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Technological Capabilities of Chinese Enterprises: Who is Going to Compete Abroad?

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Abstract

The objective of this study is to investigate the relation between increasing Chinese high-tech exports and the technological capabilities of Chinese companies. China?s recent innovation policy provides substantial incentives for companies to pursue technological upgrading and internationalization strategies. For our analysis, we extend models of New New Trade Theory to include the aspect of the technological capabilities of companies. We use the share of international patent applications as a proxy for exports and find that companies with higher total factor productivity and more valuable technology, as measured with citations received, are more likely to go international. Considering the

implications of transport cost, we find that companies located in China?s coastal region are more likely to export. We do not find evidence that the inclination to export is dominated by policy considerations.

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1 Introduction

The past years have witnessed a rapid increase in the volume of Chinese high-tech exports and in the Chinese share of wordwide high-tech exports (Word Bank, 2011). Western companies face increasing competition not only in labor-intensively produced low-tech products but now also in high-tech. However, so far it is unclear which types of companies are responsible for the rapid increase. Given the support of the Chinese economic policy for advances in science and technology the question remains, whether exporting is driven by policy considerations or by economic rationales.

The theoretical background for our study are the trade models by Melitz (2003) and Yeaple (2005). We extend these models to include the aspect of the technological capabilities of companies. So far only the aspects of trade regimes, the choice between exporting or FDI, and labor market implications have been empirically tested (Felbermayr et al., 2011; Helpman et al., 2008; Helpman et al., 2004). By investigating the influence of technological capabilities on the export decision, our paper fills an important gap in the literature.

Our analysis is based on accounting information on companies listed at the A-share segment of the Shanghai and Shenzhen stock exchanges. The accounting information is obtained from Compustat and complemented with patent information from the PATSTAT database. Since we have no direct observation of the export decision in the data at the moment, we use the share of international patent applications in the company's patent stock as a proxy. We validate this proxy at the technology level by showing that international applications influence exports with a larger elasticity than national applications. Our main results are based on 727 companies with patenting activity for which we have an unbalanced panel with 3759 observations spanning the time period 1992-2009.

We find that companies with higher total factor productivity (TFP) are more likely to export as measured with our proxy share of international patent applications. Furthermore, companies with more valuable technology, as measured with citations received, are more likely to export. Companies located in the coastal region, which face lower transportation costs for their exports, are more likely to export. Finally, the inclination to export is driven by economic rationales and is not dominated by policy considerations.

This paper contributes to a growing literature which is focusing on innovation in China. However, the exiting studies have a different focus from ours. Eberhardt et al. (2011) analyze the Chinese patent explosion and find that the explosion is driven by a small group of companies in the information and communication technology equipment industry. Filatotchev et al. (2011) find for companies located in a science park that entrepreneurs returning from abroad also cause knowledge spillovers in the local companies for which they do not work. Schminke and Van Biesebroeck (2011) evaluate regional policy programs in China and find that companies located in Economic and Technological Development Zones export more than comparable companies outside such zones and that companies in Science and Technology Industrial Parks obtain higher export prices than comparable companies ouside such parks. Bloom et al. (2011) take a different angle and investigate how Chinese exports to Europe have influenced European companies. They find that the companies reacted to Chinese imports by investing more in R&D and patents in order to escape the competition from China.

2 China's Economic Development and Innovation Policy

Recent years have seen a strong increase in Chinese exports, particularly in high-tech exports. Over the last two decades the content of high-tech in national exports has been expanding from below 5% to around 30%. The share of world high-tech exports from China has increased from 4% to 18%, whereas the share from the USA has decreased from 17% to 12% in the time period 2000 to 2007 (World Bank, 2011). However, these figures need to be interpreted cautiously. Firstly, the value specified in the trade balance only accounts for total value of exports but not for value-added. Secondly, substantial shares of high-tech exports are contributed by foreign-invested enterprises and increase with the technological sophistication of the item (Koopman et al., 2008). Thirdly, the country's gap of licenses paid to licensees received continuously expanded and peaked at 12 billion USD in 2010 (World Bank, 2011). Taken together, these developments highlight the ongoing dependence of the Chinese economy on foreign technology.

The need for technological catch-up is further emphasized by recent macro-economic trends. While China is heading towards the Lewis Turning-Point[1], surplus labor evaporates and wages increase more quickly (Song and Zhang, 2010). Together with a continuously appreciating RMB, the results may prompt China to loose its competitive advantage in a large

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[1] Lewis Turning-Point: industrial wages in developing countries begin to rise quickly when the supply of surplus labor from the countryside diminishes.

number of low-tech industries. On the micro-level, Chinese firms are facing constraints in the development of advanced technologies. Unlike the situation in Japan and Korea during earlier decades, China's weak absorptive capacity has build considerably less potential in assimilating and advancing foreign technology. Recent empirical studies show that investment by Chinese firms in foreign technology alone does not enhance innovation in domestic firms, unless it is coupled with own in-house R&D (Li, 2011). While competition effects from foreign firms drive non-competitive firms out of local Chinese markets, vertical or horizontal industry-level spillovers remain weak. Possibly caused by more advanced IP protection, studies find no spillovers from foreign to domestic firms in high technology industries in China. Beyond that, the presence of foreign R&D labs can even have depressive effects on domestic firms due to increased competition for talents and resources (Fu et al., 2011).

In order to improve the economy's potential in meeting these challenges the Chinese government has enforced an increasing number of innovation policies. While innovation-supportive policies in China go back until the early 1980s, especially the most recent policies are increasingly well coordinated and have built up a whole policy-web to foster the creation of indigenous innovation[2] in China (Liu et al., 2011). This policy-web involves science and technology, industrial, financial, tax, and fiscal policies that remain in power if successful, and get exchanged for new measures if not. Thus, the indicative planning approach is mixed with regional "tinkering around" to adjust to recent trends while following the central planners' vision of the future.

The most recent and comprehensive plans are the Medium- and Long-term National Plan for Science and Technology Development (2006-2020) and the 12th Five Year Plan (2011-2015). By strengthening China's capacity for inclusive growth[3] and indigenous innovation, and lowering the dependence on foreign demand and technology, the country should turn into an innovative nation by 2020 and a world leader in science and technology by 2050. Since the internalization-process of research, production and consumption is likely to come with a temporally decreased output-potential, the 12th FYP specifies an annual GDP growth target of 7% - quite in contrast to the 10% growth targets achieved over the last three decades.

