Received: 17 September 2021 | Revised: 22 June 2022 | Accepted: 10 August 2022

DOI: 10.1111/twec.13330

ORIGINAL ARTICLE

The World Economy WILEY

Internet penetration and multi-product exporters: Firm-level evidence from China

Shuzhong Ma | **Zengxi Hu**

China Academy of Digital Trade, Zhejiang University, Hangzhou, China

Correspondence
Zengxi Hu, China Academy of Digital Trade, Zhejiang University, 866 Yuhangtang Road, Xihu District, Zhejiang Province, Hangzhou, China.
Email: zengxi_hu@163.com

Funding information
National Natural Science Foundation of China, Grant/Award Number: 71973120

Abstract

This study explores the impact of Internet penetration on the firm-product-level behaviour of multi-product exporters. While a substantial body of literature has explored the effect of the Internet on firm performance, especially extensive and intensive margins, few studies examine the product-level behaviour within firms. Using highly disaggregated firm-product-level data covering Chinese manufacturing industrial firms from 2000 to 2007, we provide evidence on the effects of the Internet on product mix and product switching within firms. Specifically, because of the reduction in export market entry costs, the Internet can encourage more firms to enter the export market and increase market competition, which causes multi-product exporters to skew exports towards best-performing products and drop the products furthest away from its core competence. Meanwhile, the Internet can increase multi-exporters' productivity and encourage firms to introduce new products, which are also further away from the core product. Productivity and competition cause multi-product exporters to exhibit product switching, which results in the expansion of product scope.

KEYWORDS
internet, market competition, multi-product exporter

1 | INTRODUCTION

Nowadays, the Internet boom has been a nonnegligible phenomenon. According to International Telecommunication Union (ITU), the Internet users reached 4.1 billion in 2019, with the average growth rate of 10% each year.[1] Even if the whole world has been haunted by the COVID-19 pandemic, the international bandwidth usage grows by 38 per cent in 2020. Unprecedentedly, the Internet penetration rate of China has grown from less than 10 per cent in 2000 to 70.4 per cent in 2020,[2] much higher than the world average (the global penetration rate climbed from around 17 per cent in 2005 to 53 per cent or more in 2019). The development of the Internet has played an important role in the rapid growth of trade, which is an essential channel for boosting economic growth (World Bank, 2016). As shown in Figure 1, China's total export and Internet coverage rate (the number of Internet users per capita) shows a trend of simultaneous changes.

The fact that multi-product firms are ubiquitous and their contribution to exports is much higher than that of single-product firms has been revealed by many studies on international trade (Bernard et al., 2007; Goldberg et al., 2010). In the context of China's trade growth, multi-product exporters make the most contributions and are the most important component of exports. Between 2000 and 2015, more than 70 per cent of firms exported more than one product at the six-digit Harmonised System (HS) level, and their contribution to exports was over 90 per cent on average.[3] Specifically, the top product (core product) is an important reason for firms' export growth (Iacovone & Javorcik, 2010). On the other hand, product adding and dropping are frequent among multi-product exporters. As shown in Figure 2, each multi-product firm exports about 30 products every year, of which about 10 products (more than 20 per cent of all products) are dropped and introduced at the six-digit HS level in China. The Internet can greatly reduce the trade costs and enable more firms to engage in international trade (Freund & Weinhold, 2004), thereby increasing competition in the export market. At the same time, the Internet will also improve total factor productivity (TFP; Fernandes et al., 2019). Therefore, the Internet may have an impact on the product mix and product switching within firms (Bernard et al., 2011; Mayer et al., 2014).

In this study, we combine highly disaggregated firm-product-level data obtained from the Annual Survey of Industrial Firms and China Customs Transaction Database and province-industry-year level Internet penetration information to examine the effects on product mix and product switching within multi-product exporter from 2000 to 2007. As for the econometric strategy, we followed Fernandes et al. (2019), who use the interaction of Internet coverage rate at the province-year-level and Internet intensity at the industry level as the key explanatory variable. What makes a difference is that our paper considers the Internet penetration as the combination of provincial Internet coverage and industrial Internet dependence. Internet coverage can be regarded as the development of the Internet in a province, which is the 'horizontal' development of the Internet. The intensity of Internet use in an industry is the depth (dependence) of Internet use, which measures the 'vertical' depth of the Internet. The interaction between them can be

[1]See the report from https://www.itu.int/en/ITUD/Statistics/Documents/facts/FactsFigures2020.pdf

[2]Data are from the National Bureau of Statistics of China.

[3]Data are from the China Customs Transaction Database, which is described in Part 3.

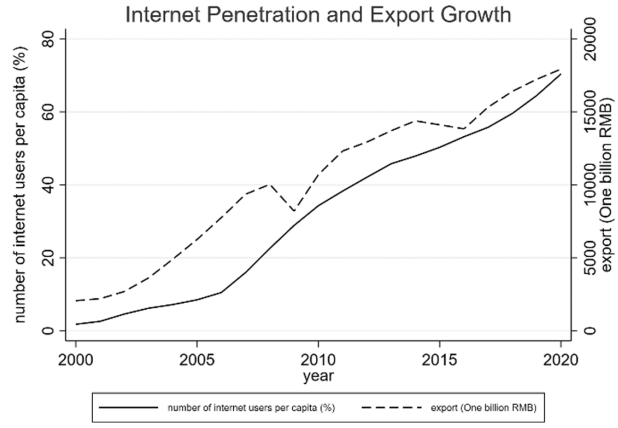

FIGURE 1 Number of internet users per capita and total export value in China from 2000 to 2020

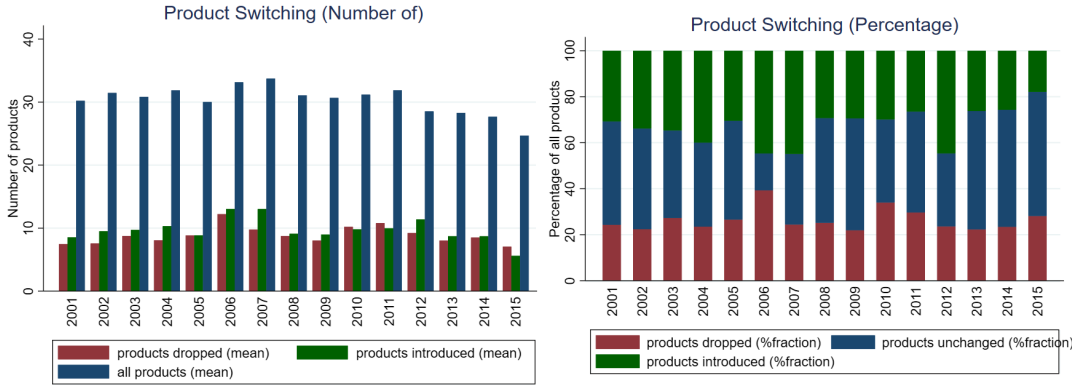

FIGURE 2 Product switching of multi-product exporters in 2001–2015. [Colour figure can be viewed at wileyonlinelibrary.com]

Note: The LHS of figure depicts the average number of dropped products, introduced products and all products for each exporter from 2001 to 2015. The right panel shows the average percentage of dropped products, introduced products and unchanged products for each exporter from 2001 to 2015

regarded as the degree of Internet penetration in the province and industry to which each enterprise belongs.

Using Internet penetration at the province-industry-year level, we first find that an increase in Internet penetration increases the skewness of total exports and can also encourage firms to drop some products and introduce new ones, which results in the expansion of product scope. Next, we take a closer look at product mix and switching behaviour at product level and find that multi-product exporters will skew its export sales towards its best-performing products. In addition, they drop their least-successful products and introduce more new products, which is also furthest from the core product and can be considered as a trial for new products in the market.

To address endogeneity issues, we use the instrumental variable approach. Following Nunn and Qian's (2014) method of constructing instrumental variables, we use the reciprocal of the degree of terrain irregularity as an exogenous proxy indicator of Internet development in each province and the US share of ICT capital services as the exogenous Internet features for China's

industry. The interaction between the reciprocal of terrain irregularity and US industrial technical features is regarded as a proxy for Internet penetration at the province-industry level at a specific time point. Referring to the methods of Angrist and Keueger (1991), we use a time dummy to interact with the province-industry-level proxy for Internet penetration as instrumental variables in our two-stage least-squares estimation.

Finally, we shed light on the mechanisms and find that Internet penetration can greatly reduce trade costs and encourage more firms to enter the export market, resulting in a market with tougher competition. To face such tough market competition, a multi-product exporter will skew exports towards its best-performing products and drop the least-successful products (Mayer et al., 2014). At the same time, Internet penetration can increase a firm's TFP and cause multi-product exporters to introduce more products to earn higher revenue (Bernard et al., 2010; Fernandes et al., 2019). As a result, although tougher competition will induce product dropping, the TFP effect will promote product adding, which means that multi-product exporters have a dynamic product switching behaviour and finally expand the scope of their products.

