The Interplay of ICT, Innovation, Per capita GDP and Chinese Tech Policy

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Abstract

China's unprecedented growth rate in the last decade is driven by its role as the global manufacturing powerhouse, but trade tensions with the U.S will affect economic growth for both superpowers. Meanwhile, several papers have sought to understand the impact of trade on innovation. Several studies emphasize the role of technology and knowledge spillovers into the real economy, driven by trade activity. Although increases in innovation stemming from R&D activities are palpable, the extent of economic growth is contingent on the market size (IMF 2004). This paper investigates the relationship between exogenously driven growth, proxied by ICT imports, and Chinese innovation. The study verifies the hypothesis by constructing an algorithm that investigates the nature and extent of the relationship, while the Augmented Dickey Fuller test is used to test for multicollinearity. The study postulates evidence-based policy recommendations that will at once facilitate the transition of the Chinese economy towards an innovation-driven and consumer-centric growth model.

Keywords: ICT, innovation, economic growth, trade innovation

JEL Classification: E52, F5, 033, 034

1. Introduction

China's economic growth over the last decade has been driven by export-oriented and labor manufacturing activities. Chinese exports have increased by 16% since 2000, driven by intentional government policies designed to facilitate knowledge transfers and innovation cooperation amongst its firms. A natural consequence of its increasing share of global exports is a resulting increase in information imports for its assembly and technology supply chains.

Furthermore, its rising share of global trade has caused the fastest sustained expansion, with growth averaging 9.5% through 2018. China is now the biggest economy on a purchasing power parity basis ($25.27 trillion), as well as the largest manufacturer and merchandise exporter. Despite rigorous coordination amongst domestic companies in an attempt to bolster competitiveness, its trade with the world created the incentive to innovate and modernize its economy. The IMF projects a 5.5% growth rate by 2024, even as its economy is poised to transition to a consumer and innovation-driven model in an attempt to lessen its reliance on exports and fixed investment. This transition suggests a greater role a renewed focus in ICT-related activities ranging from electric vehicles, I.T. infrastructure, and 5G technologies to smart platform/vehicle operating system. The U.S. and China are currently locked into a trade, technology and geopolitical rivalry, but the findings of this paper suggest that both superpowers stand to benefit from continued trade. The U.S stands to benefit from a more affluent Chinese consumer, whilst China stands to benefit from greater innovation pass-through.

According to Ulku (2004), innovation pass-through is more relevant for smaller economies, as G7 economies with a large market tend to see more significant increases from current innovation stock. This occurs, in spite of current innovation stock being rooted into longer-term growth trends, fostered by cooperation among state-owned enterprises and government-led innovation incentives.

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Whilst the Chinese economy is large, the uncertainty over the relationship between its ICT-related trade, innovation and GDP warrant closer attention.

China's Information and communication technologies (ICT) sector is one of the most advanced and transformative sectors of the economy, projected to reach $8.1trillion by 2025 representing 55% of Chinese GDP. Meanwhile, ICT exports as a percentage of GDP rose 27.1% in 2000 and 27.06% in 2018, while ICT imports grew at a much slower pace, rising 2.5% from 2000 to 22.7% respectively. The rising contribution of ICT exports to Chinese GDP provide sufficient rationale for this study which seeks to investigate the nature of ICT-related trade on GDP per capita, as well as on specific innovation variables. This is particularly salient given the current maturing phase of the Chinese economy, which suggest innovation and ICT sectors will become central to the Chinese growth model. The implementation of China's first cyber security law (effective from June 2017) and the divergence between its data localization laws with international standards suggest ICT and technology-related sectors will be central to its future economic growth. On the other hand, Haque (2012) states that, "as an element of decentralization, local government is a result of devolution".

Several papers from Roller and Waverman (2001), Yueh (2009) and Cai & Zhang (2015), investigate the causes of economic growth in China, noting innovation, R&D spending, patents and number of people employed in research activities as the leading causes of China's economic growth. Admittedly, these factors constitute the cornerstone of the Chinese growth model but fail to account for the degree of competitiveness derived from ICT exports. Rather than discount the quantitative findings linking innovation to increased productivity and economic growth, this paper seeks to complement these by investigating the presence and nature of the relationships between ICT-trade, number of people employed in research activities, patents from both residents and non-residents as well as per capita GDP. The rationale of the chosen approach rests on the salience of global trade to Chinese economic growth and innovative activities and will inform current thinking regarding Chinese dependence on exogenously derived innovation proxied by ICT imports from the United States. As a service and intellectual property-driven economy, ICT imports likely trickle into the Chinese economy by creating incentives for indigenous innovations from private-agents via generating competitive pressures.

1.2 Aim

The research aim of this project is "to investigate the relationship between ICT imports, ICT exports, and number of interlinked aspects"

1.3 Significance

The study seeks to gauge the nature and extent of the relationship between ICT imports, ICT exports, number of people employed in research activities, patents from both residents and non-residents as well as GDP per capita. It employs machine learning in other to verify the nature and interactions amongst the above variables. Further visualizations are provided by way of a heat map to better illustrate the trending relationships and the Augmented Dickey Fuller test is used to ensure methodological rigor and ensure the time series is non-stationary.

2. Literature Review

ICT is increasingly important to China's economic expansion, more so as it transitions away from an investment-led economy to one driven by innovation, services and consumption. According to the China academy of information and communications technology, the digital economy comprising payments, E-commerce, cloud computing and Information communication and technology exports comprise 30 percent, 46 percent in Japan and 20% percent in South Africa, Brazil and India.