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[2] Indigenous innovation (自主创新) is specified as innovative performance by organizations under Chinese ownership, such as firms, universities and public research institutes.

[3] Inclusive growth (包容性增长) is specified as a shift away from export dependence towards domestic demand and consumption-driven growth.

More specifically, strategic emerging industries[4] have been identified as the ultimate mean for sustaining the country's future economic development. The substantial policy support of these industries is not only meant to decrease the dependency on foreign technology, but gradually to engage in the international competition for leading technologies and future technology standards (Suttmeier et al., 2011). Thus, while the inclusive growth model generally emphasizes a shift from exports to internal demand, the support of high-tech exports satisfies both strategic and economic motives.

To provide a more favorable institutional setting for the up-and-coming high-tech firms, intellectual property rights have been strengthened, patent applications are encouraged, successful international patent application get reimbursed, procurement policies favor home-grown technologies, import quotas and market-entry restrictions decrease foreign competition, and tax incentives foster the development of R&D centers in China and abroad. For example, firms can qualify for suitable subsidies by becoming active in one or more of the strategic industries. Further, by supporting a range of leading universities and research institutes China's talent pool should be enlarged and potentially supplemented by foreign scientists and engineers. Based on these innovation policies the Chinese government intends to provide support not only for technological catching-up but also for leapfrogging into global technological leadership. Finally, indigenous technological capabilities and high-tech exports of Chinese enterprises are adequate indicators for measuring the success of innovation policies and the technological catching-up of the Chinese economy.

3 Theoretical Framework and Hypotheses

Our theoretical framework is based on the seminal work by Melitz (2003) and Yeaple (2005) on the New New Trade Theory[5]. We extend these models to include the aspect of technological capabilities of companies into the theoretical framework. So far only the aspects of trade regimes, the choice between exporting or foreign direct investments (FDI), and labor market implications have been empirically tested (Felbermayr et al., 2011; Helpman et al., 2008; Helpman et al., 2004). By investigating the influence of technological capabilities on the company's export decision, our study fills an important gap in the literature.

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[4] The seven strategic industries include biotechnology, new energy, high-end equipment manufacturing, energy conservation and energy protection, clean-energy vehicles, new materials, and next-generation IT.

[5] "New new" trade models differ from „new" trade theory models by allowing for differences in firms' marginal costs and fixed market entry costs that are added to the standard fixed cost of developing a new variety.

In the models of Melitz (2003) and Yeaple (2005), the economy is determined by imperfect competition of many firms. Companies vary in their level of TFP, which they only realize after paying a one-time fixed sunk cost of market entry. Depending on the initially observed level of TFP, a company will start production or exit. If the company decides to produce, it can choose between producing only for the domestic market or also, additionally, for export markets. Companies with the lowest marginal cost find it profitable to pay the entry cost for domestic and export markets, while companies with intermediate TFP levels only pay entry cost for the domestic market. In line with these two cut-off conditions, three possible outcomes arise. The least productive companies with marginal cost above the first cut-off point exit the market immediately. Those companies with marginal cost between the first and second cut-off point enter the domestic market and those companies with marginal cost below the second cut-off point and the highest levels of productivity (e.g. the global technology frontier) both export internationally and sell domestically. This explains why only a fraction of companies in a given industry internationalize, while the majority remains bounded to the domestic market.

Next, producing companies are free to choose between utilizing high or low technologies, both with increasing returns to scale. To enter the high-tech sector a company must pay a fixed amount of money depending on the respective technology it chooses to utilize. We discriminate between the cost of utilizing existing high-tech infrastructure (royalties) and the cost for developing and utilizing a new high-tech infrastructure (R&D investments). The payment of royalties grants the company the right to use technologies provided by third parties and results in an increase in TFP in the given time period. However, the rise of the company's TFP is temporally restricted and conditional upon technological capabilities not possessed by the company itself. On the contrary, investment into R&D enhances the company's technological capabilities and causes a more sustained increase of TFP. In line with an improving absorptive capacity, the company learns to assimilate existing technologies and to advance these into new inventions (Cohen and Levinthal, 1990). Consequently, companies choosing to develop and utilize new high-tech infrastructure will eventually reach the technological capability to create technological innovation indigenously.

For those companies that export and aim to enter more sophisticated markets and technology sectors, the choice to invest in R&D becomes more crucial. As these companies approach the global technology frontier, the option to apply for technology licenses by firms with higher

technological capabilities expires since leading firms are not willing to license their most advanced technologies to potential competitors. Thus, companies that are targeting the most advanced export markets and technological sectors can only rely on comprehensive R&D investments to reach a sufficient level of competitiveness.

Complementary to the choice of technology, firms employ workers with different skill-sets. Each worker is paid a technology-specific efficiency wage. Not surprisingly the skill of any worker employed within high-tech infrastructure is more advanced than being employed in areas of low-tech. Thus, higher wages are paid for a higher skill-set. We introduce the option for companies to hire foreign workers for the most skill-requiring positions. If a company is operates closely to the global technology frontier it may be reasonable to pay higher costs for highly-skilled foreign researchers, since they introduce novel knowledge and increase the company's likelihood for developing more advanced high-tech capabilities. Interactions between characteristics of competing technologies with the labor force heterogeneity give rise to company heterogeneity.

Hence, companies developing and utilizing high-tech infrastructure and employing highly-skilled workers are more likely to go international. Depending on the technological capabilities obtained, companies select their export markets and technology sectors. On the demand side for high-tech products, the OECD countries constitute the world's major markets for sophisticated technology. In particular the USA, the EU and Japan are the global core markets. Further, these countries guarantee strong protection of the exporting company's IP. As a company exports its most advanced technology to compete at the global technology frontier, it is also facing the risk of reverse engineering by competitors in foreign markets. The protection of the company's intellectual property and exported technologies through patenting is a crucial precondition for the choice of export markets.

