Endogenous Technological Change Model and Economic Growth in China: A Firm-Level Analysis

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Abstract: China's economic growth has been impressive since the 1978 reforms and even much better in the last two decades. The dominant composition of China's merchandized exports having changed from less sophisticated primary goods during the reforms to more sophisticated machinery and electronic products in recent years, and hence rapid economic growth, there has been an increasing need to investigate the existence of evidence of the predictions of the endogenous technological change model in China's growth especially since capital accumulation, the factor which is widely credited to have propelled growth in China becomes obsolete with increasing quantities. The study therefore employs a combination of logistic regression, OLS, and high-dimension fixed effects to examine the existence of the growth inducing 3 formal sectors of the Romer (1990) model. The findings show China's to have properly implemented the endogenous technological change model and transitioned from their prior dependence on capital accumulation.

Keywords: logit, R&D, technological change, China
JEL Classification : O32, O33 O41, O47

1.0 Introduction

China is being heralded as the greatest economic miracle of all time having lifted about 680 million people out of extreme poverty and reduced her national poverty rates down from 84% to 10% between 1980 and 2010, a period of only 30 years (The Economist, 2013). Currently an upper middle-income economy and with an average annual growth rate of about 10% from 1979-2017 (Morrison, 2019) , China is ranked by the International Monetary Fund (IMF) as world's second largest economy behind the United States of America (USA) with an economy of 13,368,073 billion USD (GDP at current US prices) in 2018, a figure projected to increase to 14,140,163 billion USD and 15,269,942 billion USD in 2019 and 2020 respectively (IMF, 2019).

Following a rigorous economic reform programme in 1978, China is now by far the world's top exporting country having recorded a total export value of 2,263.33 billion USD in 2017 and an export growth of more than 17% between 2002 – 2012 except in 2009 and 2012 (Statista, 2019b). China exported a total value of 2,487 billion USD worth of manufactured goods in 2018, a value which is 178 and 823 billion USD more than the total value of goods exported by EU (28) and the USA respectively at the same period (Statista, 2019a). The World Trade Organisation (WTO) puts this figure at 2,318 and 1179 billion USD for China and the USA for that same period (WTO, 2019). These statistics make China the world's leading merchandized exporter with 13% of the world's total exports and the world's second top exporter of services behind the USA in 2018 (Statista, 2019a).

The aforementioned economic characteristics of China as described above have not always been this impressive. In fact, prior to the economic reforms of 1978, the Chinese economy was centrally planned in such a way that industrial and manufacturing activities were limited to state owned enterprises while private firms and foreign firms hardly existed. This created very little incentives for firms, and workers to be productive and be concerned with the quality of their produce (Morrison, 2019). During the economic reforms of 1978, China's GDP at current US Prices stood at about 149.541 billion USD (World Bank, 2020a) while the economy had an average annual growth rate of 4.4% (Morrison, 2019) since 1953 when Mao Zedong was chairman of the People's Republic of China. The state of the economy resulted in low outputs and consequently low exports which was a total value of only 14 billion USD in 1979 (Morrison, 2019). In 1965 and the years towards the economic reforms of 1978, China's exports to the rest of the world consisted more of primary and unprocessed commodities which made up 48% of exports and less of machinery, and transport equipment's which contributed only 3% to total export value of only 2.2 billion USD. (Frankenstein, 1991). The Observatory of Economic Complexity (OEC) shares more light on China' s export composition as at the time of the 1978 economic reforms. According to Simoes & Hidalgo (2011) of the OEC, China's export measured at the SITC 2 classification in 1979 comprised oil (16%), garments (15%), textile (14%), meat and eggs (6.1%) cotton, rice, soy beans, and others (4.7%), food processing (4.2%), home and office products (3.4%), chemical and health related products (3.4%), machinery (3.3%), and construction materials and equipment (3.1%) many of which required low skills and technical know-how.

As part of the Chinese economic reforms of 1978 led by, Deng Xiaoping, then paramount leader of the People's Republic of China, China implemented a number of policies among which included price and ownership incentives, economic and development zones to boost and attract foreign direct investment, export promotion, importation of foreign technology into China, decentralization of economic policymaking especially, and trade liberalization and removal of price controls. (Morrison, 2019). Many of these policies were capital and labour oriented and required the use of machines and physical labour. The outcome of these economic reforms as we see today are the high and consistent growth rates of the economy leading to a doubling of the economy every 8 year from 1979-2018 and an increased gross national savings rate which is the highest among major economies in the world (Morrison, 2019).