Our study is linked to several important strands of literature. First, it contributes to extending existing studies on the Internet and firm export by focusing on product-level behaviours within the firm. In the field of the Internet and trade, some existing studies explore the influence of the development of Internet technology on the overall trade growth of a country and are usually based on the gravity model (Clarke & Wallsten, 2006; Freund & Weinhold, 2004; Lin, 2015); others study the impact of the Internet penetration or firms' application of Internet technology on their export performance (Fernandes et al., 2019; Ferro, 2011; Ricci & Trionfetti, 2012; Yadav, 2014). These studies mainly focus on firm performance, especially extensive and intensive margins, even export quality (Huang & Song, 2019), few studies examine the product-level behaviour within firms. However, we systematically and comprehensively explore the influence of Internet penetration on product mix, product switching and even productivity improvement within a firm, which may cover all the behaviours at the product level within a firm. Second, our study extends the normally discussed trade cost channel and introduces the mechanism of market competition for the Internet. Previous research mainly focuses on and discusses the mechanism of Internet development based on trade cost (Fernandes et al., 2019; Ferro, 2011; Freund & Weinhold, 2004). In this paper, we find that the Internet can increase competition in the export market and thereby influence multi-product exporters' behaviours. Third, it enriches the connotation of the multi-product firm theory and provides empirical evidence on the effect of the Internet at the firm-product level to inspire future research. It is worth noting that above studies of the Internet on firm export are based on single-product heterogeneous firm model presented by Melitz (2003), ignoring the typical reality of multi-product firms (Bernard et al., 2007, 2010; Eckel & Neary, 2010; Goldberg et al., 2010). Bernard et al. (2011) extend Melitz (2003) and mainly examine the selection effect among products in multi-product firms under the open market. Mayer et al. (2014) extend Melitz and Ottaviano (2008) and examine how the degree of competition in the export destination market affects the export decisions of multi-product firms. Based on multi-product firm theory framework, our study provides a general insight into the effect of the Internet for further research.

The remainder of this paper is organised as follows. Section 2 presents the theoretical framework and hypothesis. Section 3 describes the data and methods used to measure the variables in the following section. Section 4 describes the empirical specifications and the results. Section 5 concludes the paper.

2 | THEORETICAL FRAMEWORK AND HYPOTHESIS

Information technology represented by the Internet is regarded as the symbol of the fifth Kondratieff Cycle of the world economy (Yushkova, 2014). As a general-purpose technology, the Internet has exerted a wide impact on all fields and levels of society. Generally speaking, the Internet can reduce the economic cost including production and transaction cost, promote the generation and transmission of knowledge, information and ideas, improve resource allocation efficiency and eventually have a positive impact on production efficiency, economic growth, employment and international trade.

On the one hand, Freund and Weinhold (2004) believe that trade costs exist widely, among which search and communication costs are two important forms. Some studies find that the spread of the Internet can greatly reduce transportation costs. With the progress of communication technology, the Internet also reduces the search costs in international trade (Freund & Weinhold, 2004; Lendle et al., 2016; Rauch, 1999). Some studies have found that the Internet plays an important role in reducing sunk cost and information asymmetry cost. Consumers search for the best trader through the Internet, which is conducive to cross-border transactions by increasing the number of available objects (Rauch, 1996). Enterprises can attract potential customers across the global market through the Internet, thus greatly reducing the sunk cost of a particular market (Freund & Weinhold, 2002). Fan et al. (2018) find that e-commerce reduces fixed costs such as establishing stores and laying channels needed to enter new markets, improves product diversity in smaller markets and reduces the inequality effect in markets of different sizes, thus improving consumer welfare. According to Melitz (2003), a reduction in trade costs can induce more firms to engage in export markets, which will increase the total number of heterogeneous products and decrease average prices in this market. In the framework of multi-product firms in Mayer et al. (2014), more heterogeneous products and lower average price mean tougher market competition. And tougher market competition will reduce the price bound at which the profit of a product is zero and markup of products, which means products with exactly zero profit will have negative export profit after the development of the Internet and will have to withdraw from the export market. Therefore, firms will choose the best-performing products in export market, which means tougher market competition will promote firms to skew towards core products to concentrate on core competence and drop the worst-performing products.

> **Hypothesis 1** *The expansion of the Internet will increase the competition in export markets, thus promoting firms to skew to core products (higher skewness) and drop the worst-performing products.*

On the other hand, the Internet can influence firms' performance in other aspects. Fernandes et al. (2019) investigate the relationship between regional Internet development and the performance of Chinese enterprises from 1999 to 2007 and find that the development of the Internet will not only improve the export performance of firms but also improve the total output level of firms by improving labour and the TFP with which the effect is more pronounced in industries that rely more on the Internet. Bernard et al. (2011) prove that enterprises with high productivity will expand new product categories in existing export markets, existing products will expand into new export markets, and existing export products will export more to existing export markets. Turn to the framework of multi-product firms in Mayer et al. (2014), an increase in TFP means a reduction in marginal cost (unit labour requirement). It means that, other market conditions

being equal, firms will have more products on the price bound with zero profits. In other words, the Internet promotes the TFP of firms, so the marginal cost will decrease that more new products will be introduced.

Hypothesis 2 *The Internet will increase the total factor productivity of exporters, thus reducing the marginal cost, and introduce more new products furthest away from core competence.*

In summary, we can see from above: on the one hand, the Internet can stimulate enterprises to reduce the range of export products and concentrate on exporting core products through promoting competition effect; on the other hand, the Internet can introduce new products by improving the productivity of enterprises, reducing the unit production cost of products so as to expand the scope of export products. So how does the range of products change with the Internet? Baldwin and Gu (2009) believe that the direction of impact of falling trade costs on product diversification is uncertain. On the one hand, it will lead firms to reduce the range of products in the domestic market, and on the other hand, it will lead firms to expand the range of products in export markets. Bernard et al. (2010) defined 'product adding rate' and 'product elimination rate', pointing out that the adjustment of product mix within a firm caused by the impact of product level means a negative correlation between product adding and product dropping. However, their research shows that there is a positive correlation between the adding and dropping of American manufacturing products. Bernard et al. (2011) predicted the positive correlation between firm productivity and export scope through theoretical model. Eckel and Neary (2010) also found that market size effect had no effect on the product range within a firm, while competition effect would prompt enterprises to reduce the product range. So up to now, there is no consistent conclusion about the influence factors of export product scope. As stated by hypotheses 1 and 2 that the competition shows a negative effect and TFP shows a positive effect on product scope, we can infer that if the competition effects exceed the productivity effects, the product scope will decrease, and vice versa.

3 | DATA AND MEASUREMENTS

3.1 | Firm-level manufacturing data and product-level trade data

The highly disaggregated firm-level data set used in our empirical analysis is from the Annual Survey of Industrial Firms of National Bureau of Statistics for 2000–2007. This database covers all state-owned and non-state-owned firms above the limit of annual sales (firms with a total output value of more than 5 million yuan) in China, accounting for 98 per cent of China's manufacturing exports. It includes information of balance sheet, income statement and cash flow statement for each firm and provides detailed information on the firm's identity, ownership, exports, employment and total fixed assets, which can be used to construct firm-level variables. Unfortunately, this database does not contain detailed information on export patterns and export dynamics, which is essential for the exploration on firm's product-level behaviours. Therefore, there is a need for more detailed product-level trade data.

Product-level trade data are obtained from China's General Administration of Customs, which include all import and export information in China. This database provides information on each transaction for each firm, including the trade value, quantity, price and mode at each eight-digit HS. We identify each product category at six-digit HS level and aggregate each

TABLE 1 Characteristic fact of multi-product exporters and the product distribution

Year	Proportion of multi-product exporters	Proportion of MPE in export value	Share of core product	Share of top five product	Share of product ranked 5–10
2000	72.06%	92.96%	64.26%	84.33%	8.10%
2001	72.60%	92.88%	64.79%	84.78%	7.85%
2002	74.64%	93.85%	64.64%	84.98%	7.71%
2003	75.27%	93.71%	64.38%	84.92%	7.58%
2004	76.06%	93.73%	63.71%	84.48%	7.76%
2005	78.05%	94.17%	64.02%	85.84%	7.39%
2006	77.64%	93.79%	61.82%	82.76%	8.19%
2007	76.83%	93.28%	61.74%	83.30%	8.02%
2008	75.82%	92.73%	62.68%	84.19%	7.77%
2009	75.70%	93.28%	62.79%	84.36%	7.76%
2010	75.97%	93.06%	62.75%	84.27%	7.66%
2011	77.70%	93.01%	62.68%	84.24%	7.47%
2012	75.50%	94.05%	63.98%	85.61%	7.12%
2013	75.18%	94.05%	65.05%	87.36%	6.82%
2014	75.98%	93.26%	64.64%	87.29%	6.94%
2015	77.23%	94.72%	64.93%	88.33%	6.79%
2016	73.59%	94.47%	65.08%	87.63%	6.82%

Note: The first column is year, from 2000 to 2016. Columns 2 and 3 show the mean proportion of the number of firms and the total export volume for multi-product exporters.

commodity at eight-digit level to six-digit level.[4] In addition, ordinary trade is closer to the setup of the mainstream multi-product heterogeneous firm trade models where firms pay fixed costs for each market and product. Therefore, we only focus on ordinary trade sample and exclude processing trade data. Based on the firm-product level information from the China Customs Transaction Database, stylised facts related to multi-product exporters are shown in Table 1.