We introduce patent applications as a temporally preceding proxy for later exports (see validation of this approach in Section 5). The company's patent applications and patent stock are adequate proxies for the company's activities in export markets, as the goods a company sells need to be protected by IPRs internationally to provide counterfeiting. A company's patent stock includes valuable information about the heterogeneity of companies, e.g. information about foreign target markets, the company's technological capabilities, the value of technology developed by the company, and the contribution of foreign knowledge by foreign researchers employed.

The actual extent of exports is also influenced by general trading conditions. On the one hand, exposure to trade offers new profit opportunities in exports markets and encourages more market entry by domestic firms. At the same time, falling trading costs also reduce the minimum level of productivity that firms need to export. Highest-productivity non-exporters enter the export market, existing exporters increase sales due to opening-up of new markets overseas. On the other hand, changes in trading costs impact the average industry productivity through a selection mechanism and cause a diminishing effect on the number of firms as well as on the number of product varieties for consumers. Increases in the exposure to trade through either a transition from self-sufficiency to trade or a reduction of trade costs (e.g. due to the membership in Free Trade Agreements (FTAs)), will force the least productive firms to exit and reallocate market shares from less productive to more productive firms. In particular, the entry of more competitive foreign companies can fortify such selection effects. Increasing demand for labor by more productive firms and new market entrants increase overall wages and force least productive firms to exit. Thus, the minimum level of productivity needed to survive increases, forcing the firms with the lowest TFP to exit and firms with average industry productivity to increase over time.

We aim to prove our extended theoretical framework by empirically testing hypotheses that we derive as follows. Due to this study's explicit focus on the technological capabilities of Chinese companies it is instrumental to formulate the hypotheses for the Chinese economic environment. First, we are interested in the general link between technological capabilities of companies and their TFP levels. In China, companies started investing in R&D rather recently while a large number of companies are still depending on foreign technologies. Successful R&D leads to in increasing patent stocks and only the most ambitious companies apply for patents abroad.

> *H1: Companies with domestic patents have higher TFP levels than companies without patents and companies with international patents have higher TFP levels than companies with only domestic patents.*

In the next step of our analysis, we would like to investigate which company-specific features impact the decision to enter export markets. We employ international patent applications as a proxy for the intention to internationalize. Consistent with our theoretical framework, we expect Chinese companies with higher levels of TFP, advanced technological capabilities, and

higher shares of foreign researcher employed to go international.

> *H2: Companies with higher levels of TFP, more valuable technologies, and higher shares of foreign researchers are morel likely to enter export markets.*

Further, we consider the implications of trade cost on the companies' exporting strategies. We use the domestic distance between a company's headquarter and larger overseas ports, typically located at the coast, as a measure for company-specific trade cost. This cost is not influenced by transport costs diminishing effects of FTAs etc, and therefore serves as an adequate measure to explain company heterogeneity caused by trade cost.

> *H3: Companies located in China's coastal region find it easier to enter export markets than companies located in the landlocked central and Western regions.*

Finally, we aim to account for company heterogeneity caused by different forms of ownership. The ownership-structure of Chinese companies can broadly be classified into centrally state-owned, locally state-owned and private-owned companies. The effect of different ownership-structures is far from being obvious, since government intervention can force companies to follow other than solely profit-maximizing strategies, e.g. to support national strategies, etc. However, it remains unclear if state-ownership fosters a more export oriented innovation-driven company behavior or if private companies excel in these areas, because they are driven by profit maximization and less government intervention.

> *H4: Due to strong export and innovation policies, state-ownership of companies positively impact their internationalization and innovation strategies.*

4 Data

4.1 Data Source and Sample

In order to study which Chinese companies are seeking to compete abroad, we needed to compile a novel dataset that accommodates accounting information as well as data from patent registers. Accounting data was drawn from the Compustat database, which is one of the most important sources for data on worldwide publicly listed companies. Since data coverage of Chinese companies in our sample was far from complete, we further conducted own

research in annual reports to supplement the available data and to mitigate a reduction in sample size due to missing data. Patent data have been obtained from the PATSTAT database, which contains worldwide patent applications and publications including their bibliographic data such as patent owners or inventors.[6]

Companies' international IP portfolios needed to be compiled and reconciled with the accounting data. This matching process is not an easy endeavor due to the following reasons: First, spelling errors or systematical abbreviations might occur with regard to the patent owners. Second, accounting data are given on the consolidated level of publicly listed companies. However, in such corporations there are usually dozens (and sometime hundreds) of legal entities that file patents independently. Corporations are structured that way due to international legislations and due to the structure of business units. As these legal entities are entirely owned by the publicly listed corporation, the IP rights they filed need to be reconciled across legislations to arrive at coherent IP portfolios. Third, from an international patent legislation no requirement is given whether a Chinese patent applicant uses its English company name or the Chinese Pinyin-format of its name. In order to deal with these challenges and to still compile consistent international patent portfolios, we choose a semi-manual approach similar to Sandner and Block (2011): for each publicly listed corporation we defined a set of name patterns according to the three challenges described above. Applying these patterns to the "universe" of worldwide patent applicants yielded an adequate approach to assign all patent applications filed by a publicly listed corporation – legally acting through its array of legal entities. Depending on the format of the company name, several name patterns were constructed: that way, multiple formats of the same name could be considered (e.g., "China International Marine Containers" of course files patents under this name but also among dozen others under "CIMC" or under "China Int Marine Containers"). Also, various versions of the Pinyin name were separately added as a pattern.

Companies are frequently restructured leading to intense M&A activity. This is also true for Chinese companies as they, for example, sometimes invest in companies and assets in Europe and in the US. In case a company acquires another company, the owner names of the IPRs are usually changed to the new holding company. However, we were not able to also consider those IPRs that are owned by legal entites if the name of the legal entity does not have any

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similarities with the publicly listed corporation. In these cases the patent portfolios of the listed companies remain incomplete.