Yueh (2015), argues that these market oriented reforms as embarked on by China have been the reason behind the ever improving total factor productivity (TFP) of China which has grown at an average of 3.7% from 1979 to 2003 and 2.8% since 2004 and thus contributed to about 40% of China's GDP until now. According to Yueh (2015), although TFP has made a significant contribution to China's growth since the open door policies of 1978, Factor accumulation has accounted for 60% to 70% of China's growth, with capital accumulation alone contributing more than any other factor since it has contributed 3.2% points to the 7.3% growth in output per worker and 4.2 % of the 8.5% average annual growth rate of the Chinese economy since the reforms.

With the economic reforms having taken place over 40 years ago, the composition of China's exports to the rest of the world over the years has changed in composition in ascending order of magnitude, in terms of the number of goods exported, the different types of goods exported and even the quality of the goods exported. Simoes & Hidalgo (2011) from their OEC platform show that the top commodity exports of China in 2000 using the SITC 2 classification were electronics (36%), garments (23%), machinery (8.0%), construction materials and equipment (5.3%), home and office products (4.8%) textiles fabrics (3.0%), and chemicals and health related products (2.6%). Fast-forward to 2018, the composition of China's merchandized exports has changed again in favour of more sophisticated products that require higher skills and knowledge than in 1979 and 2000. World Bank (2020b) via the World Integrated Trade Solution (WITS) platform show machines and electronics to have constituted 43.85% of Chinese exports in 2018, an increase of 40.55% compared to the value exported in 1979, followed by in descending order, textiles and clothing (10.69%), (metals (7.47%), chemicals (5.48%), transportation (4.73%), plastics and rubber (4.12%), stone and glass (2,87%), footwear (2.47%) all of which are more sophisticated than meat and eggs, cotton, rice, and soy beans which occupied a sizeable portion in China's exports composition 40 years ago.

It is the authors conviction that the economic miracle experienced by China and seen in indicators such as their GDP, GDP growth rate, and export composition has more to do with knowledge development and accumulation of ideas over time than capital accumulation and other policies that are said to be responsible for China's success. This is because capital is proven to suffer from diminishing returns after extreme levels are employed in production and hence stops growing after a threshold is passed (Jones, 2017). Therefore, capital cannot be responsible for the long periods of growth seen in China. On the other hand, ideas and knowledge as proposed and put forward by Romer (1990) in his thesis on endogenous technological change are not subject to diminishing returns and can therefore contribute to longer periods of growth. It is the authors believe then that the impressive Chinese economic growth I recent decades has been propelled by knowledge and ideas produced by human capital having depended on capital in the early years of post-1978 reforms.

The study therefore employs a cross section firm level enterprise survey dataset for China collected by the World Bank to examine the role of the Romer (1990) model of endogenous technological change and her 3 formal sector preposition in China's production structural, output and sales and by that ascertain if China has indeed managed to transition from dependence on capital to creating knowledge and ideas necessary for economic growth and development A combination of logistic regression, ordinary least square (OLS), and high dimension fixed effects (HDFE) models are employed to scrutinize the case of the role of the endogenous technological change model in China's economic growth.

The findings of the study are enlightening. Among other things, the study finds the sectoral predictions of the Romer (1990) model to be true in China's production structure, production of intermediate goods and sale of final consumer goods while variables related to the 3 factors of quality and quantity of labour, capital and improvements in technology are found to be insignificant in long run growth determination . The factors that are responsible for the validity of the predictions in each of the 3 sectors in Romer (1990) are however not as broadly defined by Romer (1990). In that, only specific forms of human capital lead to the creation of knowledge and ideas proxied by R&D rather than the broad definition of human capital. These R&D produced by Chinese firms contribute immensely to the production of intermediate goods while specific human capital, R&D and intermediate output or produce all together contribute significantly to the sales that accrue to Chinese firms from the sale of final goods. The Romer (1990) model has therefore been effectively implemented by China and the consequence are the extreme levels of economic growth reported by china which is much more than those they recorded when they relied more on capital for production.

