column (1) to column (5) are firms' log export values, log number of products exported, log number of destination countries, Theil index of export revenues across products, Theil index of export revenues across destination countries respectively. Standard errors are two-way clustered at firm and product levels; ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

across different export destinations.[18]

To check whether firms improve product quality differently across destinations, we interact destinations' GDP with the baseline interaction term in column (1) of Table 8. The coefficient on the triple interaction term is positive and significant, suggesting that quality upgrading is more pronounced for products exported to larger countries after adopting advanced capital goods. Column (2) includes a triple interaction term with GDP per capita, which yields similar results.

GDP and GDP per capita can reflect the destination's overall market size and income levels. In column (3), we consider the product-level market size. In particular, we use the CEPII-BACI dataset to construct the destinations' imports for each product, excluding imports from China. Destination's imports from China could come from either increased demand for the product or improved supply capacity by China. By excluding China's imports, we can eliminate import changes due to China's supply factors. Interacting this product-specific market size measure with the baseline interaction term, we also find a positive and significant coefficient on the triple interaction term. These results suggest that when firms' production capacity is improved, they are inclined to increase the quality of products that serves countries with larger market sizes, as they offer more opportunities to improve firms' revenues.

6.3. *Core product, product differentiation, and export quality*

Following the adoption of imported capital goods, multi-product firms may allocate their production capacity differently across products. We focus on two dimensions: whether the product is the core product for a firm and whether the product is a differentiated good. Many studies in the trade literature have found that firms' export sales are usually skewed towards a small set of core products.[19] When their technology is upgraded by importing advanced foreign capital goods, firms might choose to improve the quality of their core products to enhance their core competitive advantage. Following Arnarson (2020), we classify a product as a core product to firm *f* if it was ranked among the top 10% of the most exported products in the pre-sample period (2005–2007).[20] In column (4) of Table 8, we include a triple interaction term using the core product dummy. The positive and significant estimate suggests that firms upgrade the quality of their core products more relative to non-core products. This could enhance their competitive advantages and this could help them capture a larger market share.

Another product characteristic we consider is whether the product is a homogeneous good or differentiated good. Eckel, Iacovone, Javorcik, and Neary (2015) show that firms would invest more to improve product quality if the product differentiation is high, as an investment in differentiated goods quality would bring a larger revenue increase. Firms adopting advanced capital goods may choose to improve the quality of differentiated goods more to gain a larger market share overseas. We test this hypothesis in column (5) of Table 8, by interacting a dummy for differentiated goods with subsidy share and *post08* dummy.[21] The result shows that firms more

[18] See Hallak (2006); Bastos and Silva (2010); Manova and Zhang (2012); Brambilla, Lederman, and Porto (2012).

[19] See Bernard, Redding, and Schott (2011); Eckel et al. (2015); Arnarson (2020).

[20] Assume firm *f* exports *P* products in total, and each product has a rank identifier *p*. A product is considered as the core if $p/P \leq 0.1$. We sum up exports across all destinations to construct the core dummy, which differs from Arnarson (2020) that identifies core products within firm-destination pairs.

[21] We follow the definition for differentiated good in Rauch (1999), who classifies goods into three groups: differentiated, traded on organized exchanges and referenced priced. We construct a dummy for differentiated goods that takes on value 1 for the first group of goods and 0 for the latter two groups of goods. The original classification is for goods using Standard International Trade Classification (SITC) Rev. 2. We map them into HS 1996 classification using a concordance table.

affected by the policy increase the quality of differentiated products more.

6.4. Intensive and extensive margins of exports

So far, the export performance we have focused on is export product quality by destination-product-year. To gain a better understanding of firms' exporting dynamics following the policy, we further explore other dimensions of export performances, including firms' export values, the number of products exported, the number of destination countries served, and Theil indexes of export values that reflect the export distribution across products and destination countries. The relevant results are presented in Table 9.

The first column shows the results for the export values aggregated at the firm-year level. The positive and significant coefficient on the interaction term suggests that increased imports of key capital goods following the policy shock would boost export values at the firm level. Column (2) uses the natural log of one plus the number of exported HS 6-digit goods as the outcome variable, which also suggests that firms more affected by the policy would see an increase in the number of products they produce. Column (3) uses the natural log of one plus the number of destination countries as the outcome variable, which shows a similar result. Columns (1) to (3) offer additional evidence that increased imports of key capital goods promote firms' production capacity. Firms that are more affected by the subsidy policy are more likely to increase their overall exports, product variety, as well as the number of destinations.