Concerning our sample, we included all publicly listed companies in the A-share segment. We admit that concerning Chinese companies this might lead to a pre-selection bias as the Chinese government only chooses those companies to go public at stock exchanges that either are strategically important or perform better than their non-listed counterparts. We therefore have a selection bias towards successful companies. This potential source of bias needs to be noted and sets a limitation for the interpretation of our results. In China, these stocks are listed at the stock exchanges in Shanghai or in Shenzhen. Initially, we started with 1762 companies from 27 Chinese provinces for which we had 15687 observations. In order to eliminate outliers, we deleted company-year observations that exhibit values above the 99th percentile of the sales-to-employees-ratio or in the sales-to-fixed assets-ratio. Depending on the concrete specifications, we had to delete observations with missing values in at least one required variable. Our TFP calculation including patenting as well as non-patenting companies is based on information about 1595 companies. We therefore cover more than 75% of the 2041 companies listed in A-share segment in December 2010 (see Figure A1 in the Appendix). For our main results on companies with patent applications we could use information on 727 companies for which we had 3759 observations.

4.2 Variable Definitions

Next to usual metrics from the companies' financial statements, we employ several variables derived from patent registers, additional information on the location of the company and measures on its ownership type.

Domestic and international patent applications. For a single invention, Chinese companies have the possibility to apply simultaneously for invention and utility patents. If they pass the patent examiners, they usually use the more valuable invention patent and abandon the utility patent. In order to avoid double counting, we only consider invention patents for our analysis. Although this is reasonable to argue, other researchers have chosen the approach of pooling all Chinese IPRs. When counting the number of national and international patent applications in the portfolios of the companies, we apply the concept of patent families. Actually, a patent family is simply a bundle of patents or patent applications. The reason for the existance of the concept of patent families is rooted in the international patent legislations: a patent by

definition is always a granted right to exclude others from use. Such a property right is granted *within* a specific legislation of a country or a region. In order to protect a novel invention, an applicant must file a bundle of patent applications filed either simultenously or subsequently. Then, this bundle of geographically distributed property rights forms a patent family. Thus, it is patent families that measure inventions while pooling patents would inflate the number of inventions through double-counting one invention filed in multiple countries. As filing patents is a costly process, companies need to decide whether to grow their patent families internationally or not. Conversely, this renders patent families an important indicator that informs analysts about the potential value of an invention (Harhoff, Scherer and Vopel, 2003; Putnam, 1996; Hall, Thoma and Torrisi, 2007). Companies will seek to get legal protection for those inventions that they deem to be valuable. Due to various rules in international IP regimes, various definitions of patent families exist exhibiting slight differences concerning which IPRs actually belong to a patent family. As the so-called INPADOC patent family is the most frequent definition, we follow this approach. Importantly, a patent family not only comprises granted patents but also patent applications. Thus, patent families are not measuring the actual territory protected but, instead, the ambitions where a company seeks protection. This is an important fact, since several years can pass between patent applications and the subsequently granted patents. Research often draws on patent applications since these data are more recent due to the long time lag until a patent application finally is getting granted.[7] Note that the variable *# patent applications* refers to the number of patent families. Thus, this variable is actually measuring the inventive activity and not the "inflation" of IPRs through covering large territories. We chose to use the term *# patent applications* since with our analysis, large fractions of Chinese companies' patent portfolios consist of "isolated" Chinese patent applications that not yet have developed into an international patent family (i.e., patent "families" consisting of one patent application only). The variable *Share of international patent applications* reflects the share of those patent applications in the entire portfolio that have been filed at least once outside of China. Domestic patent applications are simply those that have been filed with the SIPO. International patent applications are those filings that have been filed to protect inventions outside China. Thus, the international share of corporate patent portfolios consists of filings in various legislations mostly the US, Europe, and Japan. This variable is the dependent variable of our regression analysis. Patent variables are assumed to be non-missing for company-year

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[7] Also, in other domains of intellectual property rights, usually applications for IPRs are used. This, for example, is true for trademarks (Sandner and Block, 2011).

observations with at least one patent application in the patent stock. Conversely, if no patent application could be found for a specific company in a specific year, we defined this as missing values and assumed this company to be not active with regard to IP in this year.

Average number of citations per application. As in the field of research where new research studies cite older studies, new patents cite older patent. As with research studies that are cited very often, those patents that are getting cited more often can be said to be of higher value. Thus, this renders patent citations an interesting indicator for the value of patents where the number of citations a patent received is highly skewed (Bloom and Van Reenen, 2002; Hall, Jaffe and Trajtenberg, 2005; Harhoff, Narin, Scherer and Vopel, 1999; Harhoff, Scherer and Vopel, 2003; Trajtenberg, 1990). The references in a patent are included to demarcate the subject matter of the patent from so-called prior art that cannot be protected as it is already protected or as such knowledge has become public domain. Although the patent applicant has to mention relevant patent and non-patent literature during the patent examination process, the patent examiner at the patent office conducts his own research and includes the appropriate references to previous documents thus making references a rather objective measure. We use those citations as a value indicator and count for each patent application held by the Chinese companies in our sample those citations that arrive after the publication of the search report. We then aggregate all citations associated with the patents in a company's patent portfolio and compute the *average number of citations per application* which becomes a metric to characterize corporate patent portfolios (Hall, Jaffe and Trajtenberg, 2005). The data source PATSTAT which we employ generally contains references (backward citations) for patent applications in the US, Europe, and Japan but unfortunately references of applications filed at the SIPO are not included. When counting citations to the applications held by listed Chinese companies, we are therefore restricted to citations originating from outside China. For the purpose of our study this is not a limitation. The fact that we cover only international citations makes the value indicator more objective, because self-citations are automatically excluded and there is limited concern that patents are referenced for strategically opportunistic reasons.

Share of inventors located in China. At the level of the patent family we calculate the variable *share of inventors located in China*. For the majority of inventors we can determine their country of residence from the information in the patent application, but for 20% of inventors this information is missing. Judging by the names of inventors, most are probably based in China. However, we eliminate an application from the analysis if we do not know the country of residence for all inventors. At the family level we include an invention if the

number of inventors is at least known for one family. Within a family it does happen that the applications which result in publications by a foreign authority have more inventors than the applications which result in publications by the SIPO. We therefore restrict the inventor information to publications from the SIPO.

Region. We divide P.R. China into three regions, namely Coast, Central and Western. According to the postcodes of the companies' headquarters, the companies are allocated to cities, provinces, and ultimately regions. Companies located in the coastal region are closer to overseas harbors and find it less costly to export, while companies in central and western regions face higher transportation costs for their exports.