Furthermore, digital technology adoption suggests a pass-through from high-tech imports to innovation, and China currently ranks 50th out of 131 countries according to the World Bank, 59th out of 131 countries according to the World Economic Forum and 36th out of 62 as per the fletcher schools ranking. Technological adoption culminates innovation, the transmissions from ICT and technology-driven trade. Owing to the above, the literature seeks to outline relevant studies pertaining to Information communications technology, innovation and GDP per capita.

Eminent theories on economic growth ranging from the neoclassical growth theory (Solow 1956) and neo-Schumpeterian theories by Schumpeter (1934) and Pyka and Anderson (2012) have found a significant and statistically significant relationship between economic growth and ICT. While theoretical works suggest a positive relationship between ICT and economic growth, empirical studies attempting to investigate the relationship has been mixed. Roller and Waverman (2001) employ data for 21 OECD countries (Organization for Economic and Cooperation Development) between 1970 – 1990. They estimate a micro-model and find a strong relationship between telecommunications, infrastructure investment and economic growth.

Heshmati and Yang (2008) investigate the contribution of ICT to Chinese economic growth and found the impact of ICT on productivity to be significant and positive. The study further finds Chinese ICT to have net positive effects on economic growth. They found significant contributions of ICT to China's GDP growth (20%) and total factor productivity growth (38%) during the 1978. Kuo and Yang (2008), Schaaper 2009, Zhang et al. 2009 investigate the effects of knowledge capital and spill overs on regional economic growth in China. Their empirical findings suggest more than marginal contributions from of both R&D capita and technology imports. Additionally, the study also found international knowledge spill overs to be significant to economic growth, lending credence to the exogenous growth theory.

Yuh (2009) analyses the impact of patent laws of innovation in China, as it is subject to criticism on the implementation of intellectual property rights; despite variations, the success rate for patents applications are similar across the country. The study also points to per capita GDP incentivizing innovation cross all regions, despite notable heterogeneity across regions; as such, R&D is an important determinant of patent applications. Further, Huo et al (2015) and Khoung and Jorgenson (2016) found significant contributions of ICT to china's economic growth, using ICT producing sectors.

Cai and Zhang (2015) investigated the impact of ICT development and decomposed china's productivity growth between 1977 – 2012. The findings attribute 3.4% of productivity increases to ICT developments. This has bolstered the competitiveness of Chinese ICT exports and explain their rising contribution to GDP growth.

Meanwhile, Dedrick, Kraemer and Shih (2014) investigate the impact of information technology and economic development via a cross-country study. Their findings posit ICT had a positive, albeit light, impact on national development and quality of life. An IMF study by Chen Kaihua and Zhang (2019) find digitization such as e-commerce and Fin-tech is high in certain regions and sector despite being lower than advanced economies. The results show a positive boost to productivity and digitization. According to Romer (1990) and Aghion and Howitt (1992) growth in this model is driven by technological change that arises from intentional investment decisions made by profit-maximizing agents. The distinguishing feature of the technology as an input is that it is neither a conventional good nor a public good; it is a non-rival, partially excludable good. Because of the non-convexity introduced by a non-rival good, price-taking competition cannot be supported. Instead, the equilibrium is one with monopolistic competition. The main conclusions are that the stock of human capital determines the rate of growth, that too little human capital is devoted to research in equilibrium, that integration into world markets will increase growth rates, and that having a large population is not sufficient to generate growth.

According to Romer (2006), intentional and targeted government policies have increased the sophistication of the Chinese export basket. He posits "much more than the gains in competitiveness, free markets or liberalized growth models, China's future hinges not on the quantity of its exports but its ability to increase the adoption of technology into higher value-added products. This provides credence to the approach utilized in the study that seeks investigates the relationships between ICT imports and exports against Researchers, non-residents and resident patents.

Yueh (2009) finds heterogeneity in the implementation of intellectual property rights, while per capita GDP is found to incentivize innovation across all regions although variability persist. Meanwhile, R&D is found to be an important determinant of patents. As such, the hypothesis also seeks to investigate the relationships amongst ICT exports and researchers over the stipulated time frames.

The above studies investigate the impact of, and interactions between ICT, innovation, patents. Nevertheless, the literature remains limited in understanding the relationship between innovation outcomes such as ICT exports, patent applications and Researchers. Rather than attempt to quantify the extent and predictive capacity of said variables on economic growth, the study seeks to understand the relationships, if any, between GDP exports, GDP per Capita, researchers, resident and non-resident patents, ICT imports and ICT exports.

This paper, rather than confirm the findings of in the literature, investigates the nature and extent of the relationships amongst ICT imports and exports against GDP per capita, Researchers and resident & non-resident patents. The implications of our findings draw from a broad range of findings to provide greater clarity on the nature and types of interactions between innovation (resident and non-resident patents), with the pass-through to ICT exports and transmissions from ICT imports providing a better gauge to the Chinese economy by employing GDP per capita. This study emphasizes the products of innovations and the pass-through by utilizing ICT exports and Imports, while the variables – patents and researchers – are measured against GDP per capita.

Theoretical Framework and research hypothesis

Hypothesis

The study seeks to investigate the nature of the relationship between key metrics pertaining to innovation pass-through i.e. ICT exports and ICT imports and GDP per capita, as well as drivers of innovation such as Researchers, resident patents, non-resident patents.

The hypothesis outlined below are informed by the innovation and economic growth literature, but the need to identify and understand the nature of the relationships in this study, will allow for a more granular understanding of the qualitatively –driven parts of Chinese inventions and those triggered by cross-border trade. The hypothesis are as follows:

Variables.