1.1 Presentation of the Romer (1990) model

Economic growth theories have existed since the very foundation of economics and have been pioneered by leading classical economist including Adams Smith. Among the popular groundbreaking economic growth models in the past decades are the neoclassical growth models and the endogenous growth models which includes the Romer (1990) model. The neoclassical economic growth modules postulate that technological progress which produces long term growth emanates from exogenous factors which are independent from those within the economy (Todaro & Smith, 2012) and therefore perfectly contradict the endogenous growth models which explain otherwise. One such distinctive neoclassical growth model is the Solow model which postulates that the engine of growth of the economy is capital (Solow, 1956) and hence makes capital endogenous to the economy, a conversion from its exogenous nature (Jones, 2017). Altogether, the neoclassical models explain long term growth to be the product of one or more of 3 factors: increases in quality and quantity of labour via population growth and education, increases in capital made possible by savings and investment and improvements in technology (Todaro & Smith, 2012). On the other hand, endogenous growth models which determine economic growth from within the model. A significant contribution to these theories are the innovation based theories pioneered by the Schumpeterian growth theory which likens economic growth to the outcome of a sequence of quality improving innovations (Aghion, 2002) and hence the need to devote large fractions of output to research and development (Ugur, 2016). With increased involvement in research and development and hence increased innovation, all other factors being equal, growth will remain positive if there is no tendency for the economy to run out of ideas (Barro & Sala-i-Martin, 2004).

The endogenous technological change model (Romer, 1990) (explained into details below), is the most important paper in growth literature since Solow's "A contribution to the theory of economic growth" in 1956 (Jones, 2019). Paul Romer by means of this paper proves that technological change is the results of efforts by researchers and entrepreneurs who respond to economic incentives (Jones, 2019). Regardless of its theoretical difference from the Solow (1956) model, it is said to be a build-up and a continuation to the Solow model since the Solow (1956) model is unable to produce the desired long run growth because its important inputs: labour and capital exhibit diminishing returns so that the model is only able to offset depreciation on capital (Jones, 2017). As a result, growth ceases after a certain capital threshold. However, from Romer (1990), labour and ideas have increasing returns together and returns to ideas are unlimited so that growth is sustainable with the Romer (1990) model. It is for this reason that the endogenous technological model as propounded by Paul Romer can better explain the Chinese growth trends much more than the Solow (1956) model.

The Romer model as popularly referred to in economics literature is an endogenous growth model formulated and propounded by Nobel prize winning economist for 2018, Paul M. Romer. The model is an extension of the Romer (1986) model on increasing returns and long-run growth in which Knowledge happens to be an input in production and thus exhibits increasing marginal production returns.

In the increasing returns and long run-run growth theory of Paul M. Romer, long-run growth is driven by the accumulation of knowledge by forward looking profit maximizing agents so that knowledge is the engine of growth of economies and should be the main stay of an economy if it is to grow. In the Romer (1986) model of increasing returns and long-run growth, knowledge exhibits 3 major characteristics which allows it to produce growth. In that, knowledge is an outcome of research and development (R&D) and has diminishing marginal returns so that an attempt to double efforts into research will not increase the new knowledge by 2. This is the characteristic of diminishing returns to production of new knowledge. Knowledge also has positive externality on other firms so that their production capabilities is impacted by the knowledge already acquired by other firms since knowledge cannot be perfectly hidden and protected from other firms. This is the characteristic of positive externality. Finally, knowledge when used together with other production inputs in the production of consumption goods exhibits increasing returns to production of outputs and this is the characteristic of increasing returns to production of output. These 3 characteristics of knowledge together produce growth in the model of increasing returns and long-run growth as explained in Romer (1986).

Paul M. Romer propounded another theory related to knowledge which is an addition to the theory of increasing returns and long-run growth. This new theory is found in his paper, “Endogenous Technological Change” and serves as the theoretical background for this study. This second model explains the process and rate of growth resulting from invention and consequent technical progress. Unlike in his model of increasing returns and long-run growth, growth in the economy in the endogenous technological change model is “driven by technological change that arises from intentional investment decisions made by profit maximizing agents” (Romer, 1990). In that, technological change is the engine of growth and is defined as the “improvements in the instructions for mixing raw materials” (Romer, 1990). The technological change theory is based on 3 premises the first being that technological change lies at the heart of economic growth, the second being that technological change arises from the intentional actions taken by people who respond to market incentives and the third being that instructions for working with raw materials are inherently different from other economic goods so that once these instructions are received and its associated cost borne, they can be used over and over with no additional cost.

Technological change is however embedded in human capital which is defined as the cumulative effect of activities such as formal education and on the job training (Romer, 1990). This stock of knowledge embedded in human capital is independent of both population and the size of labour force. However, unlike the traditional public good, it is excludable. This means that the presence of the carrier of the human capital is mutually exclusive such that he or she can be present at only one place or one firm in one particular time. Likewise, he or she is unable to solve many problems at a time. Irrespective of this excludable characteristic of knowledge, it is said to be non-rivalry in such a way that its use in one firm does not prevent or reduce the quantity available for other firms to use. Therefore, knowledge can grow and spillover to others who in turn can use it for other purposes without infringing on the excludable right of the creator of that knowledge.