Ownership. We control for company ownership based on the majority shareholder. According to this classification a Chinese company can be owned by the central government, by local governments and by private parties. It is important to control for the ownership type, because of transformation and selection considerations the most productive state-owned companies listed first on the stock exchanges. Further, state-owned companies might not only follow profit-maximizing strategies but also fulfill social or strategic missions.

4.3 Descriptive Statistics

Table 1 contains the descriptive statistics for patenting companies, i.e., for those companies where we recorded at least one patent application. This is the sub sample (N = 3,759) used to test our main hypotheses. The average size of the companies is quite large, as could be expected for a set of listed companies. Companies have on average sales of USD 5.3 billion and have on average 5,474 employees. The ownership categories do not sum to 100%, because not all companies could be classified. Around 20% are owned by the central state, 40% by the local state and 30% are in private ownership. The geographical distribution is representative for the economic activity in China. 63% of companies are located in the coastal region, 20% in the central region and 15% in the western region.

The distribution of the number of patent applications is very skew. The data set covers a few companies with very large patent portfolios, but on average the number of national patent applications is only 40 and the number of international patent applications only 4. On average only 6.9% of the patent families contain an application for an international patent (i.e., PCT patents) filed with the World Intellectual Property Organization (WIPO). The majority of

companies with international applications have a selective patenting policy. The companies do not apply for all inventions in foreign countries. This is an indication that, even though there is a government policy to promote international applications, the companies do not respond to this policy by filing all inventions abroad. The median value of share of applications filed abroad is 16% for observations where the share is positive.

The average number of citations per application is with 0.15 quite low. This can be explained with the fact that in the worldwide PATSTAT patent database we employ the reference information used to calculate citations is only made available from patent offices outside China. 99% of inventors within the Chinese companiese we analyze are based in China. The most important other countries are USA, South Korea, Japan, France and Taiwan.

Figure 1 shows the impressive increase in companies with patent applications. Whereas even in the middle of the nineties only around 5% of companies had patent applications, this share increased to 50% in 2008. The share of companies with international patent applications increased to only 10% indicating that either not all Chinese companies are interested in international markets or that only a small share of Chinese companies has technology that is advanced enough to aim for international patent protection.

[Figure 1 about here]

5 International Patent Applications as Proxy for Exports

Currently we do not have export information at the company level. We therefore use international patent applications as a proxy for the intention to export. Companies will only go through the hazzle of applying at international patent offices and invest the large amounts of money needed, if they have a need to protect their technologies also outside of China. If companies refrain from protecting their technologies in other contries, they cannot obtain patents as legal rights to prevent counterfeiting by competitors. At the product and technology level we in this section seek to test whether there is a relationship between Chinese exports and international patent applications of Chinese companies. The following test provides a valuation of our proxy.

We use the trade-technology-concordance from the OECD patent manual (OECD 1994, p. 84-

91) which links product categories of high-tech exports to technology classes from patent applications. It is important to note that not all exports are covered; the concordance covers only a selection of high-tech exports. As we are mainly interested to see whether international patent applications are related to exports, a restriction to a subset of high-tech exports is not a major limitation.

We obtained information on Chinese high-tech exports from Comtrade, the international trade database of the United Nations (http://comtrade.un.org). For our validation test we use annual information for 120 export categories, measured at the five-digit product level. The available time period is 1992-2010. The mean value of Chinese exports at the product level is USD 550 million.

The patent data is once again taken from PATSTAT. We extracted all applications with earliest priority in China for the years 1990-2007.[8] For each family with the same priority we determined whether the family had at least one application outside China, i.e. one application at a foreign patent office or a PCT application. Families without international applications are counted as national; otherwise they are classified as international. We then counted the number of national and international patent applications at the level of the 4-digit technology in a given year.[9] We used weights for the counting, i.e. a patent with four different technology codes gets only a weight of 0.25 at each respective code.[10] As year for the application we used the application year of the earliest priority application of the patent family. For our validation test, we can use information for 73 technologies. At the 4-digit technology level, we have on average 328 national and 19 international applications per annum.

We use a log-log specification in order to be able to interpret the coefficients as elasticities. The concordance allocates several technology classes to a high-tech product. We take the average of the number of patent applications at the respective technology classes and allocate it to the value of exports at the product level. Each product category therefore enters the regression only once for each year. Furthermore, we used a two-year lagged variable of patent

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[8] Concerning the concept of patent families, the earliest priority application ist he very patent application that basically "creates"the filing. It is thus the earliest document available that underlies the patent family. Subsequent patent applications will usually refer to this earliest priority application and cover the same subject matter but in other countries. Sometimes, earliest priority applications are also called first filings.

[9] Precisely, we use the first four digits of the International Patent Classification (IPC) classes. IPC classes are assigned to a patent application by the patent examiner during the process of patent application.

[10] This method is also known as "fractional counting".

applications to allow for a delay between the time of the invention and the time exports occur. The following specification reports the results of our test (2,190 observations, R squared: 0.19, robust standard errors are below the coefficient estimates in parentheses):

$$log(\text{Chinese exports}_t) = 0.194 * log(\text{National patent applications}_{t-2})$$
$$(0.074)$$

$$+ 0.307 * log(\text{International patent applications}_{t-2}) + 18 \text{ year dummies}$$
$$(0.094)$$

The elasticities for both national and international patent applications are significant at the 1% level. Our results show that international patent applications are more closely related to export activity than national patent applications. The elasticity for international applications is more than 50% larger than the elasticity for national applications. Specifically, a 1% increase in international patents leads to an increase in the value of exports of 0.31%. We also experimented with a lag of only one year and with an alternative specification. All variants provide very similar results. We can conclude from our validation test that the use of international patent applications is a valid proxy for export activity.

6 Regression Results

In this section, we present the results of our regression analyses. We first explain how we exactly operationalized TFP. Using descriptive statistics we are able to show that companies with more advanced technological capabilities exhibit a higher TFP. Second, we investigate which factors lead companies to go international. To do so and in order to examine our hypotheses, we explain internationalization with advanced technological capabilities, geographical location, and ownership.