ICT goods exports is based on the World Customs Organization's Harmonized System (HS) which defines ICT products (including ICT goods). ICT goods must either be intended to fulfill the function of information processing and communication by electronic means, including transmission and display, or use electronic processing to detect, measure and/or record physical phenomena, or to control a physical process. This indicator is measured in million USD.

ICT imports: According to Index mundi, ICT imports include information and communication technology goods imports include computers and peripheral equipment, communication equipment, consumer electronic equipment, electronic components, and other information and technology goods (miscellaneous) (Index Mundi, 2019).

ICT exports: ICT goods exports (% of total goods exports) Definition: Information and communication technology goods exports include computers and peripheral equipment, communication equipment, consumer electronic equipment, electronic components, and other information and technology goods (miscellaneous) (Index Mundi, 2019).

Patents (Residents and non-residents): Patents are a form of intellectual property that protect a product from infringements and exclusively gives the owner the right from said infringements by way of selling, producing or importing for limited number of years. According to the OECD, patents are a key measure of innovation and can be used to track pass-through across a range of sectors. The study uses patents and non-patents in other to understand the relationship to ICT imports and exports.

Researchers: The number of researchers refer to people engaged in or employed in research activities in a range of sectors spanning health sciences, industrial production and software amongst others. The study uses researchers per thousand in other to ensure the outcome are "floats" i.e. non-integers with decimal places such as 1.25 or 0.25. The study utilises floats in a bid to ensure a standardised approach is used across the analysis as the "df. corr" function used to verify the nature and extent of relationships without transformations to integers or non-decimal numbers.

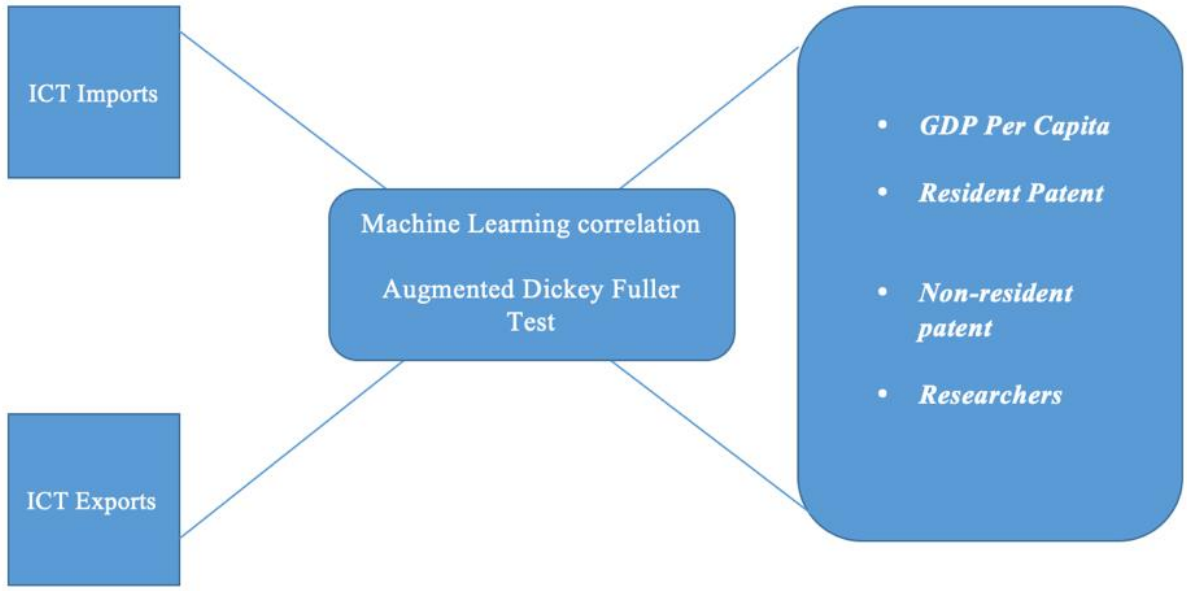


Figure 2.1: Empirical framework for ICT-trade and innovation

Variables.

ict(ex)_{t+1}: Equals the percentage change of ICT exports from China.

ict(imp)_{t+1}: Equals the percentage change of U.S. ICT imports to China.

pnt(res)_{t+1}: Patents from residents.

pnt(nonres)_{t+1}: Patents from non-residents.

$\text{Rs}_{000,t+1}$: Researchers per thousand.

$\left(\frac{\text{GDP}}{\text{pop}}\right)_{t+1}$: GDP per capita.

The hypotheses are represented as following.

H_I ict(imp)_{t+1}: are positively correlated to $\left(\frac{\text{GDP}}{\text{pop}}\right)_{t+1}$

H_A ict(imp)_{t+1}: are negatively correlated to $\left(\frac{\text{GDP}}{\text{pop}}\right)_{t+1}$

The hypothesis H_1 investigates whether ICT imports from the U.S. are positively correlated with GDP per capita, while the alternative hypothesis tests the reverse and is denoted H_{A1} ict(imp)_{t+1}.

H_2 ict(imp)_{t+1}: are positively correlated to pnt(res)_{t+1}
H_{A2} ict(imp)_{t+1}:are negatively correlated to pnt(res)_{t+1}

The hypothesis H_2 verifies whether ICT imports from the United States are positively correlated with patent from Chinese residents, while the alternative hypothesis tests the reverse and is denoted H_{A2}

H_3 ict(imp)_{t+1}: are positively correlated to pnt(nonres)_{t+1}
H_{A3} ict(imp)_{t+1}: are negatively correlated to pnt(nonres)_{t+1}

The hypothesis H_3 verifies the posited positive correlation between ICT imports from the United States and GDP per capita. Meanwhile the alternative hypothesis tests the reverse and is denoted H_{A3}.