Table 1 shows the proportion of multi-product exporters and the distribution of their products based on the customs database for 2000 to 2016. Columns 2 and 3 show the importance of multi-product exporters in terms of the number of firms and the total export volume. Our findings are similar to those of Bernard et al. (2007) and Goldberg et al. (2010). Bernard et al. (2007) find that 57.8% of American manufacturing export firms are multi-product firms, and their exports accounted for 99.6%. Goldberg et al. (2010) use Indian data for statistical analysis and find that from 1989 to 2003, 47% of export firms exported more than one product contributing

[4]It should be noted that China's HS code rules are formed based on the internationally accepted six-digit trade code coordination system (revised in 2002 and 2007 since 2000). Therefore, one important problem that needs to be solved in determining a new kind of commodity is that existing goods may be given new codes and considered as 'fake' new products (Amiti & Freund, 2010). To avoid such errors caused by the revision of the code coordination system, we use the correspondence between different versions of the HS code coordination system provided by the World Bank to convert all commodity codes into the 1996 standard and determine which category a product belongs to and explore product switching on this basis.

80% of the total export value. In this study, we find that multi-product exporters account for more than 70% of the total number of firms engaged in export, and their exports account for more than 90% of the export volume, indicating that multi-product exporters contribute most of the strength to export growth. Columns 4–6 show the statistics of the average share of the core product (top 1 product), the average share of the top five products, and the average share of products ranked 5th to 10th of multi-product exporters from 2000 to 2016. It can be seen that the average annual share of the core product exceeds 60%, while the share of the 5th to 10th products tends to hover around 7%, which indicates that the distribution of export products of multi-product exporters is characterised by skewness distribution. Consistent with Eckel and Neary (2010), multi-product exporters tend to concentrate on exporting their core products.

In this study, we apply the cleaning procedures and match the two sets of data following the methods of Yu (2015) and Upward et al. (2013). The methods of matching the two databases mainly consist of the following three steps: The first step is to match the two databases directly using the firm's name. Second, we remove the matched sample from the original sample and identify the same firms in the remaining sample according to the postal code of the location for each firm and the last seven digits of the firm's telephone number. Third, we remove firms that have been successfully matched from the original sample in steps 1 and 2 and identify the same firms in the remaining sample according to the postal code of the firm's location and legal person information. For the successfully matched data, we apply the following cleaning procedures to obtain the final estimation sample: (1) drop firms with fewer than eight employees; (2) drop firms with zero or negative trade value and that cannot be matched one-to-one according to the firm code; (3) drop firms with zero or negative value in industrial added value, intermediate input, annual average balance of net fixed assets, and any item in fixed assets; (4) drop firms with zero or negative value in sales and average salary; (5) drop firms whose age is less than zero.

3.2 | Province-industry level internet penetration

As discussed above, the measurement of Internet penetration is the interaction between the province's Internet rollout and the industry's intensity of Internet use. Internet rollout can be regarded as the development of the Internet in a province, which is the "horizontal" development of the Internet. The intensity of the Internet use in an industry is the depth of (or dependence on) Internet use, which measures the "vertical" depth of Internet penetration. An increase in Internet penetration either means an increase in the province's development or an increase in the industry's use intensity, both of which mean the deepening of Internet penetration. Combining these two levels, we can explain the degree of Internet penetration in the province and industry to which the enterprise belongs.

The measurement of Internet rollout per province year is the number of Internet users per capita, which is obtained from the reports presented by the China Internet Network Information Center. It should be noted that the sample used in this study is from 2000 to 2007, and there are two reasons for using this period. First, we can eliminate the impact of the rapid development of e-commerce (Fernandes et al., 2019). Second, the total number of Internet users in China increased from about 680 thousand in 1999 to 137 million in 2007, which is one of the most rapid stages of China's Internet development. Meanwhile, this period also witnessed the fastest growth of China's exports since China entered the World Trade Organisation, helping us investigate the Internet effect on trade properly. Fernandes et al. (2019) argue that identification can mitigate the concerns of endogeneity at the province

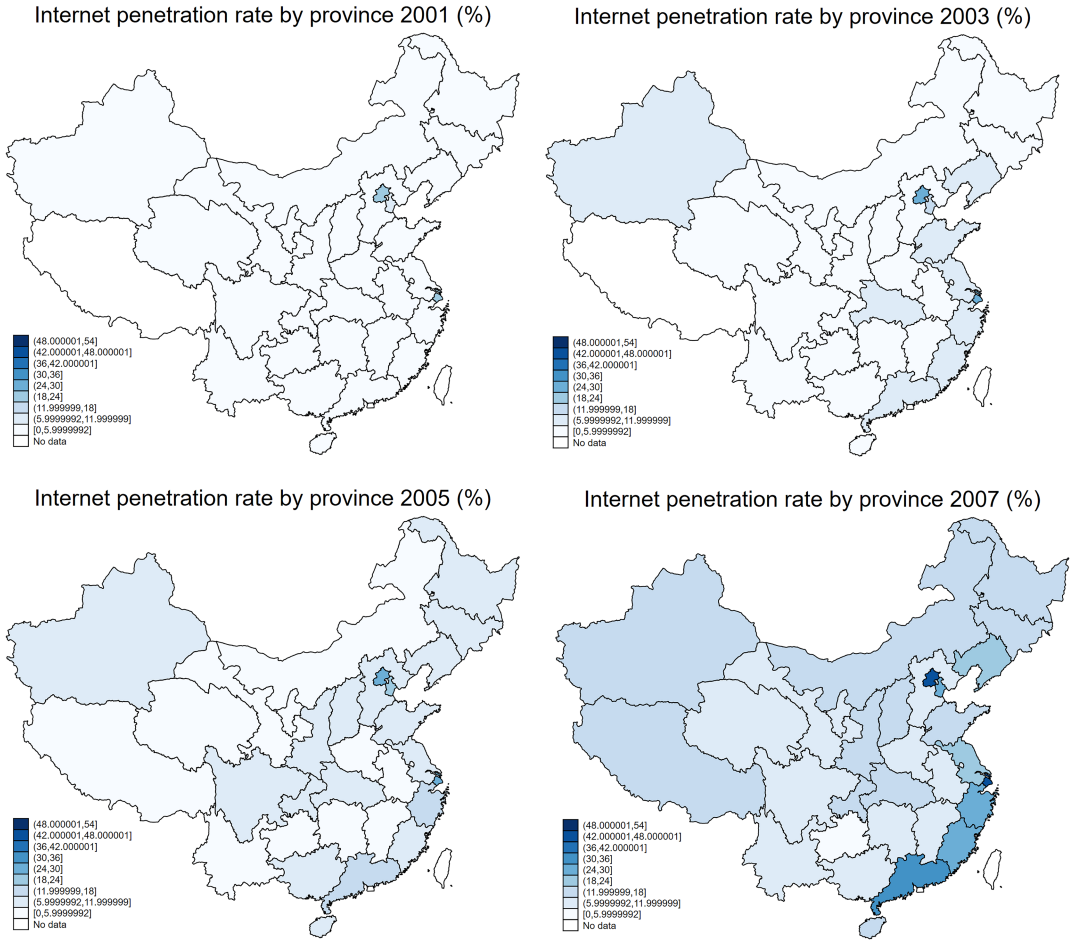

FIGURE 3 The Internet development of China in 2001, 2003, 2005 and 2007. [Colour figure can be viewed at wileyonlinelibrary.com]

Note: This figure depicts the number of internet users per capita for each province in China

level because the firm's performance is unlikely to cause Internet network expansion in China, but there may be other endogeneity issues, which are discussed and solved in the next section. Figure 3 depicts the development and the difference of the Internet rollout for each province. It shows that the Internet users grows faster in eastern coastal areas and the difference between eastern and western areas are large.