6.1 Calculation of Total Factor Productivity

To analyze which of the Chinese companies are seeking to export and to compete abroad, we use a TFP format. In a simplified functional form of the production function, income is basically explained by capital and labor. We operationalize income with total annual sales of the company, capital with net fixed assets, and labor with the number of employees. We estimate the production function with a fixed effects panel estimator and allow for autocorrelation of the error terms of a single company to obtain robust standard errors. The

error term in this specification corresponds to the output which is not explained by the determinants capital and labor. In the functional form of the productivity function, these determinants are leveraged by the TFP which we operationalized by this error term. We would have liked to include the R&D stock of the company as additional determinant of output, but, unfortunately, our data source does not contain information on R&D expenditures.

Applying this approach for all companies in the sample results in the following specification of the production function (12,989 observations for 1,595 companies, standard errors are below the coefficient estimates in parentheses):

$$log(\text{Sales}) = 0.36 * log(\text{Fixed assets}) + 0.36 * log(\text{Employees})$$
$$(0.02) \qquad\qquad\qquad (0.03)$$

Recall that we expect companies with higher technological capabilities to perform better. To assess companies' technology base we use patent data. Consequently, from corporate patent portfolios we are able to derive multiple metrics that characterize companies' technological capabilities. For those companies that filed patents we decompose their IP portfolio in a domestic share and an international share. Calculating the average of TFP for three distinct groups of companies based of the characteristics of their patent portfolio allows identifying whether companies' technology base is associated with a higher productivity: first, the mean TFP for those companies with no patents yields -0.092. Second, the average of TFP for companies with solely domestic patents is 0.152. Third, the mean of TFP for those companies with both domestic and international patent portfolio yields 0.443. These three means for the three groups of companies show that those companies which own a more advanced technology exhibit a higher productivity.

In another estimation of the production function we do not include all companies but only those that have filed for patents. The resulting specification is (3,908 observations for 795 companies):

$$log(\text{Sales}) = 0.34 * log(\text{Fixed assets}) + 0.37 * log(\text{Employees})$$
$$(0.04) \qquad\qquad\qquad (0.06)$$

Once again, we compute the means for the groups of companies defined according to the characteristics of their patent portfolio. As, in this specification, we excluded those companies having never filed for patents, we are left with only two groups. The mean TFP for the companies filing solely domestic patents is 0.063 whereas the average of TFP for companies with an international IP portfolio is 0.228. This adds to our finding above that a more advanced technology base is associated with higher total factor productivity. We use this subsample in the next section since our approach requires a metric to measure exports or rather, international presence. In this paper, we use international IPRs to proxy international presence. Therefore, the sample can only consist of companies that file patents.

6.2 Who is Going to Compete Abroad?

In the next step of our analysis, we investigate which companies go international. To operationalize international presence we chose to rely on patents that have been filed internationally, since these patent filings reflect companies' ambitions to be present in other parts of the world. In other words, these companies seek to export their goods. Yet, they first need to secure the technological ground *internationally* on which they build their products in order to exclude others from counterfeiting.

As follows, we ran several regressions that indicate which characteristics support companies in competing abroad. Thus, as dependent variable we use the share of international patent applications in companies' patent portfolios. Obviously the range for this variable is between 0 and 1. We thus use Tobit estimation with these boundaries and once again cluster in companies to yield robust standard errors. The results are depicted in Table 2: All specifications use a sample of 3,908 observations on 795 companies (see previous section). In models (1) through (3) the three variables which reflect companies' TFP or their technological capabilities enter separately whereas in model (4) these variables enter the regression jointly. Each model contains a set of year and sector dummies to control for systematic trends over time and within industries.

[Table 2 about here]

Concerning the effect of companies' productivity, model (1) accommodates the TFP variable which has been computed as explained in the previous section. The estimation results show that the coefficient for TFP is significant (b = 0.0720, with p < 0.1). This indicates that those

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companies with higher factor productivity also seek to compete abroad. Regarding the effect of companies' technological capabilities, model (2) includes the average number of citations received per application. Recall that this variable reflects the value of companies' technology base. The coefficient of this variable is positive and highly significant (b = 0.3849, with p < 0.01). Thus, technology of higher value drives companies to go international. In model (3) we included the share of inventors located in China, a variable that reflects whether international knowledge is available. In the regression, this variable also appears to be highly significant and negative (b = -1.6915, with p < 0.01). Hence, companies whose corporate R&D can also rely on international knowledge are competing internationally.

In model (4), the variables which entered models (1) through (3) separately, are jointly included. Therefore, we elaborate more on this full specification. Compared to model (1), the coefficient TFP remains positive and significant (b = 0.0567, with p < 0.05). Companies with a higher TFP also go abroad to compete internationally. This supports hypothesis H1. Also, the coefficient of the citation metric informing us about the value of the technology base is significantly positive (b = 0.2423, with p < 0.01). Thus, companies that have built a technology base of higher value tend to compete internationally. Consequently, our hypothesis H2 is supported. With regard to the share of inventors located in China, the coefficient of this variable has lost its significance when comparing model (4) and model (3). We interpret this finding as follows: the availability of international knowledge measured by this variable is not itself a driver for companies to go abroad. The location of inventors outside of China is likely a value to correlate as well. Higher costs of employing inventors abroad mean that companies will find it only worthwhile to locate inventors abroad, if more valuable inventions are targeted. In model (4) we see that the value aspects measured by citations dominate. Interestingly, the coefficient of citations declines in the full specification. This is also an indication that share of inventors located in China is correlated with value. The coefficient of TFP could be estimated more precisely (p = 0.0567, with p < 0.05 in model (4) compared to model (1): b = 0.0720, with p < 0.1). This is important to note since when the citation and the inventor variable are also included, characteristics of the technology base are to some degree isolated so that this technological component is removed from TFP. The coefficient of the total number of patent applications is also significant (b < 0.0001, with p < 0.05).

Next, we assess the effect export costs have on companies competing internationally. Recalling hypothesis H3, we expected that companies with lower export costs are more

likely to enter export markets. Thus, we included a dummy variable in the regression which indicates whether a company is located in a coastal region. The coefficient of this dummy is positive and significant (b = 0.0935, with p < 0.1). The size of this coefficient reveals that companies in the coastal region appear to have a 9.4% higher share of international applications in their patent portfolio in comparison to companies in the central or western region. Thus, we are able to confirm hypothesis H3. Being located in a coastal region drastically reduces the distance to overseas harbours. The geographic location of a company in China is thus important for its ambitions to compete abroad.