H_4 ict(imp)_{t+1}: are negatively correlated to $\text{Rs}_{000,t+1}$
H_{A4} ict(imp)_{t+1}: are positively correlated to $\text{Rs}_{000,t+1}$

The hypothesis H_4 investigates whether ICT imports are negatively correlated to a number of researchers. Meanwhile, the alternative hypothesis tests whether ICT imports are positively correlated to a number of researchers per thousand.

H_5 ict(ex)_{t+1}: are positively correlated to $\left(\frac{\text{GDP}}{\text{pop}}\right)_{t+1}$
H_{A5} ict(ex)_{t+1} : are negatively correlated to $\left(\frac{\text{GDP}}{\text{pop}}\right)_{t+1}$

The fifth hypothesis tests whether ICT exports are positively correlated to GDP per capita. The alternative hypothesis tests the reverse proposition.

H_6 ict(ex)_{t+1} : are positively correlated to pnt(res)_{t+1}
H_{A6} ict(ex)_{t+1} : are negatively correlated to pnt(res)_{t+1}

The hypothesis H_6 tests the proposition that ICT exports are positively correlated to patent. Meanwhile, the alternative hypothesis tests whether ICT exports are negatively correlated to patents.

H_7 ict(ex)_{t+1}: are positively correlated to pnt(nonres)_{t+1}
H_{A7} ict(ex)_{t+1}:are negatively correlated to pnt(nonres)_{t+1}

The hypothesis H_7 tests the proposition that ICT exports are positively correlated to non-resident patent. Meanwhile, the alternative hypothesis tests whether ICT exports are negatively correlated to non-resident patents.

H_8 ict(ex)_{t+1}: are positively correlated to $\text{Rs}_{000,t+1}$
H_{A8} ict(ex)_{t+1}: are negatively correlated to $\text{Rs}_{000,t+1}$

The hypothesis H_7 tests the proposition that ICT exports are positively correlated to number of researchers per thousand. Meanwhile, the alternative hypothesis tests whether ICT exports are negatively correlated to number of researchers per thousand.

3. Research Methodology

The study employs a quantitative approach to investigating the presence and nature of relationships amongst ICT imports, ICT exports, number of researchers per thousand, patents – residents, patents – nonresidents, GDP per capita. The study employs a machine-learning approach in testing the hypothesis outlined in Chapter three. The Pearson's correlation, entailed creating a data frame, verifying the presence of a unit root via the augmented dickey-fuller test.

The data frame titled "df" encompasses the variables outlined in the study, and the relevant statistical libraries such as Pandas, matplotlib and the application program interface is used to facilitate the application of relevant libraries. The machine-learning approach to econometric analysis, allows for a diverse range of processes to be applied to the data, ranging from visualization via heat maps, to better illustrate the nature of relationships amongst the variables. Where "df" = the data frame comprising GDP per capita, ICT imports and Exports, researchers (per thousand) resident and non-resident patents. ICT imports and exports, resident and non-resident patents, researchers per thousand of the population and GDP per capita

Furthermore, the "corr" function is applied to the data frame and the visual representations underpin the outcomes to facilitate a less nuanced understanding of the variables. Rather than seek to measure the predictive ability of said variables, which fall outside the confines of this paper, the study seeks to employ a novel approach to correlation and hypothesis-testing. Meanwhile, a heat map is applied to synchronously link each relationship and allow for a visual representation of the presence of stationary. While persistent statistical properties are seen to change over time, the augmented dickey-fuller test is used to verify the presence of any such relationships.

Machine learning Libraries used in statistical analysis.

The study employs a machine learning approach to data analysis and hypothesis. As such, it requires the import of several libraries that facilitate data cleaning and hypothesis testing via Python, a programming language. The libraries imported are as follows. Pandas enables the software, to read the data into the program. Furthermore, matplotlib facilitates plotting of the variables outlined above. The summary statistics and the outlined econometric tests are facilitated via the libraries Statsmodels, Sklearn and Scipy.

Corr: The study utilizes a Pearson's' correlation via the syntax "df.corr". The correlation matrix is calculated via the syntax outlined below. Meanwhile, the visual representation via a "heatmap" availed by the library "seaborn". This was first introduced into the study as "import seaborn as sns"

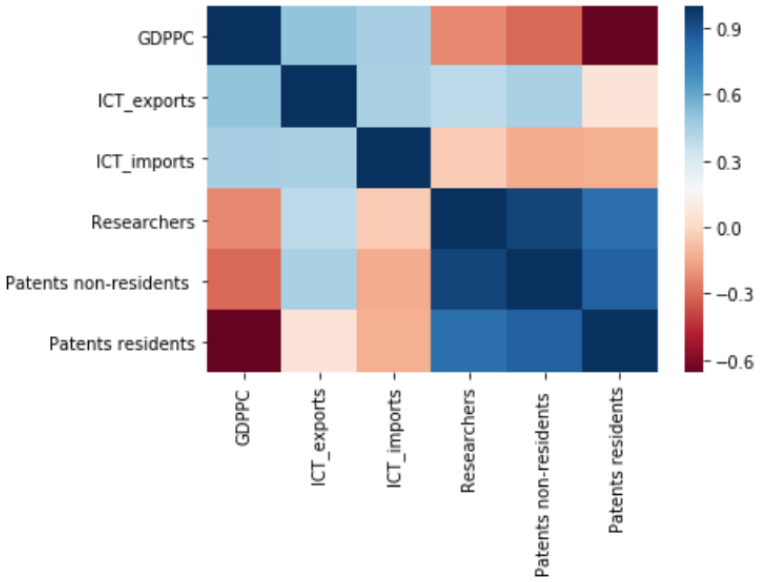
Augmented Dickey-Fuller: The Augmented Dickey-Fuller is used to test whether the time series in stationary. I.e. its statistical properties are static and do not change over time.