With the use of 4 inputs namely capital, labour, human capital and technology, Romer (1990) argues the existence of 3 formal sectors of activity in an economy with preceding sectors depending on the output of successive sectors in the production of consumer goods and services. These 3 sectors form the bases of the analyses of this study and they are: the research sector, the intermediate good sector and the final good sector.

The research sector kick starts economic activity in this forward linkage sector dependent model until economic goods are produced and sold. In this sector human capital and already existing stock of knowledge are used to produce new knowledge or new designs. The productivity of this sector depends to a larger extent on the available stock of knowledge so that the larger the available stock of knowledge, the larger the output and evolution of the research sector. An important assumption in this sector is that labour and physical capital are fixed and constant such that they do not impact on the production of new designs or new knowledge.

In the intermediate goods sector, the new designs produced by the research sector are used together with forgone outputs as inputs to produce durable intermediate goods that are available for the production of final goods. Here, the new designs are bought by intermediate producers who then own exclusive rights to these designs and rent them to others to use for onward production or use them for their own internal production activities. The exclusive rights to these designs offer a sought of market power to the producers and this is the motivation which ensures intentional R&D.

The final goods sector is the last sector of the Romer economy. In this sector, final goods producing firms rent the intermediate goods which are produced in the intermediate sector and combine them with labour, human capital, physical capital and other producer durables to produce final outputs which can then be either consumed or saved as new capital. The consumption of these final outputs leads to a spillover effect of newly produced R&D and this increases the stock of knowledge available to the general public so that all other factors being equal there is long-term economic growth.

1.2 Review of Related Empirical Literature

Empirical economic literature surrounding the growth models responsible for the Chinese success story include those influenced by neoclassical growth models and those inspired by the endogenous growth models which includes Romer's endogenous technological change model. While some simply test the influence of such growth models on China's economic growth, others focus on testing the interaction and combination of growth models and their effects on China. In general, their findings have been consistent with economic growth theory although they are unable to point specific growth theories are responsible for the Chinese growth path.

Among the early economic growth models to have been suggested and implemented by economist are the neoclassical growth models including the Solow model. The Solow model and its effects on China has therefore been widely studied in economic literature. Such studies include Ding & Knight (2009) who used a 5 year interval data gathered from the Penn world tables, the world development indicators, and the statistical database of the Food and Agriculture Organisation (FAO) from 1980-2000 together with growth regression models estimated by general method of moments (GMM) to examine the extent to which the growth differences between China and other countries can be explained by the augmented Solow model. They find among things that high physical capital investment, conditional convergence gains, structural changes in employment and output, as wells as low population growth many of which are Solow variables to be responsible for China's relative success in economic growth. Ding & Knight (2009a) in their paper "Why has China grown so fast? The role of structural change" adds more by means of Bayesian model averaging, automated general-to-specific approach, and panel data system GMM to arrive at the conclusion that "improvements in productive efficiency have been an important part of the explanation for China's fast growth".

Hong Li et al. (1998) tested the neoclassical theory of economic growth using China which is the largest developing country in the world to examine the extent to which their growth process since 1978-1995 can be explained by the augmented Solow-Swan model. Among other Solow-Swan variables, greater investment in physical and human capital are found to produce higher growth rates of GDP per capita. To examine the relationship between the growth of domestic savings and economic growth in china, Hooi Lean & Song (2009) employed cointegration and causality tests and found China's economic growth to have a long run relationship with household and enterprise savings. Chow (1993) measured the contribution of capital formation on Chinese economic growth for the period spanning between 1952 and 1980 by estimating a Cobb-Douglas production. His findings reveal the absence of technological progress during the period of study and also that the high capital accumulation reported by the Chinese State did improve the total productivity of China. To investigate if growth regressions help us to understand why China has grown so fast and to know the type of investment that explain Chinese growth, Ding & Knight (2011) used related data from the China Compendium of Statistics (1949–2004) and China Statistical Yearbook (2005-2007) and applied panel data techniques to find that both human and physical capital promote economic growth and that investment in innovation, private investment, secondary and higher education have been important to Chinese economic growth.

Apart from studies that have sought to test the role of the neoclassical model predictions on the growth of the Chinese economy, several others have argued a strong influence of endogenous growth models on the Chinese economic miracle. This has led to an inquiry into testing the relevance of such models as the AK model, the Lucas model and most especially the Romer (1990) in China's economic growth. Romero-Ávila (2013) is one such study that focused on investigating the AK model and its influence on China's economic growth. Having investigated if large permanent movements in the physical investment rates lead to permanent movements in growths by means of methods including autoregressive distributed lag, Romero-Ávila (2013) concluded that the Chinese growth is consistent with the AK model and that the model better describes the Chinese growth pattern when it is augmented to make room for structural transformation, imbalances in factor endowments, and R&D based technology transfer. Jiang (2011) on the other hand focused on the Lucas (2009) model and investigated the patterns, causes, and implications of China's structural change and how it contributed to China's regional growth using 31 Chinese province level data gathered from Chinese statistical yearbooks (1980-2006) together with variance decomposition of output growth and found out that the Lucas (1990) model is consistent with structural change and growth in China.