Our main measure of the intensity of Internet used in each two-digit industry is the share of post and telecommunications expenses in the total intermediate expenses of China, which comes from China's 1998 input–output table of the World Input–Output Database. China's industrial technical characteristics may be endogenous to firm behaviour in China; therefore, we use the US share of information and communications technology (ICT) capital services in total capital services in 1998 as an alternative measure, which comes from the KLEMS database. The US industrial characteristics are exogenous to firm behaviour in China and will be used in robustness and endogeneity issues.[5]

[5]Table A1 presents the industry-level Internet intensity.

3.3 | Key dependent variables and controlled variables

The firm-level dependent variables used in the following analysis are defined as follows: First, we are interested in the distribution of products within a firm, which reflects the product mix for a multi-product exporter. To capture the product distribution, we use the widely used Theil index to account for the skewness within the firm (Mayer et al., 2014, 2021):

$$\text{theil}_i = \frac{1}{n}\sum_{s=1}^{n}\left(\frac{\text{export}_{\text{is}}}{\overline{\text{export}_i}}\right)\ln\left(\frac{\text{export}_{\text{is}}}{\overline{\text{export}_i}}\right) \tag{1}$$

In this expression, $\text{export}_{\text{is}}$ is the export value of product s exported by firm i at 6-digit HS level. $\overline{\text{export}_i}$ is the average export value of firm i over all its products, which is obtained by dividing total export by the number of products exported for each firm, and n is the total number of products exported for each firm. The larger the index, the greater the skewness, which means that firms concentrate more on their core products.

Second, as product switching is frequent in each multi-product exporter, to capture this behaviour more precisely, we need to specify which product is dropped and which one is introduced. We combine matched data for two consecutive years and define dropped products as the products exported by a multi-product exporter in the current period but not in the next period. Similarly, the products not exported in the previous period but exported in the current period are new products. Based on this definition, we calculate the number of dropped products and new products for each firm. The product scope is measured by the number of products exported each year for each multi-product exporter.

The controlled variables in this study include the firm size (denoted by Scale), firm age (denoted by Age), capital intensity (denoted by KL), wage (denoted by Wage) and total factor productivity (denoted by TFP). Firm size is obtained by taking the logarithm of the number of employees. Firm age is obtained logarithmically by subtracting the opening year from the year in which the firm is documented; in particular, the negative value of age is adjusted to 0, and a value over 100 is adjusted to 100 to eliminate abnormal observations. Capital intensity is obtained by taking the logarithm of the ratio of fixed assets to the number of employees plus one. The wage level is the logarithm of the wage payable in the current year. For the calculation of TFP, we use the LP method (Levinsohn & Petrin, 2003) to calculate TFP in the baseline results and the OP method (Olley & Pakes, 1996) for robustness and mechanism. The descriptive statistics of the main variables are shown in Table 2.

4 | EMPIRICAL ANALYSIS

4.1 | Baseline results

To estimate the effect of Internet penetration on product mix and product switching of multi-product exporters, the empirical specification is as follows:

$$\text{Measure}_{ft} = \alpha_0 + \alpha_1 \text{Internet\_penetration}_{ipt} + \beta X_{ft} + \eta_f + \eta_{pt} + \eta_{it} + \varepsilon_{fipt} \tag{2}$$

TABLE 2 Summary statistics

Variable	Obs	Mean	SD	Min	Max
Internet penetration	167,257	0.10	0.082	0.0011051	0.4913886
Theil	175,014	0.83	0.523	0	4.310977
Drop	175,014	3.40	5.565	0	347
New	175,014	3.02	5.349	0	381
Product scope	175,014	7.54	9.856	2	644
Scale	175,014	5.34	1.152	2.079442	12.145
Age	175,014	1.86	0.871	0	4.61512
KL	175,014	3.78	1.271	0	9.79331
Wage	174,902	8.04	1.264	0	15.79103
Tfp_op	148,766	4.35	0.947	−4.103211	12.03014
Tfp_lp	148,766	6.88	1.126	−1.999287	15.00387

Note: Internet penetration is the interaction between the province's Internet rollout and the industry's intensity of Internet use. Theil is Theil index measuring the skewness. Drop is the number of products dropped for a firm, and New is the number of products introduced for a firm. Product scope is the number of products exported. Scale, Age, KL, Wage, TFP_op and TFP_lp denote firm size, firm age, capital intensity, wage, total factor productivity using OP method and LP method.

where Measure_{ft} represents measures of the distribution of products and product switching of firm f at year t (discussed above). In detail, the Theil index is used to measure the distribution of products within a firm, and the products added and dropped will be summed at the firm level to account for the number of products added and dropped. The scope of products per firm, measured by the number of products, is also considered. $\text{Internet\_penetration}_{ipt}$ is the measure of Internet penetration[6] at industry level i and province level p. X_{ft} denotes the control variables, including TFP, firm size (Size), age (Age), capital per capita (KL) and wage. In addition, we consider firm ownership, including state-owned, private and foreign firms. Considering the contemporaneous changes at the province-year and industry-year level, we control the province-year and industry-year fixed effect (denoted by η_{pt} and η_{it}) to capture the unobserved attributes varying with province/industry and time. In addition, to exclude unobserved heterogeneity between firms that might influence export behaviour, we control firm fixed effect (denoted by η_f). ϵ_{fipt} is an independent and identically distributed error term.

Considering the Internet can affect product mix through TFP, so it would be interesting to see the results with and without TFP as the explanatory variables. Table 3 shows the results. The columns (1)–(4) show results without TFP, and columns (5)–(8) show results with TFP controlled. The estimates in Column (1) and (5) show that an increase in Internet penetration at the province-industry level will increase the firm's skewness of all products, which means that multi-product exporters will concentrate on some products with the expansion of the Internet. The estimates in Columns (2) and (3) as well as (5) and (6) show that higher Internet penetration encourages multi-product exporters to drop more products and introduce more products. These results confirm our hypotheses 1 and 2 at first. The results in Column (4) and (8) show that the exporter's product scope will expand with the expansion of the Internet. To be specific,

[6]In the baseline results, we use the share of post and telecommunications expenses in total intermediate expenses of China to measure the industry's Internet intensity, which is interacted with province level Internet users per capita to be our main regressor Internet_penetration1.

TABLE 3 Estimates on internet penetration effect at firm level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Theil	**Drop**	**New**	**Scope**	**Theil**	**Drop**	**New**	**Scope**
Internet_penetration1	0.929***	0.517***	3.052***	1.261***	0.969***	0.504***	2.303***	1.269***
	(0.068)	(0.107)	(0.204)	(0.084)	(0.079)	(0.121)	(0.131)	(0.096)
Tfp_lp					0.031***	0.029***	0.006*	0.037***
					(0.002)	(0.003)	(0.004)	(0.003)
Scale	0.084***	0.068***	0.082***	0.122***	0.080***	0.069***	0.103***	0.123***
	(0.005)	(0.007)	(0.008)	(0.006)	(0.005)	(0.008)	(0.009)	(0.007)
Age	0.008*	0.016*	−0.019**	0.005	0.005	0.014	−0.018*	0.004
	(0.005)	(0.008)	(0.009)	(0.006)	(0.005)	(0.009)	(0.010)	(0.007)
KL	0.018***	0.023***	0.017***	0.033***	0.021***	0.028***	0.025***	0.038***
	(0.002)	(0.004)	(0.004)	(0.003)	(0.003)	(0.005)	(0.005)	(0.004)
Wage	0.035***	0.038***	0.017***	0.047***	0.029***	0.031***	0.020***	0.037***
	(0.003)	(0.005)	(0.006)	(0.004)	(0.004)	(0.006)	(0.007)	(0.005)
_cons	−0.065**	0.292***	0.230***	0.385***	−0.217***	0.144**	0.217***	0.191***
	(0.030)	(0.049)	(0.053)	(0.039)	(0.035)	(0.057)	(0.063)	(0.045)
N	146,231	146,231	146,231	146,231	124,700	124,700	124,700	124,700
Ownership	√	√	√	√	√	√	√	√
Firm FE	√	√	√	√	√	√	√	√
Province-Year FE	√	√	√	√	√	√	√	√
Industry-Year FE	√	√	√	√	√	√	√	√
R^2_adjusted	.53	.44	.46	.70	.53	.45	.47	.70

Note: The dependent variables Theil, Drop, New and Scope are Theil index, the number of products dropped, the number of products introduced and product scope respectively. Internet_penetration1 is measured by the interaction of province level Internet users per capita and the share of post and telecommunications expenses in total intermediate expenses of China. Scale, Age, KL, Wage and TFP_lp denote firm size, firm age, capital intensity, wage and total factor productivity using LP method. Standard errors in parentheses are clustered at the province-industry-year level.