- The null hypothesis investigates the presence of a unit root in the time series sample.
- The alternative hypothesis verifies the absence of a unit root. In other words, this test whether the given time series is stationary.

The study fails to reject the null hypothesis for ICT imports, number of researchers and Per Capita GDP. Meanwhile, the ADF statistics for ICT exports and patents and higher than the critical values. While these suggest the presence of stationary in the data, the inclusion of said variables are driven by the fact that a significant portion of Chinese exports comprise imported products; This chimes with findings from Yuging Xing (2019).

Meanwhile, the ADF statistic for patents are higher than the critical values as the competitive pressures from ICT imports as well as the state-driven model of economic development suggest

bi-directionality amongst ICT imports and patents. Similarly, non-residents are also found to be statistically significant as the ADF statistic at -2.05 is higher than the critical value.



Source: Author's calculations

The work of Kot et al. (2020), Kot et al. (2019), and Haque et al. (2019) revealed that the adoption of sampling techniques could be used by making proper considerations to avoid biases through having fair representation of the sample. In this study, different techniques of non-probability sampling technique are combined to determine sample size. Purposive, snowball and convenience sampling techniques are types of non-probability sampling techniques (Haque, Sher, & Urbanski, 2020; Haque, Yamoah & Sroka 2020), which are used in the present study. Using Urbański and Haque (2020) approach of ensuring the fair representation, the biases are avoided. Hence, it is preferred because the resources are limited, and the attempt was made to ensure data analysis procedure remains cost-effective (Ślusarczyk and Haque, 2019). Using sophisticated tools, researcher determined the relationship.

4. Results, Finding and Discussions

Based on the algorithms and tests employed in the study, the findings of the study are outlined in greater detail below. Policy implications are illustrated and supported by relevant findings from the literature.

H_1 $ict(imp)_{t+1}$: are positively correlated to GDP_{per}-capita year, Δ %
H_{A1} $ict(imp)_{t+1}$: are negatively correlated to GDP_{per}-capita year, Δ %

The study finds a positive correlation between ICT imports and GDP per capita. The 0.45% correlation is mildly strong, but this suggest a greater contribution to overall GDP growth. The extent of diffusion from the is palpable; as argued by Chatham house's, Jue Wang (2019) international trade stimulates innovation. This finding, however true is contingent on the innovation backdrop of an economy. In China's case, its state-led model of innovation ensures forced technological transfers in exchange for access to business licenses or market access. Admittedly, Roller and Waverman (2001) find a strong positive relationship between Telecommunications, infrastructure investment and economic growth. It is important to note that the study spanning 1970 – 1990 includes infrastructural development, which suggest that the positive impacts of trade are contingent on an advanced ICT system, one that prioritizes electrification, digitization in payments, taxes, online market places, cloud computing, energy, telecoms infrastructure and information storage.

Policy implication:

Emerging markets seeking to leverage the full benefits of international trade must ensure that the digital infrastructure prioritizes technology and skills transfers, formalized into law, whilst the digital space spanning payments comprises a wealth of companies and all business functions should be remote i.e. performed online in other to address governance issues, whilst facilitating the uptake of innovation and ensuring there are domestic competitors for every good or service that is included in international trade. By formalizing technology transfers from online market places such as Amazon, and technology and skills transfers from foreign companies who engage in international countries, emerging economies can ensure that international trade contributes to the existing knowledge stock and facilitate the emergence of domestic incumbents in transport, renewable energy, electric grids, payments systems, online and mobile money transfers.

China's uniqueness in ICT imports cannot be understated; its ICT market grew 8.2% in 2018 reaching CNY 2.86 trillion (Fitch Solutions). As such, its state-driven model of economic development and innovation has ensured steady diffusions through various sectors. This has not only bolstered China's competitiveness as illustrated by its 5G technology and Huawei digital infrastructure used in cars, cloud storage and across a range of sectors spanning services such as restaurants, manufacturing, airlines, green energy production and grid monitoring as well as transport.

H_3 ict(imp)_{t+1}: are positively correlated to pnt(res)_{t+1}
H_{A3} ict(imp)_{t+1}: are negatively correlated to pnt(res)_{t+1}

The study finds a negative correlation between imports and resident patents at -0.13. This is not surprising as the rate of diffusion from ICT trade is more palpable in exports as the transmissions into the economy spurs innovation across a range of sectors spanning health care, social media and ICT, advanced manufacturing, precision agriculture and vertical farming. This is even more apparent in China as its technology transfers suggest a more "co-operation-driven" model of competition. One that prioritizes a level playing field for domestic companies who do not possess the expertise.