Li (2005), by means of the multiple break unit root tests and Chinese provincial level data, investigated China's economic growth to identify the steady state and transitional growth paths of national and sectoral output and output per worker. His findings validated the importance of endogenous growth theory in China as it was found to be consistent with the growth behaviour of the Chinese economy. The importance of endogenous growth theories in China's economic history is once again emphasized by Wei et al. (2011) who tested the endogenous innovation growth theory for 27 provinces across China by means of panel data and standardized t-bar tests for unit roots for data from the Chinese statistical yearbook. The study found evidence of convergence which supports the presence and implementation of the endogenous innovation growth model in China. Lai et al. (2006) adds to the role of the endogenous growth theories in China's development by establishing an endogenous growth model with knowledge driven R&D in their paper "Technological spillover, absorptive capacity and economic growth" which employed Panel data estimation techniques and Chinese province level data from 1996-2002 and found long run growth to arise from improvements in absorptive capacity and higher human capital stocks. Finally, Hongyi Li & Huang (2009) examined the augmented Mankiw, Romer and Wiel (MRW) model which considers both health and education in human capital in the framework of the Chinese economy using panel data models and Chinese provincial data (1978-2005) and concluded that both health and education have positive significant effects on growth.

The empirical studies reviewed reveal the extent to which growth models and their role in China's economic development hav been studied. Regardless, studies vary widely with respect to their objectives, growth model of interest, methodology, dataset, scale of study and even findings. Related empirical literature surrounding the economic growth of China in all of its variety and to the best of the knowledge of the author as reviewed does not include one that actually tests the theory of endogenous technological change together with its sectoral predictions as propounded by Romer (1990). The data as used for many of the studies reviewed above happen to be macroeconomic data that concerns the economy as a whole and less of firm level data which is first of all primary data and comprises various data measurements and definitions that are missing from macroeconomic datasets that are used by several studies to investigate the growth responsible for the Chinese economic model. Furthermore, from the review of empirical literature, there seem to be a lack of consensus on what has actually propelled the Chinese economy to these greater heights in recent times since the model of growth which they are known to have used in times past is also used and implemented by several other countries who have unfortunately not seen the kind of growth rates posted by China in the last decades.

1.3 Objectives and Hypothesis of the Study

Following the gaps and inadequacies identified in the empirical literature surrounding the subject matter as introduced and discussed above, the study generally aims to examine the role of the Romer (1990) model of endogenous technological change in China's production structural and output change as well as sales. Specifically, the study aims at testing the 3 stages or sectors of the endogenous technological change model and by that answer the following questions:

1. How much R&D due to human capital do Chinese firms produce? (Stage 1)
2. How much R&D is used to produce intermediate goods in China? (Stage 2)
3. How much of final produce due to R&D do Chinese firms manage to sell? (Stage 3)

The hypothesis of the study which follows the outlined objectives is to ascertain if the Romer (1990) model has any role to play in the recent impressive and successful performances of Chinese firms. The null hypothesis (H_0) and the alternative hypothesis (H_1) are as follows:

$H_{0:}$ There is no significant relationship between the Romer (1990) model predictions and Chinese firm performance.

H_1: There is a significant relationship between the Romer (1990) model predictions and Chinese firm performance.

With a successful test and verification of this hypothesis and objectives respectfully, it shall be factually established if the endogenous technological change model as composed by Paul M. Romer in 1990 is still relevant in an ever-dynamic world especially in developing countries such as china whose economic dynamics differ from those of developed countries with whose parameters the theory was formulated with and tested.

The study has important policy implications as the findings will influence policy directions of developing economies who are still in pursuit of growth and desperately need to catch up with and converge to the level of growth of the global north as well as already developed countries who hitherto have pursued economic growth and development via other economic models and have struggled to implement or imitate the Chinese economic development path which is manufacturing aided. This shall bring closure to all misgivings or otherwise on the important role of human capital development and R&D implementation and usage in the pursuit for economic development and growth. It shall further add to existing literature as it brings to bear totally new dimensions that have hardly been touch on and researched by growth and development economist with respect to the changing trajectory and composition of Chinese manufacturing, firm performance and economic development.