*$p < .1$.; **$p < .05$.; ***$p < .01$.

multi-product exporters drop products and also introduce new products, eventually expanding the product scope. The results can also be explained by the fact that higher development of the Internet at the province level will increase the skewness, disappear and new products as well as product scope significantly more for firms in industries that rely more on the Internet, which means that firms in industries that are more intensive in Internet use will benefit more from the rise of the Internet in China.

We are also interested in the difference of the coefficient of Internet penetration between Columns (1)–(4) and (5)–(8), because our hypothesis 2 claims that the TFP is the channel through which the Internet can make multi-product exporters introduce more new products. Consistent with our hypothesis, there is not much difference in the coefficients of the Internet on skewness, products dropped and product scope with and without controlling TFP. However, the coefficient of Internet penetration decreases approximately 1/4 after controlling TFP, which means the TFP is the channel through which the Internet affects the number of new products. Column (7) also shows that an increase in a firm's productivity promotes the introduction of new products.

However, the estimates in Table 3 only tell us that multi-product exporters will concentrate on, drop and introduce some products. However, we cannot know the products' characteristics. Do firms concentrate on core products and drop non-core products? Which products will be introduced simultaneously? To confirm our hypothesis in detail, we explore this further in the following sections.

4.2 | Robust analysis

4.2.1 | Alternative measures for the internet penetration

In the baseline results, the industrial Internet intensity we use is from China's input–output table, which most directly reflects the situation of China's industries using the Internet. However, the endogeneity concerns might be caused by the industry measure of Internet intensity based on China's industrial data, which may be related to the performance of Chinese enterprises. To alleviate endogeneity concerns, we replace China's industrial Internet measure with the US share of ICT capital services (discussed above) to characterise the characteristics of technology inherent in the industry to deal with endogeneity issues. By interacting with Internet users per capita at the province level,[7] we can obtain the measure of Internet penetration, which is quite exogenous. Table 4 presents the results, which is consistent with the baseline estimates.

4.2.2 | Alternative measures for dependent variables two-digit HS level

In addition, considering many Chinese exporters are multi-industry firms, the industry level internet usage only captures the main (largest) industry. We calculate alternative measures (products dropped, added and scope) for the firms' main industries at largest two-digit HS export

[7]This robust measure for Internet penetration at province-industry level is denoted by internet_penetration2 in the following results.

TABLE 4 Robust estimates using alternative measures for the internet penetration

	(1)	(2)	(3)	(4)
	Theil	**Drop**	**New**	**Scope**
Internet_penetration2	0.024***	0.011***	0.061***	0.023***
	(0.002)	(0.003)	(0.004)	(0.003)
Tfp_lp	0.032***	0.029***	0.007*	0.037***
	(0.002)	(0.003)	(0.004)	(0.003)
Scale	0.080***	0.069***	0.101***	0.123***
	(0.005)	(0.008)	(0.009)	(0.007)
Age	0.005	0.014	−0.019*	0.003
	(0.005)	(0.009)	(0.010)	(0.007)
KL	0.021***	0.028***	0.025***	0.039***
	(0.003)	(0.005)	(0.005)	(0.004)
Wage	0.029***	0.031***	0.019***	0.037***
	(0.004)	(0.006)	(0.007)	(0.005)
_cons	−0.188***	0.162***	0.279***	0.246***
	(0.035)	(0.056)	(0.063)	(0.045)
N	124,700	124,700	124,700	124,700
Ownership	√	√	√	√
Firm FE	√	√	√	√
Province-Year FE	√	√	√	√
Industry-Year FE	√	√	√	√
R^2_adjusted	.53	.45	.47	.70

Note: The dependent variables Theil, Drop, New and Scope are Theil index, the number of products dropped, the number of products introduced and product scope respectively. Internet_penetration2 is measured by the interaction of province level Internet users per capita and the US share of ICT capital services. Scale, Age, KL, Wage and TFP_lp denote firm size, firm age, capital intensity, wage and total factor productivity using LP method. Standard errors in parentheses are clustered at the province-industry-year level.

*$p < .1$.; ***$p < .01$.

industry. As for skewness of products, we use Herfindahl index to replace the Theil. Table 5 presents the results, which support the baseline estimates.

4.2.3 | Further exploration on firm-product-level behaviour

As stated in the Section 4.1, what kind of products will multi-product exporters skew, drop or introduce? To explore more specifically, we use the firm-product-level trade data from the Annual Survey of Industrial Firms and China Customs Transaction Database, and the specifications are as follows:

$$\text{Value}_{sft} = \alpha_0 + \alpha_1 \text{Internet}_{ipt} + \alpha_2 \text{Internet\_penetration}_{ipt} \times \text{Rank}_{sft} + \alpha_3 \text{Rank}_{sft} + \beta X_{ft} + \eta_f + \eta_{pt} + \eta_s + \varepsilon_{sfipt} \quad (3)$$

$$\text{Drop}_{sft} = \alpha_0 + \alpha_1 \text{Internet}_{ipt} + \alpha_2 \text{Internet\_penetration}_{ipt} \times \text{Rank}_{sft} + \alpha_3 \text{Rank}_{sft} + \beta X_{ft} + \eta_f + \eta_{pt} + \eta_s + \varepsilon_{sfipt} \quad (4)$$

TABLE 5 Robust estimates using alternative measures for dependent variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	HHI	**Drop**	**New**	**Scope**	**HHI**	**Drop**	**New**	**Scope**
Internet_penetration1	0.131***	0.042	0.878***	0.910***				
	(0.033)	(0.098)	(0.096)	(0.062)				
Internet_penetration2					0.001	0.003	0.026***	0.020***
					(0.001)	(0.003)	(0.003)	(0.002)
_cons	0.287***	0.139***	0.179***	0.505***	0.296***	0.137***	0.197***	0.537***
	(0.016)	(0.046)	(0.043)	(0.028)	(0.016)	(0.045)	(0.043)	(0.028)
N	124,700	124,700	124,700	124,700	124,700	124,700	124,700	124,700
Controlled variables	√	√	√	√	√	√	√	√
Ownership	√	√	√	√	√	√	√	√
Firm FE	√	√	√	√	√	√	√	√
Province-Year FE	√	√	√	√	√	√	√	√
Industry-Year FE	√	√	√	√	√	√	√	√
R^2_adjusted	.708	.415	.457	.756	.708	.415	.457	.756

Note: The dependent variables HHI, Drop, New and Scope are Herfindahl index, the number of products dropped, the number of products introduced and product scope at largest two-digit HS respectively. Internet_penetration1 is measured by the interaction of province level Internet users per capita and the share of post and telecommunications expenses in total intermediate expenses of China. Internet_penetration2 is measured by the interaction of province-level Internet users per capita and the US share of ICT capital services. Controlled Variables include Scale, Age, KL, Wage and TFP_lp. Standard errors in parentheses are clustered at the province-industry-year level.

***$p < .01$.

$$\text{New}_{sft} = \alpha_0 + \alpha_1 \text{Internet}_{ipt} + \alpha_2 \text{Internet\_penetration}_{ipt} \times \text{Rank}_{sft} + \alpha_3 \text{Rank}_{sft} + \beta X_{ft} + \eta_f + \eta_{pt} + \eta_s + \varepsilon_{sfipt} \quad (5)$$

where Value_{sft} is the export value of product s of firm f, measured in logarithm. Drop_{sft} is the dummy variable of whether firm f continues to export s. Specifically, when the firm exports s product in period t but not in period $t+1$, this variable is denoted by 1. New_{sft} is the dummy variable of whether firm f exports a new product s. Specifically, when the firm does not export product s in period $t-1$ but exports in period t, this variable is denoted by 1. The latter two specifications are the linear probability model. To identify the characteristics of each product within a firm, we follow Mayer et al. (2014) and define the importance of a product according to its export rank. Rank_{sft} is an index that measures the importance of product s in firm f, which is measured by the order of product s after it is ranked according to the export scale within the firm. The larger the index, the smaller the export value of the product, that is, the further the product is from the core product. Other variables are the same as above. We also control the product-fixed effects at two-digit HS level. The estimates are presented in Table 6.

Columns (1), (3) and (5) present the results with the Internet penetration measure using China's industrial data, while Columns (2), (4) and (6) present the results using US ICT share. We are interested in the coefficient of the interaction between Internet penetration and product order. Columns (1) and (2) show that an increase in Internet penetration will have a greater effect on the products that are closer to the core competence, which means that multi-product exporters will skew exports towards the best-performing products. The estimates in Columns (3) and (4) show that the further the product is from the core competence, the more likely it is to be dropped. Considering the results shown in Columns (1) and (2), the multi-product exporters will skew towards the core products and drop the worst-performing products. In addition, Columns (5) and (6) show that the newly introduced products are furthest away from the core product. In a word, these results confirm our hypotheses 1 and 2.