Further, the regressions also included variables that reflect companies' ownership structure. As a consequence, we included two dummy variables, one variable indicating that the company is owned by central government and one variable indicating that the company is owned by local government bodies. In model (4), the coefficients of both dummies are not significantly different from zero. Thus, with regard to companies' going international, no difference can be noted between privately owned companies and state owned companies. Both types of ownership lead to similar characteristics of patent portfolios with regard to the share of international applications. However, when only TFP was included, see model (1), the coefficient for ownership by local authorities has been significantly negative (b = -0.1725, with p < 0.05). The size of this coefficient reflects that companies owned by local government bodies exhibit a 17.3% lower share of international patent applications.

7 Conclusions

Recently, China has become the second largest economy in the world. This position so far has been mainly achieved by exports of especially labor-intensive low-tech goods. However, as time passes, Western companies will increasingly face competition by Chinese companies in the area of high-tech products. The Chinese government aims to accelerate this development by providing substantial incentives for companies to pursue technological catching-up and internationalization strategies. So far we have only witnessed the beginning of that development. Our study contributes to a growing literature which is focusing on innovation in China. We build on the New New Trade Theory by Melitz (2003) and Yeaple (2005) and incorporate the factor of technological capabilities in this model. We argue that technological capabilities are an important driver for a company to go abroad and compete on an international level. More specifically, in this study we investigate the relation between increasing Chinese high-tech exports and the technological capabilities of Chinese companies.

To investigate the influence of technological capabilities, we find that companies' productivity (i.e., TFP) is a driver for them to export and compete internationally. Further, we find that a more valuable technology base is also leading companies to go international. Also, companies which have lower transportation costs, for example due to their location in coastal regions, are also more likely to compete on an international level. Finally, we show that during the last years those Chinese companies which are publicly listed on Chinese stock exchanges systematically developed national and also international patent portfolios and collect impressive amounts of patent protected technology.

These results do not come without caveats. Mainly, it is not an easy endeavor to approach the research questions which we sought to analyze in this work, since it is difficult to obtain appropriate data both in terms of representativeness and depth. We therefore relied on the share of international patents in companies' patent portfolios in order to proxy exports and international presence. This exhibits a limitation as we were not able to obtain company-specific export data on an annual basis which would have been ideal for our analysis. Further, our sample of listed companies suffers from a pre-selection bias since only those companies become publicly listed if they presumably are (more) successful than other companies. Especially in the first decade of the Chinese stock markets operations, a quota-based regulatory decentralization policy motivated regional governments to select their better-performaning state-owned companies for initial public offerings (Du and Xu 2009). The China Securities Regulatory Commission (CSRC) finally decided which companies were allowed to go public. While the quota-based policy was faded out after 2001, the CSRC remains the authority to decide which companies are allowed to go public in the Chinese A-share segment. Consequently, the companies in our sample are the better performing ones or serve strategically important targets. This restriction on listed companies means that we do not observe the full set of technological capabilities inside China. It is not clear whether unlisted companies follow the same determinants for interest in foreign markets. However, consistent with the theoretical framework we applied, the better performing companies are of higher interest for the purpose of this study thus rendering this issue not a major limitation.

There are also interesting avenues for future research. Most importantly, patent portfolios and detailed export metrics would allow to conduct fine-grained analyses which companies and in particular which industries are prone to go abroad and compete internationally. It can be expected that strong differences exist between industries such as consumer goods and long-living industrial goods.

Tables and Figures

TABLE 1 –
DESCRIPTIVE STATISTICS

| Variable	Mean	Median	Stdev.	Min	Max
Sales (in mio. USD)	5335	1307	31049	-19	1071146
Employees	5474	2296	18593	15	539168
Fixed assets (in mio. USD)	2694	594	27071	-472	1075467
Ownership by central state (1/0)	0.195	0		0	1
Ownership by local state (1/0)	0.424	0		0	1
Private ownership (1/0)	0.316	0		0	1
Shanghai stock exchange, main segment (1/0)	0.578	1		0	1
Shenzhen stock exchange, main segment (1/0)	0.300	0		0	1
Shenzhen stock exchange, SME segment (1/0)	0.122	0		0	1
Coast (1/0)	0.632	1		0	1
Central (1/0)	0.195	0		0	1
Western (1/0)	0.150	0		0	1
# patent applications	49.5	4	447	1	17539
# international patent applications	3.92	0	53	0	2266
Share of international patent applications	0.069	0	0.202	0	1
Avg. # of citations per application	0.152	0	0.782	0	14
Share of inventors located in China	0.992	1	0.079	0	1

Note: Only companies with at least one patent application included. Number of observations is 3765-3914.

TABLE 2 –
TOBIT REGRESSION RESULTS

|	(1)	(2)	(3)	(4)
Dependent variable	Share of international patent applications			
TFP	0.0720*			0.0567**
	(0.0404)			(0.0261)
Avg. # of citations per application		0.3849***		0.2423***
		(0.0710)		(0.0558)
Share of inventors located in China			-1.6915***	-0.7696
			(0.1760)	(0.4987)
# patent applications	0.0001**	0.0001**	0.0001***	0.0000**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Coast (1/0)	0.1801**	0.1435**	0.1379**	0.0935*
	(0.0858)	(0.0711)	(0.0551)	(0.0505)
Ownership by central state (1/0)	-0.0004	-0.0908	0.0851	-0.0111
	(0.1013)	(0.0854)	(0.0706)	(0.0608)
Ownership by local state (1/0)	-0.1725**	-0.0856	-0.0464	-0.0351
	(0.0865)	(0.0701)	(0.0552)	(0.0495)
Year dummies	10 cats.	10 cats.	10 cats.	10 cats.
Sector dummies	8 cats.	8 cats.	8 cats.	8 cats.
Observations	3908	3908	3759	3759
Number of companies	795	795	727	727
Log pseudolikelihood	-1970	-1750	-1520	-1358

Note: Standard errors are clustered by company. Only company-year observations with at least one national patent application included. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