The rest of the study is organized as follows: Chapter 2 discusses the data as used for the study and the source of the data. Chapter 3 describes the data to throw light on the specific details of the variables employed in the study. Chapter 4 discusses the econometric specification of the model and the identification of the methodology. Lastly, Chapter 5 discusses the results of the study and the conclusion with includes limitations and possible future research directions into the subject matter of the study.

2.0 Data and Data Sources

The study uses the World Bank enterprise survey data (World Bank, 2012) conducted in the People's Republic of China between September 2011 and February 2013. Since its publication, the dataset has widely been used in academic research to investigate different aspects of firms across the globe (including cross-country studies) and in China. Popular among the areas of firm studies the data has been applied are enterprise innovation studies such as Xu (2017) and Huang et al. (2017) both of whom studied innovation in enterprises vis-à-vis enterprise characteristics including ownership and size as well as Lin & Liu (2017) who investigated the topic of tax burden and firm R&D innovation. The data has equally been used in the investigation of human capital which is a contributing factor to knowledge development as stipulated by Romer (1990). Ranking high among the human capital related studies is (Wang et al., 2012) who applied the data in their study "The quality of enterprise human capital: Empirical evidence based on enterprise survey in China.

Apart from its application to innovation and human capital, the data has been used in research related to environmental regulation and the growth of small and medium sized enterprises (SMEs). These include Liu (2016) who applied the data to examine environment regulation and technological innovation in China and Wang (2016) who investigated the obstacles to growth and SMEs in developing countries. Therefore, this rich dataset has been widely applied in economic research and this demonstrates the extent to which it is acceptable and reliable.

The 2012 world bank enterprise survey in China interviewed 2700 privately owned firms and 148 state-owned enterprises from 25 metropolitan areas in China. However, owing to the objectives and hypothesis of this study, only the data on the privately-owned firms are used. Furthermore, due to issues of ineligibility, and incomplete responses etc., the final data employed comprises fewer number of firm observations with each firm having a unique firm identification number. The firms having been interviewed first in 2011 were interviewed for a second time to update their responses.

In general, the world bank enterprise survey which is conducted in several other countries aims to collect data on business environment indicators related to the state of private enterprises and also to track changes in enterprises over time to allow for such studies as impact assessment, and a lot more. Furthermore, the survey helps to reveal and asses the challenges and limitations of privately-owned enterprises and this is the first step to resolving these problems.

2.1 Descriptive Statistics

Appendix I provides relevant tables for descriptive statistics. From appendix 1, Table 1 shows summary statistics of key variables used for the investigation of the 3 stages of the Romer model as applied to China. These statistics include number of observations (obs.), the mean, standard deviation (SD), minimum values (min) and maximum values (max) of key variables for the study. The number of observations statistic provides information about the number or frequency of non-missing variables whiles the mean statistic is simply a measure of the average value recorded for a respective variable. The Standard deviation statistic measures how much the firms used for the study differ from the mean values of the variables employed. Lastly, the minimum value (min) and maximum value (max) statistics provide information on the lowest and highest data point of the variables employed. This gives a clear idea of the range and dispersion of data of a variable such that one understands how varied the variable is in the Chinese context. Stage 1 is used to explain the meaning, essence and impact of these statistics on the selected variable and what it means in the Chinese context. The explanations given to the stage 1 variables are similar and attributable to the variables in both stage 2 and in stage 3.

With respect to stage 1 variables, 2,692 firms provided responses to the binary response question as to whether they introduced new products or services whiles 1,667 provided binary responses to suggest that they made expenses towards developing innovation via R&D. Of the 2,692 and 1,667 firms who responded to having introduced new products or services and made R&D related expenses respectively, 47% introduced new products or services while 43% made expenses related to R&D either within their firms or together with other firms. From the standard deviations (SD) of the 2 variables; 0.499 and 0.495, the mean distributions of new products or services produced and R&D expenditure are not so far or different from firm to firm so that the production of new products and likewise R&D expenditure is done by almost half of Chinese firms without so much difference in their occurrence from firm to firm. It can then be deduced that almost half of Chinese enterprises introduced at least 1 new product or service and equally made expenses related to R&D in 2011. This suggests a relatively high rate of innovation in China all other factors being equal. These 2 statistics together make China a top innovative country and this is confirmed by China's ranking among the top innovative economies in the world as revealed by the World Intellectual Property Organisation (WIPO) and the World Economic Forum (WEF) who rank China 14/127

(Cornell University et al., 2019) and 28/141 (World Economic Forum, 2019) countries in the 2019 global innovation index and global competitiveness index respectfully. Indeed China increased its R&D expenditure by 42% between 2007 and 2013 and currently contributes more to global R&D expenditure than any other single country in the world and the global population put together (UNESCO, 2015).