In columns (4) and column (5), we investigate whether firms' exports become more concentrated or more dispersed in terms of products exported and the destinations they serve. To achieve this, we construct the Theil index for firms' exports by product and destination, which are used as outcome variables in columns (4) and (5) respectively. The coefficients on the interaction term in both columns are positive and significant at the 1% level, which suggests that firms' exports become more concentrated in products and in the destination markets they serve. In Appendix Fig. A3, we display event-study analysis results for the above firm-level export outcomes. It is clear from the figure that the pre-event estimates of the $Subsidy\_shr_f$ and year dummies interaction terms are statistically insignificant; while the post-event trends are significantly above zero. This alleviates endogeneity concerns regarding firm-level export outcomes.

Combining the results in Table 8 and Table 9, we can get a fuller picture of how capital goods subsidy policy can affect firms' export performance. First, firm production capacity is increased following the import subsidy policy. Firms subsequently would upgrade their product quality, and increase their overall export values, number of products, and number of destination countries served. Second, firms strategically adjust their exporting portfolio to maximize their revenues. They would sharpen their competitive advantages by tilting more resources to upgrade their core products and differentiated, leading to increased quality and increased revenues in these key products. They also focus more on larger and richer markets, as these markets could offer them higher revenues potentially.

7. Mechanisms

7.1. Capital-skill complementarity

This section tests the mechanisms that drive quality upgrading following the adoption of key capital goods. We start by testing whether complementarity between advanced capital goods imports and skilled labor could jointly improve firms' export quality.

Unfortunately, we cannot directly examine firms' employment of skilled labor before and after the policy, because there is little information on the skill composition of firms' employment in the ASIF database. Instead, we exploit cross-prefecture differences in skilled labor abundance to observe how export quality upgrading varies geographically. The underlying logic of this approach is that firms located in regions with abundant skilled labor can access skilled labor at a lower cost. Therefore, if the capital-skill complementarity channel exists, firms in skilled labor abundant regions are better able to upgrade their export product quality than their peers in skilled labor-scarce regions.

We use three variables to proxy for skilled labor abundance at the prefecture level. First, we employ China's 2005 mini-population census to construct the share of working age population with a bachelor degree or above for each prefecture. Second, prefectures with a larger number of colleges and universities would have greater access to a large pool of high-skilled labor. We collect information on the number of colleges and universities in a prefecture from China's City Statistical Yearbook. Third, there are more than one-hundred 985/211 universities in China considered as *prestigious universities*. Graduates from *Prestigious universities* are more likely to be high-quality skilled labor. We thus construct a dummy to indicate whether there are any 985/211 universities in the prefecture.

In columns (1) to (3) of Table 10, we interact the three skilled labor proxies with the baseline interaction term, to see whether export product quality upgrading following the policy implementation is greater for firms located in prefectures with more abundant skilled labor.[22] As evident from the table, the coefficients on the triple interaction terms in all three columns are positive and significant at the 1% or 5% levels. This is consistent with the capital-skill complementarity hypothesis, showing that firms in locations with access to more skilled labor can better exploit the capital goods subsidy policy.

7.2. Relaxed credit constraints

Another potential explanation for quality upgrading is that capital goods subsidy can reduce the cost of importing capital goods,

[22] To rule out other time-varying prefecture confounders, we include Prefecture-Year fixed effects in these regressions.

Table 10
Mechanism: capital skill complementarity and credit constraints.

Variables	Skilled labor abundance		Credit constraint		
	(1)	(2)	(3)	(4)	(5)
Subsidy shares×Post08 × Skilled labor share	2.292***				
	(0.887)				
Subsidy shares×Post08 × Ln number of colleges		0.113**			
		(0.053)			
Subsidy shares×Post08 × Prestigious University			0.284***		
			(0.076)		
Subsidy shares×Post08 × Firm's short-term liquidity				0.103	
				(0.131)	
Subsidy shares×Post08 × City's credit to GDP ratio					0.092
					(0.094)
Firm-Country-Product FE	Yes	Yes	Yes	Yes	Yes
Country-Product-Year FE	Yes	Yes	Yes	Yes	Yes
City-Year FE	Yes	Yes	Yes	Yes	Yes
Baseline Controls	Yes	Yes	Yes	Yes	Yes
Interaction Controls	Yes	Yes	Yes	Yes	Yes
Observations	2,833,611	2,833,391	2,833,611	2,594,261	2,833,611
R-squared	0.796	0.796	0.796	0.794	0.796