4.3 | The instrumental variable approach

To address endogeneity issues further, we use the instrumental variable approach. For our province-industry-time level Internet penetration, we must find an exogenous proxy for each level variance of our measure following Nunn and Qian's (2014) method of constructing instrumental variables. We first use the reciprocal of the degree of terrain irregularity as an exogenous proxy indicator of Internet development in each province (Juhász & Steinwender, 2018). The degree of terrain irregularity is suitable as an exogenous instrumental variable for Internet development for two reasons: First, terrain irregularity measures the difficulty of Internet infrastructure (such as laying optical cables), and the more rugged the terrain, the more difficult it is to build the Internet, which satisfies the correlation hypothesis. Second, terrain is an inherent feature of a region which can better satisfy the assumption of exogeneity of instrumental variables. At the industry level, we use the US share of ICT capital services as the exogenous Internet features for China's industry. The interaction between the reciprocal of terrain irregularity and US industrial technical features is regarded as a proxy for Internet penetration at the province-industry level at a specific time point. In addition, the variance in the time dimension plays an important role in the regression of our study. The time dimension should be considered while constructing the instrumental variable. Therefore, referring to the methods of Angrist and Keueger (1991), we use a time dummy to

TABLE 6 Internet penetration effect at firm-product-level

	(1)	(2)	(3)	(4)	(5)	(6)
	Value	**Value**	**Drop**	**Drop**	**New**	**New**
Internet_penetration1	7.339***		−0.402***		−0.007	
	(0.290)		(0.027)		(0.028)	
Order×Internet_penetration1	−1.326***		0.027***		0.057***	
	(0.058)		(0.005)		(0.006)	
Internet_penetration2		0.160***		−0.074***		0.002**
		(0.008)		(0.007)		(0.001)
Order×Internet_penetration2		−0.033***		0.001		0.001***
		(0.002)		(0.002)		(0.000)
Order	−3.372***	−3.415***	0.226***	0.229***	0.214***	0.216***
	(0.008)	(0.008)	(0.001)	(0.001)	(0.001)	(0.001)
_cons	6.447***	6.743***	0.434***	0.413***	0.700***	0.696***
	(0.132)	(0.131)	(0.012)	(0.012)	(0.013)	(0.013)
N	1,265,699	1,265,699	1,265,699	1,265,699	1,212,307	1,212,307
Ownership	√	√	√	√	√	√
Controlled varibles	√	√	√	√	√	√
Firm FE	√	√	√	√	√	√
Province-Year FE	√	√	√	√	√	√
Product FE	√	√	√	√	√	√
R^2_Adj	.36	.36	.23	.23	.25	.25

Note: The dependent variables Value, Drop and New are export value, dummy variable of whether to drop this product and dummy variable of whether to export a new product. Internet_penetration1 is measured by the interaction of province-level Internet users per capita and the share of post and telecommunications expenses in total intermediate expenses of China.Internet_penetration2 is measured by the interaction of province-level Internet users per capita and the US share of ICT capital services. Controlled Variables include Scale, Age, KL, Wage and TFP_lp. Standard errors in parentheses are clustered at the province-industry-year level.

**$p < .05$.; ***$p < .01$.

interact with the province-industry-level proxy for Internet penetration as instrumental variables in our two-stage least-squares estimation. The second stage of the IV estimation results is shown in Panel A of Table 7, and the first stage results are shown in Panel B of Table 7. As

TABLE 7 IV results on Internet penetration effect at firm level

	(1)	(2)	(3)	(4)
Dependent variables	**Theil**	**Drop**	**New**	**Scope**
Panel A second-stage results of IV				
Internet_penetration1	1.589***	0.618*	3.586***	1.060***
	(0.202)	(0.334)	(0.363)	(0.246)
Tfp_lp	0.031***	0.029***	0.000	0.037***
	(0.002)	(0.003)	(0.004)	(0.002)
Scale	0.079***	0.069***	0.083***	0.123***
	(0.005)	(0.008)	(0.009)	(0.006)
Age	0.006	0.014*	−0.018**	0.004
	(0.005)	(0.008)	(0.009)	(0.006)
KL	0.020***	0.028***	0.019***	0.039***
	(0.003)	(0.005)	(0.005)	(0.003)
Wage	0.029***	0.031***	0.015**	0.037***
	(0.004)	(0.006)	(0.006)	(0.004)
N	124,700	124,700	124,700	124,700
Ownership	√	√	√	√
Cragg–Donald Wald *F* statistic	1582.362	1582.362	1582.362	1582.362
Sargan statistic	41.341	5.470	17.923	8.180
Firm FE	√	√	√	√
Province-Year FE	√	√	√	√
Industry-Year FE	√	√	√	√
Panel B First stage results of IV				
IV_2000	−0.021***	IV_2001		−0.017***
	(0.001)			(0.000)
IV_2002	−0.012***	IV_2003		−0.012***
	(0.000)			(0.000)
IV_2004	−0.013***	IV_2005		−0.012***
	(0.000)			(0.000)
IV_2006	−0.010***	N		124,700
	(0.000)			

Note: In Panel A, the dependent variables Theil, Drop, New and Scope are Theil index, the number of products dropped, the number of products introduced and product scope respectively. Internet_penetration1 is measured by the interaction of province-level Internet users per capita and the share of post and telecommunications expenses in total intermediate expenses of China. Scale, Age, KL, Wage and TFP_lp denote firm size, firm age, capital intensity, wage and total factor productivity using LP method. In Panel B, IV_2000 is the combination of the reciprocal of terrain irregularity and US industrial technical features interacted with dummy of year 2000. Other dummies are similar to this. Standard errors in parentheses are clustered at the province-industry-year level.

*$p < .1$.; **$p < .05$.; ***$p < .01$.

for the tests of the instrumental variables, we find that the Cragg–Donald Wald F statistics are above the Stock–Yogo weak ID test critical values at the 5% level, which means our IV is not weak. Most of the p-values of the overidentification test (Sargan statistics) are above 5%, which means that our IV satisfies the exogeneity assumption. In addition, the estimates are robust to baseline results after addressing endogeneity issues.

4.4 | Further discussion on the mechanisms

In the previous sections, we have explored the effects of Internet penetration on multi-product exporters' behaviours and find that multi-product exporters will skew towards their core products, drop worst-performing products and introduce new products with the deepening of Internet penetration at the province-industry level. However, why does Internet penetration lead to this? In other words, what is the channel through which Internet penetration affects firms? In this section, we discuss the mechanisms. Our theoretical analysis and hypothesis show that the Internet can reduce trade costs, which means that more firms will enter the export market with the development of the Internet. Market competition will be tougher because an increasing number of firms are engaged in export. As a result, firms will skew to core products (higher skewness) and drop the worst-performing products (more dropped products). On the other hand, the Internet will increase the total factor productivity of exporters, thus reducing the marginal cost and introduce more new products furthest away from core competence. So, we will discuss the mechanism of competition and productivity separately. As stated above, the effects of market competition and TFP on product mix and switching are discussed clearly in the previous literatures. Therefore, we only focus on the effects of Internet penetration on the channel variables.

To investigate the competition mechanism on product mix effect of the Internet, we should measure market competition at first. As is well known, market competition will be tougher with more firms entering. Therefore, we use the number of all exporters and new exporters (exporters are those firms reporting positive exports) to capture the market competition characteristics at province-industry-year level from the full Annual Survey of Industrial Firms data. We explore the effect of Internet penetration on market competition at the province-industry-year level. To capture the unobserved attributes varying with province/industry and time, we control province-year, industry-year fixed effect as well as province-industry fixed effects. The estimates using data at the province-industry-year level are shown in Table 8. The first two columns report the results using OLS with fixed effects, and the latter two columns report the results using IV discussed above. We find that an increase in Internet penetration will intensify market competition, which is either measured by the number of all exporters or new exporters in each province and two-digit industry. This also means that more new firms will enter the export market with the penetration of the Internet leading to a market with tougher competition naturally.