FIGURE 1 –
SHARE OF COMPANIES WITH PATENT APPLICATIONS
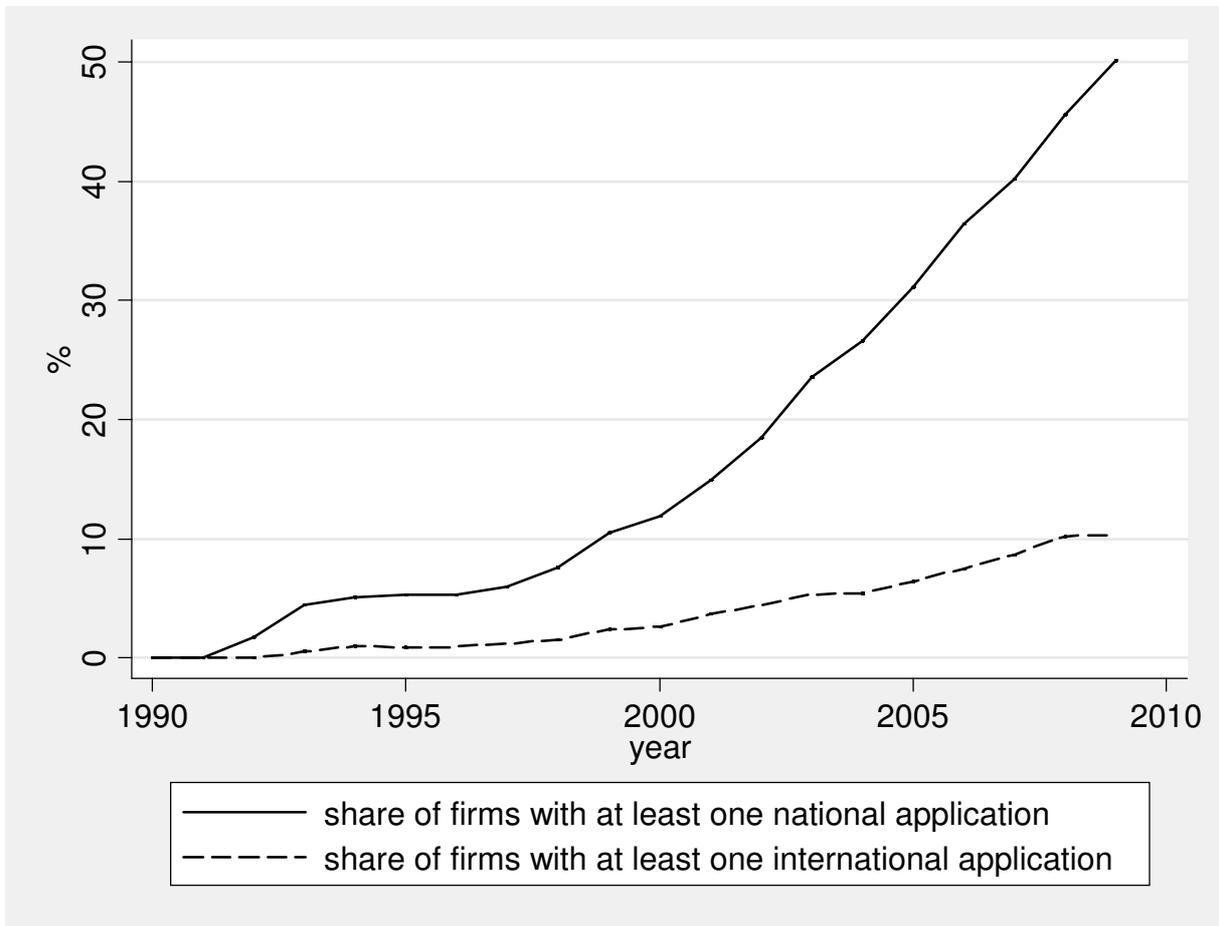
Appendix

FIGURE A1 –
NUMBER OF LISTED COMPANIES IN CHINA'S A-SHARE SEGMENT
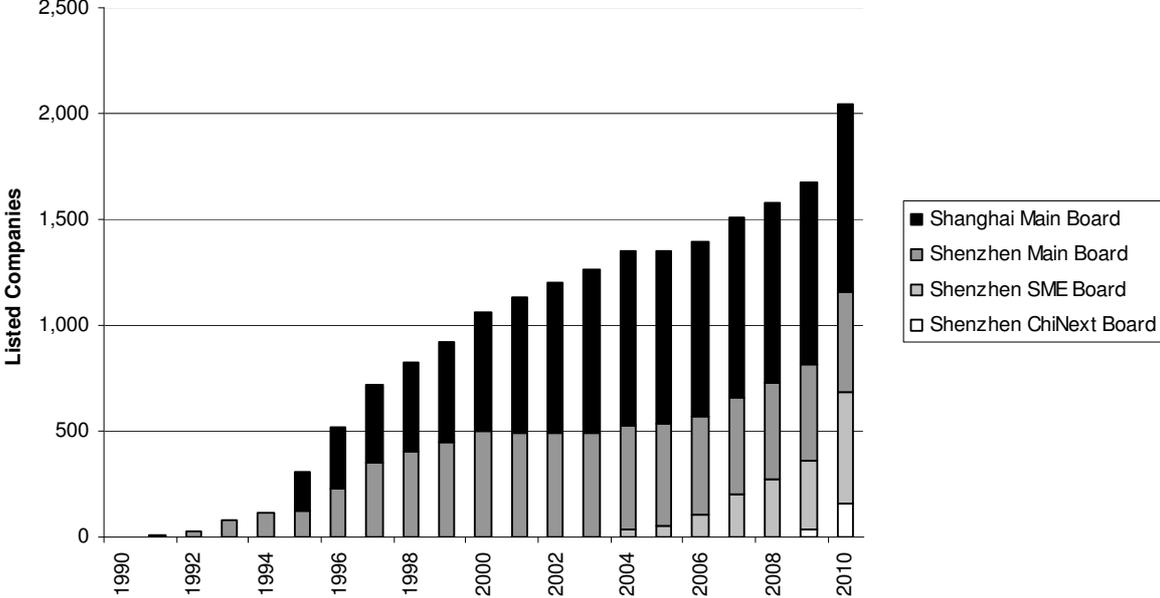
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