Notes: This table reports results that estimate potential channels for the subsidy policy to affect export product quality. The dependent variable is estimated export product quality. Baseline controls include firms' employment, input tariff rates and import-weighted exchange rates, the industry-level HHI index and EG index. Bootstrapped standard errors are two-way clustered at firm and product levels; ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

thus relaxing the credit constraints for subsidized firms. Firms can invest more to upgrade product quality through R&D investment or other forms of investment. If this is the case, then our baseline results simply reflect quality upgrading through improved liquidity, rather than improved production capacity due to imports of advanced capital goods.

We test this potential channel using two approaches. First, if the subsidy policy can improve output quality by relaxing firms' credit constraints, then the effects should be more pronounced for firms that are more financially constrained in the pre-policy period. To investigate this situation, we use information from ASIF data to construct a short-term liquidity variable that measures firms' financial constraints.[23] Then we interact this short-term liquidity variable with the baseline interaction term to see how the impact of subsidy policy differs across firms. If the credit constraint channel exists, we expect the estimate on the triple interaction term to be negative and significant. However, the estimate on the triple interaction term in column (4) of Table 10 is positive yet significant. This offers suggestive evidence that the credit channel is of minor importance in promoting output quality upgrading.

We further consider the credit channel from the perspective of credit access. There are regional variations in firms' access to credit. Some prefectures are more financially developed, with more bank branches and more private savings. If the credit channel exists, we expect firms located in financially underdeveloped regions to benefit more from the policy, as the subsidies can relieve their credit constraints to a larger degree. From China's City Statistical Yearbook, we obtain each prefecture's total credit to GDP ratio and use this as a measure for easy access to credit. The triple interaction with this ratio has a positive yet insignificant coefficient, indicating that quality upgrading is larger for firms in financially developed regions. This further invalidates the credit channel, suggesting that imported key capital goods have direct effects on quality improvements. The relaxed credit credits contribute little to quality upgrading.[24]

7.3. Improvement in the management

We have established the importance of complementarity between capital goods imports and skilled labor in promoting export product quality in Section 7.1. It is also possible that firms importing advanced key capital goods may improve their management by appointing highly educated managers. Using data from India, Chakraborty and Raveh (2018) show that input trade liberalization has increased demand for managers since increased technology inflows require better management practices. Knowledge transfers are also embodied in capital goods imports, which may boost the demand for skilled managers. Appointing more capable managers could improve firms' management efficiency, reduce organizational costs, and better mobilize firms' internal resources. The complementarity between more productive capital goods and more efficient management could also jointly contribute to improvements in export product quality.[25]

[23] Short-term liquidity = (Current assets−Current liability)/Total asset.
[24] Since large prefectures differ in skilled labor endowments and credit access from other prefectures, we rerun regressions in Table 10 by excluding four Tier-1 prefectures and present results in Appendix Table A3. The patterns without Tier-1 prefectures are similar to that in Table 10.
[25] The export performance improving effect of management practices is also found in Bloom, Manova, Van Reenen, Sun, and Yu (2021).

Table 11
Mechanisms: managers' entry, exit and compensation.

	Entry		Exit		Ln compensation	
	(1)	(2)	(3)	(4)	(5)	(6)
Subsidyshares× Post08 × EducYrs	0.007**	0.007**	−0.005*	−0.005*	0.059**	0.061**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.027)	(0.027)
EducYrs× Post08	−0.005***	−0.005 ***	−0.000	0.000	−0.021	−0.021
	(0.001)	(0.001)	(0.001)	(0.001)	(0.016	(0.016)
Subsidy shares×EducYrs	−0.006***	−0.006**	0.004	0.004	−0.043*	−0.044 *
	(0.002)	(0.002)	(0.002)	(0.003)	(0.025)	(0.025)
Male dummy	−0.001	−0.001	0.005	0.005	0.006	0.007
	(0.003)	(0.003)	(0.003)	(0.003)	(0.032)	(0.031)
EducYrs	0.005***	0.005***	−0.001	−0.001	0.037 **	0.037**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.015)	(0.015)
Age	−0.001 ***	−0.001***	0.003***	0.003***	0.005*	0.005*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.003)
Tenure	−0.064 ***	−0.064 ***	0.015 ***	0.015 ***	0.051 ***	0.051 ***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.005)	(0.005)
Firm-position FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Position-Year FE	No	Yes	No	Yes	No	Yes
Observations	82,460	82,448	88,162	88,148	68,849	68,836
R^2	0.457	0.458	0.302	0.304	0.398	0.399