Human capital is captured by the variables: Permanent full-time (FT) non-production workers, skilled production workers, female permanent full-time non-production workers, Full-time (FT) seasonal or temporary workers, Years of education of typical production worker, and FT permanent workers who completed sec. sch. (%) and FT permanent production employees trained (%). The variables "Permanent full-time non-production workers", skilled production workers, and female permanent full-time non-production workers are the most important human capital variables since they represent the carriers of knowledge as explained by the Romer (1990) model. Each of these 3 variables received 1664, 1645, and 1557 responses respectfully from the 2700 firms interviewed. However, due to the very high importance of these 3 variables since they determine to a larger extent the research and development (R&D) and innovation competences of firms. Therefore, they are included in the analyses although their shortfall will cause the sample size as given to reduce.

On the average Chinese firms tend to have more skilled production workers than non-production workers and this is depicted by the rather higher mean value of 95.04 of skilled production workers and 62.33 of non-production workers across the total number of firms interviewed. This I should say is relative and differs from firm to firm as the SD statistic reveal these two variables to be widely dispersed with 451.1 for non-production workers and 463.6 for skilled production workers far from their mean values of 62.33% and 95.04% respectively. Female full-time non-production workers happens to low among the non-production workers employed in Chinese firms as only an average of 17.89 are employed in a firm compared to the average of 62.33 non-production workers employed. Unlike the case of skilled production workers and non-production workers where there are issues with wide dispersion and hence number of employed differs largely from firm to firm, there exist relatively fewer female non-production workers across Chinese firms since its SD statistic of 64.27 is not so far from the mean value of 17.89. The UNESCO science report

(UNESCO, 2015) affirms these statistics as it shows China to have the highest count of researchers for any single country in the world.

The variables: Years of education of typical production worker, FT permanent workers who completed sec. sch, and FT permanent production employees trained (%) explain the state of human capital development in China with respect to education. Based on the responses provided, the typical production worker has 10.15 years of schooling while 60.22 % of permanent workers have at least a high school diploma. The maximum number of years of education for a typical Chinese production worker is 18 years and this corresponds to a master level education in most western countries in the world. Also 91.99% of Chinese production workers are trained or have received some kind of training related to their work. The average years of education is however widely dispersed since the corresponding SD statistic of 1.891 is so far from the average suggesting that years of education among Chinese workers differ from firm to firm and even from region to region. This is in tandem with Heckman (2005) who show Chinese urban regions to a have higher concentration of educated population than rural regions.

Irrespective of the successes of the Chinese economy, these human capital development indicators with respect to education are still low and behind the levels of the developed and industrial nations of the world. The lower levels of education attainment in China is confirmed by Li et al. (2017) who show China as lagging behind countries such as Brazil, South Africa, Korea, Mexico, Malaysia, Russia, Thailand, Turkey, Philippines, the OECD and the G20 etc., when it comes to its proportion of labour force who have college education and high school education in 2015.

Table 2 shows the sectoral distribution of firms as used for the study. Out of the total number of 2700 firms, 1692 are manufacturing firms and these represent 62.67% of the total number of the firms interviewed for the survey. 158 firms representing 5.85% of the total firms engage in retail activities while 850 firms provide other services different from manufacturing and retail. The sectoral distribution of the dataset is thus very suitable for the study since a majority of 62.67% of firms are manufacturing firms whose parameters are used in the formulation of the Romer (1990) model.

Production activity among firms in the database differ from one firm to the other. Although most firms engage in manufacturing activities, the firms in the database produce different end products or intermediate products and thus operate in different manufacturing industries or sub-sectors. Without any single industry dominating the dataset, in descending order of magnitude, most firms are involved in machinery and equipment (5.74%), and plastics and rubber (5.63%), hotels and restaurants (5.56%). Apart from these, the food, textile, non-metallic mineral products, Electronics, motor vehicle services firms each represent 5.44% of the total number of firms in the dataset while chemicals and IT firms represent 5.30% of the dataset respectively.

Transport section firms make 5.37% of the firms while fabricated metal producing firms and transport machines producing firms also represent 5.26% respectively. Retail firms represent 5.22% followed by Basic metal producing firms who make up 5.15% of the total number of firms, wholesale firms, and construction firms who make up 4.96% and 4.89% of the total number of firms respectively. On the very bottom of the list of industries are leather producing firms, wood producing firms, paper producing firms, recorded media, refined petroleum producing firms, precision instrument firms, furniture producing firms, and recycling firms all of whom have less than 1% representation respectively in the dataset.