A positive correlation will suggest reformed global IP laws that factor cross-border R&D collaboration rather than one that seeks to cement and legalize first mover advantage. The latter stymies innovation and development, and the absence of strong knowledge management frameworks exacerbate innovation-driven global imbalances in trade and macroeocnomiceconomic outcomes. As such, the social development goals are unlikely to be attained under current IP laws and only serve to exacerbate non-concessional loans veiled as official development assistance. In the absence of sufficient innovation pass-through through legally outlined frameworks to facilitate technology adoption, the economic divergence amongst richer and more technologically advanced nations and developing nations are likely to persist.

Policy implications:

ICT imports spur innovation by causing domestic firms to innovate, this was the case in Italy following what is termed, albeit in a contrived manner, a "China shock". This was nothing more than China leveraging its wage differential i.e. cheaper labor cost and technological advancements and intentionally crafted infrastructure in other to gain a competitive advantage. However, it is now evident that economic development via patented technology is drive by indigenous domestic innovations spanning agriculture, information and communication technology, advanced materials for road, physical and digital infrastructure, software and education.

It is, therefore, imperative for countries to set-up specific innovation units across a range of sectors, where best practices, findings and relevant research are shared in a practicable manner to ensure innovations are diffused throughout the economy and products and services reflect such

innovations in a manner that facilitates economic convergence towards high-income status, improves economic opportunity and bolsters productivity. The absence of a correlation is also consistent with China's raking in global patents; it remains one of the most technologically advanced economies with patents, trademarks and industrial designs rising by 11.6%, 28.3% and 12.7% respectively. China ranks first in patent fillings, trademarks and industrial designs. As such, ICT trade might have spurred competition, but its domestic innovation has been driven by its state-led model of economic development that has focused on building indigenous innovations.

Separate innovation and policy units must be designed with an emphasis on application in machine learning, artificial intelligence, agriculture, health care, finance, digital technology and technological innovation.

H_3 ict(imp)_{t+1}: are positively correlated to pnt(nonres)_{t+1}
H_{A3} ict(imp)_{t+1}: are negatively correlated to pnt(nonres)_{t+1}

The study found a negative correlation i.e. -0.13 between ICT imports and patents from non-residents. The finding is consistent with the state-led model. While ICT imports are more closely correlated with ICT exports, the pass-through from patents likely life the potential growth rate. As such, the negative correlation between ICT imports and patents suggest the benefits of indigenous innovation accrue throughout the growth cycle while non-resident patents appear to drive domestic innovation.

Policy Implications

As the Chinese economy transitions from an investment-led towards a consumer and innovation led economy, the government should seek to ensure a faster diffusion from patents and ICT trade into the least developed parts of the economy. China's working age population currently stands at 806 million, a one million decrease from 2017. Given over 28.1% and 44.9% of its workforce are employed in the secondary and tertiary sector, policy makers should focus on ensuring a faster rate of pass-through from indigenous innovations to process innovations to facilitate the transition towards a highly digitized workforce. The extent of pass-through, not the types and extent of innovation will determine the success of the economic transition away from an investment-led to an innovation-driven economy. Furthermore, an ageing demographics suggest higher rates of pass-through as innovation can be more readily spread amongst its working age population. Meanwhile, China saw $34 billion in venture capital flows in 2018, and Shanghai, Shenzen, Hangzhou and Chengdu currently rank among the world's top tech cities. It is, however, incumbent on policy makers to ensure innovation gains both competitive and otherwise accrue to other cities by investing in clean technology, transport and virtual reality.

H_4 ict(imp)_{t+1}: are negatively correlated to $\text{Rs}_{000,t+1}$
H_{A4} ict(imp)_{t+1}: are positively correlated to $\text{Rs}_{000,t+1}$

ICT imports and researchers per thousand are negatively correlated, albeit marginally at -0.04. Researchers add to the knowledge stock, and are unlikely to be significantly present in ICT imports that appear to be driven by exogenously derived competition by way of U.S. imports. Not only does China rank first in the patent, trademarks and industrial designs, it also recorded a growth rate of 11.6%, 28.3% and 12.7% respectively in 2018. Meanwhile, the growth rate of patents in the United States fell 1.6%, while trademarks grew 4.35 in the same period.

Policy implications

China's changing demographics suggest policy makers should employ technological solutions in a bid to alleviate the burden on the government fiscal balances. As it current account deficits widens, it must focus on improving the quality of its tax base in other to lessen the demographic-driven constraints in future budgets. As such, the government should focus on marketable health

solution in a bid to generate economic activity whilst providing care that aligns with the needs of its ageing demographic.

H_5 ict(ex)_{t+1}: are positively correlated to $\left(\frac{\text{GDP}}{\text{pop}}\right)_{t+1}$

H_{A5} ict(ex)_{t+1} : are negatively correlated to $\left(\frac{\text{GDP}}{\text{pop}}\right)_{t+1}$

The study finds a positive correlation between exports and GDP per capita. Whilst the literature confirms hypothesis, Heshmati and Yang (2006) find a significant and positive relationship between ICT trade and GDP growth in China. As such, the granularity of the study only serves to confirm the proposition.

Policy implications

As the government's exports grow increasingly competitive driven by competition, its transition towards a more innovation-driven model will not only increase the domestic value added and of its exports, it will also improve the total value of the export basket. The general assumption had been that analysis of the existing mechanisms to support open innovation (Gusakov et al. 2020). As argued by Dani Rodrik (2006), much more than the gains from export competitiveness, China's future economic growth is contingent on the value-added component of its exports. As such policy makers should seek to align longer-term developmental needs with shorter-term applications in a manner that facilitates diffusions to process innovations.