Notes: This table estimate the impact of the subsidy policy on entry, exist, and compensation of managers of different skill levels. The dependent variable in columns (1) and (2) is the managers' entry dummy. The dependent variable in columns (3) and (4) is the managers' exit dummy. The dependent variable in columns (5) and (6) is managers' log compensation. Standard errors are clustered at the firm level; ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

There is no information on individual managers in the ASIF dataset. However, from the China Stock Market & Accounting Research Database (CSMAR), we can obtain information on changes in public firms' top management teams from 2002 to 2013.[26] In particular, CSMAR offers information on top managers' age, education background, gender, position in the firm, start date, and end date. Rich information on managers' tenure allows us to directly test firms' adjustments in management in response to the subsidy policy.

We match the CSMAR with the Customs Database, to construct the subsidy share measure for firms engaging in imports from the 2005 to 2007 period. Then we study how public firms' differential exposures to the capital goods subsidy policy influence the entry, exit, and compensation of top managers with different education years, which proxies for managers' skill levels. To achieve this goal, we estimate the following regression specification:

$$Y_{ijft} = \varphi_1 Educ\_Yrs_i + \varphi_2 Subsidy\_shr_f \times Post08_t \times Educ\_Yrs_i + \varphi_3 Educ\_Yrs_i \times Post08_t + \varphi_4 Subsidy\_shr_f \times Educ\_Yrs_i + X_{it}\delta + \gamma_{ft} + \theta_{fj} + \epsilon_{ijft} \tag{5}$$

where Y_{ijft} is the outcome variable (entry, exit, and compensation) for individual i, in position j, working in firm f at year t. We identify management adjustments in response to capital subsidy policy through the triple interaction term $Subsidy\ shr_f \times Post08_t \times EducYrs_i$. If there exists complementarity between capital upgrading and skilled managers, we expect a positive estimate of $\varphi_2$for entry and compensation, and a negative estimate of φ_2 for the exit. We include individual controls X_{it} such as individuals' age, gender, and the number of years stayed in the current firm. We include firm-year fixed effects γ_{ft} and firm-position fixed effects θ_{fj} to identify the effects using within firm-position changes over time. In some of the regressions, we further include a position-year FE to consider market-wide changes in a specific management position, such as the computerization of the occupation.

We present the estimation for Eq. (5) in Table 11. Column (1) uses an entry dummy as the outcome variable and includes firm-year FE and firm-position FE. Column (2) further includes position-year FE. Results in columns (1) and (2) suggest that firms more affected by the subsidy policy are more likely to hire highly educated managers. Columns (3) and (4) repeat regressions with an exit dummy as the outcome variable. The negative coefficients suggest that highly-educated managers are less likely to exit from management positions in firms more affected by the subsidy policy. Columns (5) and (6) use the natural log of managers' compensation as the outcome variable. The estimates on triple interaction terms are positive and significant at the 5% level, indicating that skill premiums for managers would increase if a public firm is more affected by the policy. Taken together, Table 11 provides evidence that increases in advanced capital goods would affect firms' management teams as well. In terms of managers' composition, there would be more skilled managers due to increased entry rates and decreased exit rates of highly educated managers. In terms of compensation, managers with higher education levels would see higher increases in wages. These results are consistent with Chakraborty and Raveh (2018) that find increased demand for managers following input trade liberalization.

[26] There are in total 3379 public firms during this period, and 1287 of them have import record in the 2005 to 2007 period.

8. Conclusion

Using a matched micro dataset of China's manufacturing firms and transaction-level custom databases, we empirically investigate the effect of an import subsidy policy aiming to promote capital goods imports in China since 2008. We employ a DiD strategy for the identification and find that the subsidy policy increased firms' imports of subsidized products, and led to improved export product quality. There also exist heterogeneities for different firms, destinations, and products. We find supporting evidence that the complementarity between capital goods imports and skilled labor/skilled managers may drive quality upgrading in export products.