As the stylised facts suggest, product switching is frequent within a firm. As discussed in the hypothesis 2 in theoretical analysis, Internet penetration improves a firm's productivity, and firms with higher productivity are more profitable for all products, eventually leading to the introduction of more export products. To explore the TFP channel, we will investigate the effects of the Internet on TFP, which is also discussed in Fernandes et al. (2019). Except for the TFP calculated using LP method, we also measure the TFP using OP method for robustness. The results, in Table 9, show that Internet penetration can greatly increase the productivity of multi-product

TABLE 8 Internet penetration effect on market competition

	(1)	(2)	(3)	(4)
	OLS		IV	
	The number of all exporters	The number of new exporters	The number of all exporters	The number of new exporters
Internet_penetration1	1.135**	0.261**	1.554*	1.076**
	(0.488)	(0.113)	(0.888)	(0.428)
_cons	0.018	0.011**		
	(0.025)	(0.006)		
N	5725	5725	5725	5725
Province-Industry FE	√	√	√	√
Province-Year-FE	√	√	√	√
Industry -Year FE	√	√	√	√
R^2_Adj	.69	.62		
Cragg–Donald Wald F statistic			32.617	32.617

Note: The dependent variables are the number of all exporters in (1) and (3), and the number of new exporters in (2) and (4). Internet_penetration1 is measured by the interaction of province level Internet users per capita and the share of post and telecommunications expenses in total intermediate expenses of China. (1) and (2) are OLS results, and (3) and (4) are IV results. Standard errors in parentheses are clustered at the province-industry-year level.

*$p < .1$.; **$p < .05$.

TABLE 9 Internet penetration effect on TFP

	(1)	(2)	(3)	(4)
	OLS		IV	
	Tfp_lp	Tfp_op	Tfp_lp	Tfp_op
Internet_penetration1	0.810***	0.813***	1.221***	1.224***
	(0.120)	(0.121)	(0.333)	(0.334)
_cons	4.330***	4.377***		
	(0.062)	(0.062)		
N	124,700	124,700	124,700	124,700
Ownership	√	√	√	√
Controlled variables	√	√	√	√
Firm FE	√	√	√	√
Province-Year FE	√	√	√	√
Industry-Year FE	√	√	√	√
R^2_Adj	.72	.60		
Cragg–Donald Wald *F* statistic			1584.127	1584.127

Note: The dependent variables are total factor productivity using LP method in (1) and (3), and total factor productivity using OP method in (2) and (4). Internet_penetration1 is measured by the interaction of province-level Internet users per capita and the share of post and telecommunications expenses in total intermediate expenses of China. (1) and (2) are OLS results, and (3) and (4) are IV results. Standard errors in parentheses are clustered at the province-industry-year level.

***$p < .01$.

exporters, which is similar to Fernandes et al.'s (2019) findings, but our study only focuses on multi-product exporters.

In summary, we find that an increase in Internet penetration will result in a market with tougher competition and also can promote the TFP of multi-product exporters. On the one hand, tougher market competition will force a multi-product exporter to skew exports towards its best-performing products and drop the least-successful products (Mayer et al., 2014). On the other hand, the TFP effects cause multi-product exporters to introduce more products to earn higher revenue (Bernard et al., 2010; Fernandes et al., 2019). As a result, although tougher competition will induce product dropping, the TFP effect will promote product adding, which means that multi-product exporters have a dynamic product switching behaviour and finally expand the scope of their products. In addition, the results in Table 3 column (4) show the expansion of product scope without controlling TFP, which means that the productivity channel may exceed the market competition channel on the effect on product switching, which is discussed in the theoretical analysis.

4.5 | Internet penetration and imported products

The discussion above does not take import into consideration, which is of vital importance for firms. The development of the Internet strengthens the international division of labour (Liu & Nath, 2013). From the perspective of production, in order to stand out from the fierce competition in the Internet era, firms may focus more on producing superior products. In this context,

firms will concentrate on importing intermediate inputs of specialised products. As a result, imports may have impacts on multi-product exporters' behaviours. For robustness, we include firm's total imports at right-hand side of the specification (2) as control variables and use IV to estimate. The results are presented in Table A2. After considering imports, we find that import plays a positive role in multi-product firms' behaviour. It's effects on skewness, products added, products dropped and product scope are all significantly positive. For more robustness check, we only include firms that are non-importers and use IV to estimate, whose results are shown in Table A3. After excluding importers, we find our baseline results are still robust.

In addition, for further investigation, we consider the effects of the Internet penetration on import side, including the total value of imports and the number of products imported. The results presented in Table 10 show that the effects of the Internet penetration on the total value of imports and the number of products imported are all positive and significant. This result is worth investigating for further research, which is beyond the main scope of this paper. One possible reason is that with the improvement of regional development level, firms gradually begin to demand high-tech intermediate inputs, and the domestic market has been unable to meet the needs for production. However, firms can obtain relatively limited international market information, there is no way to import needed products from the international market. At this point, the Internet becomes a bridge connecting domestic manufacturers and the international market, helping firms to find the commodities they need from the international market, enabling firms to have the opportunity to import more kinds of commodities, promoting the increase of the total import value.

5 | CONCLUSION

We take advantage of the dramatic expansion of the Internet in China to explore its effect on firm-product-level behaviours of multi-product exporters, even before the main e-commerce

TABLE 10 Results of the Internet penetration effects on import

	(1)	(2)	(3)	(4)
	OLS		IV	
	Import	Num_good	Import	Num_good
Internet_penetration1	1.231**	0.302***	2.984*	0.990***
	(0.617)	(0.047)	(1.586)	(0.179)
N	124,700	124,700	124,700	124,700
Control variables	√	√	√	√
Ownership	√	√	√	√
Firm FE	√	√	√	√
Province-Year FE	√	√	√	√
Industry-Year FE	√	√	√	√
Cragg-Donald Wald *F*	1582.362	1582.362	1582.362	1582.362

Note: The dependent variables are import in logarithm in (1) and (3), and the number of imported goods in (2) and (4). Internet_penetration1 is measured by the interaction of province level Internet users per capita and the share of post and telecommunications expenses in total intermediate expenses of China. (1) and (2) are OLS results, and (3) and (4) are IV results. Standard errors in parentheses are clustered at the province-industry-year level.

*$p < .1$.; **$p < .05$.; ***$p < .01$.

platforms surged. We combine highly disaggregated firm-product-level data matched from the Annual Survey of Industrial Firms and China Customs Transaction Database and province-industry-year level Internet penetration information to examine its effects on product mix and product switching within a multi-product exporter in the period 2000–2007. After addressing endogeneity issues and shedding light on the mechanisms, we identify the causal impact of Internet penetration.

We find that province-industry-year level Internet penetration can greatly reduce trade costs and encourage more firms to enter the export market, which will result in a market with tougher competition. To face such tough market competition, a multi-product exporter will skew exports towards its best-performing products and drop the least-performing products furthest away from core competence. At the same time, Internet penetration can have a positive effect on a firm's TFP and cause a multi-product exporter to introduce more products. As a result, although the tougher competition will induce product dropping, the TFP effect will promote product adding, which means multi-product exporters will have dynamic product switching behaviour and finally expand the scope of products.

Interestingly, access to the Internet can induce product mix of multi-product exporters, which suggests that firms will concentrate on their 'core competence' and gain competitiveness in the export market. It is also interesting that Internet penetration not only promotes product dropping to attain 'core competence' but also helps to introduce more new products, which can also be seen as a market strategy to adapt to the export markets. Recognition of such benefits of access to more basic Internet services could inform policies in developing countries that are trying to improve the 'core competence' of firms and break 'product locking' under the global value chain.

ACKNOWLEDGEMENTS

This letter is supported by National Natural Science Foundation of China (No. 71973120). The authors would like to thank the editor and the two anonymous referees for helpful comments and suggestions. Authors are listed in alphabetical order. All remaining errors are our own.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID


Zengxi Hu https://orcid.org/0000-0003-4464-8274

REFERENCES

Amiti, M., & Freund, C. (2010). The anatomy of China's export growth. In *China's growing role in world trade* (pp. 35–56). University of Chicago Press.

Angrist, J. D., & Keueger, A. B. (1991). Does compulsory school attendance affect schooling and earnings? *The Quarterly Journal of Economics*, *106*(4), 979–1014.

Baldwin, J., & Gu, W. (2009). The impact of trade on plant scale, production-run length and diversification. In *Producer dynamics: New evidence from micro data* (pp. 557–592). University of Chicago Press.

Bernard, A. B., Jensen, J. B., Redding, S. J., & Schott, P. K. (2007). Firms in international trade. *Journal of Economic Perspectives*, *21*(3), 105–130.

Bernard, A. B., Redding, S. J., & Schott, P. K. (2010). Multiple-product firms and product switching. *American Economic Review*, *100*(1), 70–97.

Bernard, A. B., Redding, S. J., & Schott, P. K. (2011). Multiproduct firms and trade liberalization. *The Quarterly Journal of Economics*, *126*(3), 1271–1318.

Clarke, G. R., & Wallsten, S. J. (2006). Has the internet increased trade? Developed and developing country evidence. *Economic Inquiry*, *44*(3), 465–484.

Eckel, C., & Neary, J. P. (2010). Multi-product firms and flexible manufacturing in the global economy. *The Review of Economic Studies*, *77*(1), 188–217.