H_6 ict(ex)_{t+1} : are positively correlated to pnt(res)_{t+1}
H_{A6} ict(ex)_{t+1} : are negatively correlated to pnt(res)_{t+1}

ICT exports are found to have a significantly marginal, albeit positive, impact on resident patents. The 0.06 outcome is consistent with the claim that patents tend to accrue over the growth life cycle and tend to be less palpable in ICT exports. The latter, is driven by tech-centric competition on products spanning computers, laptops, solar panels and cloud computing. Admittedly China's manufacturing process is characteristically "assembly-like" in nature. In other words, the value of ICT exports might be, somewhat, overstated as a significant portion of the value-added is externally derived.

Policy implications

In other to facilitate the transmissions from patents from residents to ICT exports, it should incentivise market-centric innovations that address structural vulnerabilities stemming from its ageing demographics to the regional imbalances that inevitable results from knowledge clusters.

H_7 ict(ex)_{t+1}: are positively correlated to pnt(nonres)_{t+1}
H_{A7} ict(ex)_{t+1}:are negatively correlated to pnt(nonres)_{t+1}
The hypothesis H_7 tests the proposition that ICT exports are positively correlated to non-resident patent. Meanwhile, the alternative hypothesis tests whether ICT exports are negatively correlated to non-resident patents.

Policy implications

However peculiar, ICT exports are positively correlated to non-resident patents. This is not surprising as the value-added of Chinese ICT exports are externally-driven. As such, the foreign-based components of such innovations likely accrue to Chinese It exports. As such, the 0.45 correlation amongst both variables suggest greater impact from U.S. ICT imports. One could therefore assert that U.S. ICT imports incentivised a great deal of domestic competition.

H_8 ict(ex)_{t+1}: are positively correlated to $\text{Rs}_{000,t+1}$
H_{A8} ict(ex)_{t+1}: are negatively correlated to $\text{Rs}_{000,t+1}$

The hypothesis H_8 is found to be true, with ICT exports and researchers' per thousand positively correlated at 0.39. Whilst a strong correlation does not equate to causation, this view is consistent with a somewhat faster rate of pass-through from the number of researchers employed in research activities to ICT exports. As the content of the Chinese export baskets changes synchronously to its model of economic development, we are likely to see a faster transmission from researchers into China exports and across regions spanning the tech-centric city.

Policy implication.

China currently ranks first in patent fillings, trademarks and industrial designs, which will become increasingly apparent in its exports spanning operating technology for vehicles, 5G products and ICT products and equipment to cloud computing. This trend suggests positive net spill overs from economic growth into the real economy. Policy makers should therefore lessen the distributional effects, which tend to accrue to a service-driven model of economic growth. The above recommendations are supported by findings from Jason Dedrick, Kraemar and Shih (2014); they find the diffusions from advanced economies to developing countries much more apparent. The study that finds a 0.45 positive correlation between ICT exports and number of researchers; this suggest that a greater portion of Chinese exports are driven by indigenous innovations. Admittedly, this is consistent with the Chinese state-led model of economic development, but also suggest a faster rate of transmissions from ICT trade with the United States. While the number of researchers tend to contribute to the potential growth rate, competition with foreign firms have exacerbated competitive pressures in the Chinese market.

5. Conclusion

The last decade has culminated unprecedented changes in global trade, with the Chinese economy becoming central to global manufacturing and supply chains. As China has integrated global value chains and displaced both Germany and the U.S. as the largest export economy, it has developed synergies across manufacturing and technology supply chains. These rely on imports of vital inputs from the U.S. such as semiconductors for Huawei phones or advanced chips from U.S. multinationals. As such, imports from the United States have become indispensable for domestic manufacturers in China, as well as assembly plants that are now maturing across most urban centres.

China has slowly opened its economy as multilateral institutions have argued the merits of free trade and less restrictive policies. As China has become entrenched to more advanced economies, imports have played an increasingly important role. Ict trade has had a noticeable and quantifiable effect on Chinese GDP and Standards of living. This study investigates the transmissions from ict-trade to innovation and its relationship with per capita GDP outcomes. The study finds a positive correlation between ict imports, ict exports and per capita GDP. This suggest a faster rate of pass-through from ict imports to innovation-driven exports and explains the weak positive correlation of 0.44% exports and non-resident patents.

Global trade tensions between the U.S. and China have impeded trade amongst both superpowers, even as the rationale for free trade is palpable in greater gains in innovation, per capita GDP and broader firm and industry-level competitiveness. As such, the prevalence of trade amongst both superpowers bode well for economic growth, innovation and long-term competitiveness as they stand to enjoy from a large consumer base, demand-driven innovation and innovation driven by competition. Admittedly, such an outcome is only possible if China were to reform intellectual property laws, refrain from forced technology transfers and emphasises indigenous innovations. However salient, this paper finds significant cross-border benefits from trade activities to China from the United States.

Due to intentional policies, skills and technology transfers; China stands to benefit from continued trade with the rest of the world. However, it now ranks number one in patents, industrial designs and trademarks, which creates an incentive for it to protect in intellectual property. However, China's approach to trade i.e. forced technology and intellectual property theft can be more readily applied across its trading partners, more so in BRI countries that are increasingly in need of technology to up skills their workforce. This paper finds that imports boost innovation and countries should pursue free trade in other to benefit from positive spillovers.

References

Aghion, P., and Howitt, P. (1988). *Growth and Cycles through Creative Destruction*, Unpublished, University of Western Ontario.

Chen, Kaihua & Zhang, Yi & Fu, Xiaolan, (2019). International research collaboration: An emerging domain of innovation studies?, *Research Policy,* 48(1), 149-168.