Our findings carry important policy implications for developing countries around the world. Developing countries can improve their technology and production capabilities by either investing heavily in R&D or by importing foreign technologies and advanced capital goods. Given the enormous costs and uncertainties of the former, it may be more desirable to realize industrial upgrading by absorbing frontier technologies through importing advanced capital goods. Implementing trade policies such as the subsidy policy we study in this paper may accelerate this process, which allows a developing country to benefit from the *"late movers' advantage"*. However, policymakers also need to be aware of the situation where domestic innovative incentives are dampened because of easy access to foreign technology. Thus, it is vital to implement policies that can improve the complementarity between foreign technology adoption and indigenous innovations.

Data availability

Data will be made available on request.

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Appendix A. Appendix

附表 2：

_____年进口贴息资金申请表

申请企业：

序号	海关报关单号/技术合同号	进口商品/技术			实际进口额（美元）	备 注
		商品税号/技术目录编号	商品名称/技术合同号	商品技术规格		
总计						
省、自治区、直辖市、计划单列市商务厅（委、局）、中央管理企业意见： （盖章） 年 月 日			省、自治区、直辖市、计划单列市财政厅（局）意见： （盖章） 年 月 日			

企业联系人： 联系电话：

Fig. A1. Firm's application form for the import subsidy policy.

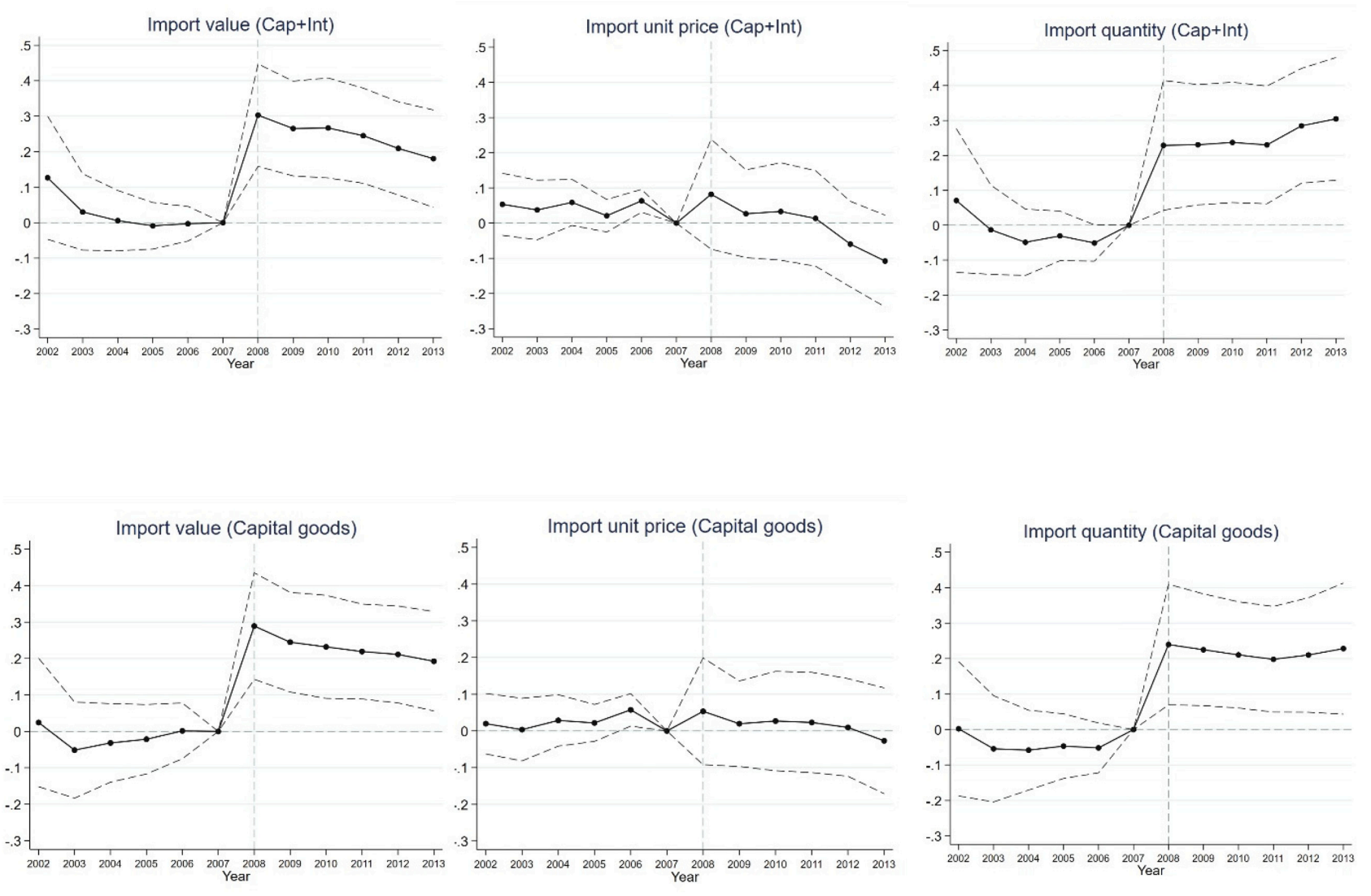
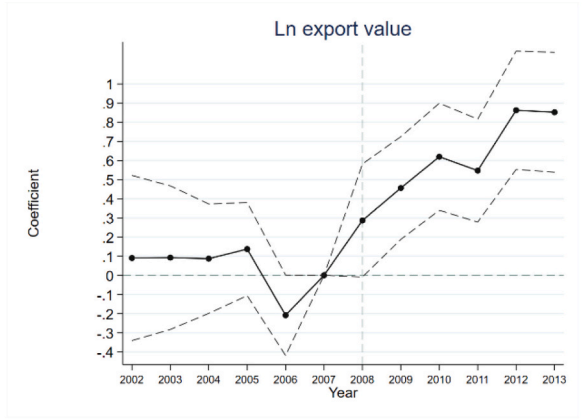
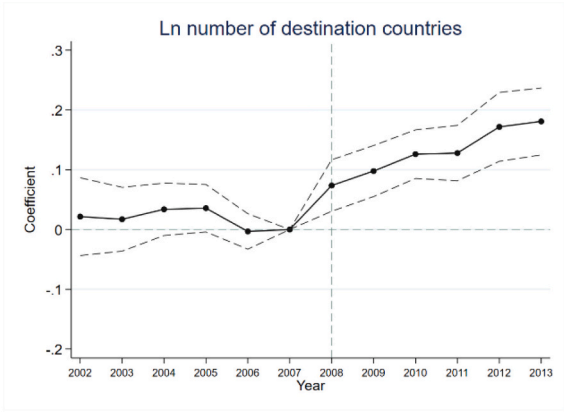
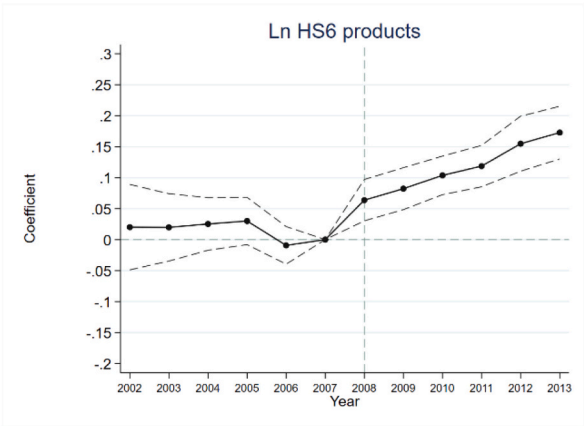