Fan, J., Tang, L., Zhu, W., & Zou, B. (2018). The Alibaba effect: Spatial consumption inequality and the welfare gains from e-commerce. *Journal of International Economics*, *114*, 203–220.

Fernandes, A. M., Mattoo, A., Nguyen, H., & Schiffbauer, M. (2019). The internet and Chinese exports in the pre-ali baba era. *Journal of Development Economics*, *138*, 57–76.

Ferro, E. (2011). Signaling and technological marketing tools for exporters. World Bank Policy Research Working Paper, (5547).

Freund, C., & Weinhold, D. (2002). The internet and international trade in services. *American Economic Review*, *92*(2), 236–240.

Freund, C. L., & Weinhold, D. (2004). The effect of the internet on international trade. *Journal of International Economics*, *62*(1), 171–189.

Goldberg, P. K., Khandelwal, A. K., Pavcnik, N., & Topalova, P. (2010). Multiproduct firms and product turnover in the developing world: Evidence from India. *The Review of Economics and Statistics*, *92*(4), 1042–1049.

Huang, X., & Song, X. (2019). Internet use and export upgrading: Firm-level evidence from China. *Review of International Economics*, *27*(4), 1126–1147.

Iacovone, L., & Javorcik, B. S. (2010). Multi-product exporters: Product churning, uncertainty and export discoveries. *The Economic Journal*, *120*(544), 481–499.

Juhász, R., & Steinwender, C. (2018). Spinning the web: The impact of ICT on trade in intermediates and technology diffusion (No. w24590). National Bureau of Economic Research.

Lendle, A., Olarreaga, M., Schropp, S., & Vézina, P. L. (2016). There goes gravity: eBay and the death of distance. *The Economic Journal*, *126*(591), 406–441.

Levinsohn, J., & Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. *The Review of Economic Studies*, *70*(2), 317–341.

Lin, F. (2015). Estimating the effect of the internet on international trade. *The Journal of International Trade and Economic Development*, *24*(3), 409–428.

Liu, L., & Nath, H. K. (2013). Information and communications technology and trade in emerging market economies. *Emerging Markets Finance and Trade*, *49*(6), 67–87.

Mayer, T., Melitz, M. J., & Ottaviano, G. I. (2014). Market size, competition, and the product mix of exporters. *American Economic Review*, *104*(2), 495–536.

Mayer, T., Melitz, M. J., & Ottaviano, G. I. (2021). Product mix and firm productivity responses to trade competition. *Review of Economics and Statistics*, *103*(5), 874–891.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, *71*(6), 1695–1725.

Melitz, M. J., & Ottaviano, G. I. (2008). Market size, trade, and productivity. *The Review of Economic Studies*, *75*(1), 295–316.

Nunn, N., & Qian, N. (2014). US food aid and civil conflict. *American Economic Review*, *104*(6), 1630–1666.

Olley, G. S., & Pakes, A. (1996). The dynamics of productivity in the telecommunications equipment. *Econometrica*, *64*(6), 1263–1297.

Rauch, J. (1996). Trade and Search: Social Capital, Sogo Shosha, and Spillovers (No. 5618). National Bureau of Economic Research, Inc.

Rauch, J. E. (1999). Networks versus markets in international trade. *Journal of International Economics*, *48*(1), 7–35.

Ricci, L. A., & Trionfetti, F. (2012). Productivity, networks, and export performance: Evidence from a cross-country firm dataset. *Review of International Economics*, *20*(3), 552–562.

Upward, R., Wang, Z., & Zheng, J. (2013). Weighing China's export basket: The domestic content and technology intensity of Chinese exports. *Journal of Comparative Economics*, *41*(2), 527–543.

World Bank Group. (2016). World development report 2016: Digital dividends. World Bank Publications.

Yadav, N. (2014). The role of internet use on international trade: Evidence from Asian and sub-Saharan African enterprises. *Global Economy Journal*, *14*(2), 189–214.

Yu, M. (2015). Processing trade, tariff reductions and firm productivity: Evidence from Chinese firms. *The Economic Journal*, *125*(585), 943–988.

Yushkova, E. (2014). Impact of ICT on trade in different technology groups: Analysis and implications. *International Economics and Economic Policy*, *11*(1), 165–177.

How to cite this article: Ma, S., & Hu, Z. (2023). Internet penetration and multi-product exporters: Firm-level evidence from China. *The World Economy*, *46*, 1444–1470. https://doi.org/10.1111/twec.13330

APPENDIX A

TABLE A1 Industry level internet intensity

Industry	Share of post and telecommunication in China	Share of ICT capital services in US
Food, Beverages and Tobacco	0.002	0.112
Textiles, Wearing Apparel, Leather and Related Products	0.005	0.100
Wood and Paper Products	0.004	0.083
Printing and Publishing	0.003	0.186
Coke and Refined Petroleum Products	0.004	0.155
Chemicals and Chemical Products	0.005	0.201
Rubber and Plastics Products	0.005	0.074
Other Non-Metallic Mineral Products	0.005	0.124
Basic Metals and Fabricated Metal Products	0.011	0.139
Machinery and Equipment N.E.C.	0.011	0.337
Electrical and Optical Equipment	0.006	0.302
Transport Equipment	0.009	0.312
Other Manufacturing	0.009	0.236

TABLE A2 IV estimates considering import 1

	(1)	(2)	(3)	(4)
	Theil	**Drop**	**New**	**Scope**
Internet_penetration1	1.607***	0.642*	3.600***	1.094***
	(0.236)	(0.354)	(0.387)	(0.281)
Tfp_lp	0.030***	0.027***	0.001	0.035***
	(0.002)	(0.003)	(0.004)	(0.003)
Scale	0.075***	0.063***	0.080***	0.115***
	(0.005)	(0.008)	(0.009)	(0.007)
Age	0.006	0.014*	−0.018*	0.004
	(0.005)	(0.009)	(0.010)	(0.007)
KL	0.018***	0.025***	0.017***	0.035***
	(0.003)	(0.005)	(0.005)	(0.004)
Wage	0.028***	0.030***	0.014**	0.035***
	(0.004)	(0.006)	(0.006)	(0.005)
Ln_import	0.006***	0.008***	0.005***	0.011***
	(0.000)	(0.001)	(0.001)	(0.001)
N	124,700	124,700	124,700	124,700
Ownership	√	√	√	√
Firm FE	√	√	√	√
Province-Year FE	√	√	√	√
Industry-Year FE	√	√	√	√
Cragg–Donald Wald *F*	1582.931	1582.931	1582.931	1582.931

Note: The dependent variables Theil, Drop, New and Scope are Theil index, the number of products dropped, the number of products introduced and product scope respectively. Internet_penetration1 is measured by the interaction of province-level Internet users per capita and the share of post and telecommunications expenses in total intermediate expenses of China. Ln_import is the import value in logarithm. Scale, Age, KL, Wage and TFP_lp denote firm size, firm age, capital intensity, wage and total factor productivity using LP method. Standard errors in parentheses are clustered at the province-industry-year level.
*$p < .1$.; **$p < .05$.; ***$p < .01$.

TABLE A3 IV estimates considering import 2

	(1)	(2)	(3)	(4)
	Theil	**Drop**	**New**	**Scope**
Internet_penetration1	0.934**	0.027	2.928***	0.511
	(0.398)	(0.690)	(0.743)	(0.503)
Tfp_lp	0.036***	0.026***	0.006	0.040***
	(0.003)	(0.005)	(0.006)	(0.004)
Scale	0.067***	0.061***	0.042***	0.105***
	(0.007)	(0.013)	(0.013)	(0.010)
Age	0.002	0.003	−0.018	−0.000
	(0.007)	(0.012)	(0.014)	(0.010)
KL	0.021***	0.024***	0.017**	0.032***
	(0.004)	(0.007)	(0.007)	(0.005)
Wage	0.029***	0.028***	0.018*	0.040***
	(0.005)	(0.009)	(0.010)	(0.007)
N	57,022	57,022	57,022	57,022
Ownership	√	√	√	√
Firm FE	√	√	√	√
Province-Year FE	√	√	√	√
Industry-Year FE	√	√	√	√
Cragg–Donald Wald *F*	408.173	408.173	408.173	408.173

Note: The dependent variables Theil, Drop, New and Scope are Theil index, the number of products dropped, the number of products introduced and product scope respectively. Internet_penetration1 is measured by the interaction of province-level Internet users per capita and the share of post and telecommunications expenses in total intermediate expenses of China. Scale, Age, KL, Wage and TFP_lp denote firm size, firm age, capital intensity, wage and total factor productivity using LP method. Standard errors in parentheses are clustered at the province-industry-year level.

*$p < .1$.; **$p < .05$.; ***$p < .01$.