Dedrick, J., Kraemar, K. and Shih, E. (2014). Information Technology and Productivity in Developed and Developing Countries. *Journal of Management Information Systems*, 30(1).

Gusakov, A., Haque, A. U., & Jogia, A. V. (2020). Mechanisms to Support Open Innovation in Smart Tourism Destinations: Managerial Perspective and Implications, *Polish Journal of Management Studies,* 21(2), 142-161.

Haque, A. (2012). *Theoretical Perspective of Local Government - Literature Review.* Research Institute of Behavioural Psychology. MPRA Paper No. 46301. Retrieved from: https://mpra.ub.uni-muenchen.de/80754/1/MPRA_paper_80754.pdf

Haque, A.U., Nair, S.L.S., & Kucukaltan, B. (2019). Management and Administrative Insight for the Universities: High Stress, Low Satisfaction and No Commitment, *Polish Journal of Management Studies,* 20(2), 236-255.

Haque, A. U., Sher, A., & Urbański, M. (2020). Is the role of Authentic Leadership Effective in Managing Occupational Stress and Psychological Capital? *Forum Scientiae Oeconomia,* 8(2), 59-77.

Haque, A. U., Yamoah, F., & Sroka, W. (2020). *Willingness to Reduce Food Choice in Favour of Sustainable Alternatives: The Role of Government and Consumer Behaviour (chapter 3)*, In: W. Sroka (ed), Perspectives on Consumer Behaviour, Springer.

Heshmati. A. & Wanshan. Y. (2006). *Contribution of ICT to the Chinese Economic Growth,* Ratio Working Papers 91, The Ratio Institute.

Huo, H., Cai, H., Zhang, Q., Lui, F., and He. K. (2015). *Life-cycle assessment of greenhouse gas and air emissions of electric vehicles: A comparison between China and the U.S.,* 108, 107-116

ICT goods exports (% of total goods exports) (2019). *ICT goods exports*. Available at: https://www.indexmundi.com/facts/indicators/TM.VAL.ICTG.ZS.UN

Index Mundi (2019). *ICT goods imports (% total goods imports) definition.* Available at: https://www.indexmundi.com/facts/indicators/TM.VAL.ICTG.ZS.UN

Index Mundi (2019). *ICT goods export's (% total good imports)*. Available at: https://www.indexmundi.com/facts/indicators/TM.VAL.ICTG.ZS.UN

International Monetary Fund. (2004). *R&D, Innovation, and Economic Growth: An Empirical Analysis*. Prepared by Hayla Uku. IMF working paper

Kot, S., Haque, A.U., and Baloch, A. (2020). Supply Chain Management in SMEs: Global Perspective, *Montenegrin Journal of Economics,* 16(1), 87-104

Kot, S., Haque, A.U., and Kozlovski, E. (2019). Mediating Effect of Strategic Supply Chain Management on Social and Environmental Sustainability: Evidence from SMEs of Canada,

Iran and Turkey, *International Journal of Supply Chain Management,* 8(6), 105-117.

Kuo, C-C., and Yang, C-C. (2008). Knowledge Capital and Spillover on Regional Economic Growth: Evidence from China, *China Economic Review*, 19(4), 594-604.

Jorgenson, D., & Khuong, V. (2016). The ICT revolution, world economic growth, and policy issues. *Telecommunications Policy*.

Lars-Hendrik R., & Waverman, L. (2001). Telecommunications Infrastructure and Economic Development: A Simultaneous Approach, *American Economic Review*91(4), 909-923, September.

Li Wenfang in Guangzhou (2019). *6 Chinese cities among world's top 30 in tech*. Available at: https://www.chinadaily.com.cn/a/201904/11/WS5caf0754a3104842260b5b3b.html

Linda, Y. (2009). Patent Laws and innovation in China, *International Review of law and Economics,* 29(4).

Pyka.A and Anderson.E.S. (2012), *Introduction: long term economic development – demand, finance, organization, policy and innovation in a Schumpeterian perspective.* 22, 621-625

Schaaper, Martin (2009). *Measuring China's Innovation System: National Specificities and International Comparisons*, STI Working Paper 2009/1, Statistical Analysis of Science, Technology and Industry, OECD, Paris.

Schumpeter, J. A. (1934). *The Theory of Economic development*. Oxford University Press: London

Ślusarczyk, B., & Haque, A. U. (2019). Public services for business environment: challenges for implementing Industry 4.0 in Polish and Canadian logistic enterprises. *Administratie si Management Public*, (33), 57-76.

Romer. D. (2006). *Do Firms Maximize? Evidence from Professional Football*. University of California, Berkeley and National Bureau of Economic Research

Romer, P. M. (1990). Endogenous Technological Change, University of Chicago, *Journal of Political Economy,* 98(5).

Urbański, M., and Haque, A.U. (2020). Are You Environmentally Conscious Enough to Differentiate between Greenwashed and Sustainable Items? A Global Consumers Perspective, *Sustainability,* 12(5), 1-26.

Wang, J., & House, C. (2019). *The implication of Global Technological Innovation on U.S. –China strategic competition.*

Yuging Xing (2019). *China's High-Tech Exports: The Myth and Reality (2014): The Earth Institute at Columbia University and the Massachusetts Institute of Technology*.

Zhang, C., Douglas, Z., Zeng, W., Mako, P., and Seward, J. (2009). *Promoting Enterprise-Led Innovation in China,* The World Bank, Washington DC.

Appendix
Plot of Scatter Matrix