Fig. A2. Dynamic impact of the policy on import values, prices and quantities.
Notes: This figure plots estimates for the dynamic impact of the subsidy policy on import values, import prices and quantities. The three figures in the upper panel use capital goods imports and intermediates imports as the regression sample, while the lower three figures use only capital goods imports as the regression sample. Year 2007 (1 year prior to the policy) is treated as the benchmark. 95% confidence intervals are presented.







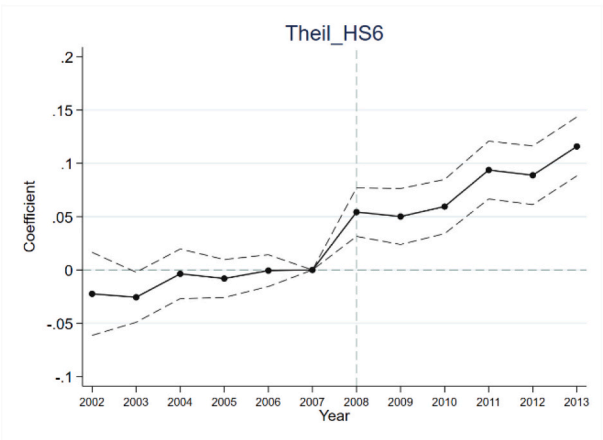


Fig. A3. The impact of the policy on other export performances.
Notes: This figure plots estimates for the dynamic impact of the subsidy policy on firms' other aspects of export performances, with 2007 (1 year prior to the policy) treated as the benchmark. 95% confidence intervals are presented.

Table A1
Entry and exit from importing market.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	All imports	All imports	Cap+Int	Cap+Int	Cap	Cap
	Entry	Exit	Entry	Exit	Entry	Exit
Affected HS6 products×Post08	0.010**	−0.000	0.011**	0.001	0.001	−0.006*
	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)
Contract intensity×Post08	−0.004	−0.001	−0.005	−0.004	0.024	0.018
	(0.011)	(0.009)	(0.011)	(0.009)	(0.020)	(0.022)

(*continued on next page*)

Table A1 (*continued*)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	All imports	All imports	Cap+Int	Cap+Int	Cap	Cap
	Entry	Exit	Entry	Exit	Entry	Exit
Capital intensity×Post08	−0.001	−0.001	−0.001	−0.001	−0.004***	−0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Skill intensity×Post08	0.004**	0.004**	0.005**	0.005**	0.002	0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Initial import share×Post08	−0.291***	−0.109***	−0.289***	−0.107***	−0.306***	−0.118***
	(0.004)	(0.003)	(0.004)	(0.003)	(0.007)	(0.005)
Ln tariff	0.010	0.048*	0.015	0.063**	0.043	0.048
	(0.025)	(0.028)	(0.028)	(0.031)	(0.057)	(0.055)
Firm-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm-Product FE	Yes	Yes	Yes	Yes	Yes	Yes
Product-Linear trend	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,645,614	9,645,614	9,231,915	9,231,915	2,737,042	2,737,042
R-squared	0.426	0.346	0.426	0.346	0.444	0.388

Notes: This table reports entry and exit dynamics for firms' imports of HS-6 digit products. The dependent variable in column (1), (3) and (5) is the dummy for entry that takes on value 1 if the firm imports a product in year t but not year t - 1. The dependent variable in column (2), (4) and (6) is the dummy for exit that takes on value 1 if the firm imports a product in year t but not year t + 1. Standard errors are two-way clustered at firm and product levels; ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

Table A2
Subsample analysis for domestic and foreign firms.

	Foreign firms	Domestic firms
Subsidy shares×Post08	0.180***	0.134***
	−0.046	−0.032
Firm-Country-Product FE	Yes	Yes
Country-Product-Year FE	Yes	Yes
Baseline controls	Yes	Yes
Observations	1,183,264	1,404,013
R-squared	0.803	0.811

Notes: This table repeats baseline regressions for foreign firms and domestic firms. The dependent variable is estimated export product quality. Firm controls include firms' employment, input tariff rates and import-weighted exchange rates. Industry controls are the industry-level HHI index and EG index. Bootstrapped standard errors are two-way clustered at firm and product levels; ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

Table A3
Mechanism: capital skill complementarity and credit constraints.

	Skilled labor abundance			Credit constraint	
	(1)	(2)	(3)	(4)	(5)
Subsidy shares×Post 2007 dummy×Skilled labor share	2.590*				
	(1.492)				
Subsidy shares×Post 2007 dummy×Ln number of colleges		0.127**			
		(0.055)			
Subsidy shares×Post 2007 dummy×Prestigious University			0.292***		
			(0.083)		
Subsidy shares×Post 2007 dummy×Firm's short-term liquidity				0.168	
				(0.152)	
Subsidy shares×Post 2007 dummy×City's credit to GDP ratio					0.074
					(0.098)
Firm-Country-Product FE	Yes	Yes	Yes	Yes	Yes
Country-Product-Year FE	Yes	Yes	Yes	Yes	Yes
City-Year FE	Yes	Yes	Yes	Yes	Yes
Interaction controls	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes
Industry controls	Yes	Yes	Yes	Yes	Yes
Observations	2,191,340	2,191,144	2,191,340	1,999,311	2,191,340
R^2	0.800	0.800	0.800	0.797	0.800

Notes: This table reports results that estimate potential channels for the subsidy policy to affect export product quality. Four Tier-1 prefectures are excluded from the sample (Beijing, Shanghai, Guangzhou, and Shenzhen). The dependent variable is estimated export product quality. Firm controls

include firms' employment, input tariff rates and import-weighted exchange rates. Industry controls are the industry-level HHI index and EG index. Standard errors are two-way clustered at firm and product levels; ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

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