These leading sectors as revealed by the world bank Chinese enterprise survey in 2012 happened to be the main export sectors of China in 2012 and continue to dominate Chinese product exports even in 2018 which is the latest credible trade data made available by the World Bank and other global trade institutions such as the World Trade Organisation. As reported by the Observatory for Economic Complexity's visualization platform (Simoes & Hidalgo, 2011), machinery and equipment dominated Chinese exports in 2012 by 48% followed by textiles (11%), metals (7.2%), chemicals (4.7%), plastics and rubbers (3.8%), and transportation (3.2%) in that order. The World Bank (2020) on their world integrated trade solutions visualization platform seconds this trend as it reports machinery and equipment to dominate Chinese enterprises exports in 2018 by 43.85% followed by textiles and clothing (10.69%), metals (7.47%), chemicals (5.48%), transportation (4.73%), plastics and rubber (4.12%) in descending order of magnitude. The dataset as used for this study is hence very representative of the Chinese economy and findings can be extended to cover the entire country of China.

With respect to the number of people employed by Chinese firms, Table 3 shows the distribution of firms by sizes as contained in the dataset. The firm sizes are defined as small, medium and large according to their number of employees. In that respect, small firms are defined as firms with employees greater than or equal to 5 and less than or equal to 19. Medium firms have between 20 to 99 employees whiles large firms are classified as firms having 100 or more employees. As shown by table 3, most of the firms used and contained in the database are small sized firms. These small sized firms are exactly 991 and they represent 36.70% of the total number of firms. After small sized firms come medium sized firms in descending order of magnitude. There are 950 of such firms in the dataset and they represent exactly 35.19% of all firms interviewed for the purpose of building this dataset. The large sized firms are exactly 756 and represent 28.11% of the total number of firms in the database as used for the studies.

Ceteris paribus, most of the firms in China in 2012 by inference could be said to be small and medium sized firms since these firms dominated the national enterprise survey conducted by the World Bank and its developing partners in China in 2012. The inference is consistent with (OECD, 2016) who explain that micro, small and medium size enterprises comprised 97% of all firms in china in 2013 and that this figure translates to 11.7 million small and medium size enterprises in total.

Irrespective of firms being either small or medium or large sized firms, a number of these firms happen to be part of larger firms and thus exist as branches, subsidiaries or satellite plants in other parts of the country or even the same town or province. Table 4 shows a cross tabulation of the firm sizes in relation to the firm being part of a larger firm or not. In total 358 firms are part of a larger firm while 2342 firms are not part of a larger firm. Of the 385 firms that are part of a larger firm, 82 are small firms, 121 are medium firms while 155 are larger firms. All other factors being equal, 909 firms out of the 991 small sized firms, happen to be really small firms since they are independent and are not part of any large firm. The situation is different for the 829 medium sized firms and 604 large sized firms. These firms tend not to be small firms and thus possess a relatively higher number of human capital all other factors being equal.

3 Econometric Specification of the model

The study employs a number of econometric testing, identification and predictive methods to the various stages of the Romer (1986) model as investigated in this study. These methodologies were chosen largely due to the limitations and challenges of the study. Also, they were chosen due to the cross-sectional structure of the World Bank enterprise survey 2012 data conducted for the People's Republic of China. Lastly, they were chosen due to the hypothesis and objectives of the study. Specifically, the econometric identification used for the study include logistic regression for stage 1, ordinary least square regression (OLS) together with high dimension fixed effects (HDFE) method for stages 2 and 3 of the Romer model as investigated for the study.

The econometric specification of the model for stage 1 follows Silva & Leitão (2007) who used a combination of the second Community Innovation Survey (CIS II) conducted by EUROSTAT and logistic regression methodologies to investigate the determinants of innovation capacity in Portuguese industrial firms. However, the variables are modified to include only those variables available in the Chinese enterprise survey 2012 database. The model as used for the study follows the format below:

$$Y_i = \beta_0 + \beta_1 X_i + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \cdots + \beta_n X_{ni} + \varepsilon_i \quad (1)$$

Where:

Y_i = Outcome variable for firm i

β_0 = Intercept

$\beta_1, \ldots, \beta_n$ = Coefficients to be estimated

$X_i, \ldots, X_{ni}$ = Input variables for firm i

ε_i = Error term

The study employs 2 different proxy variables to define R&D which is the outcome variable (Yi) for stage 1. This is done to boost the robustness of the results and consequently the findings of the study since the definition of R&D is broad and can be defined by several parameters. These 2 proxy variables are dummy variables so that their responses are binary and consist of either 0 or 1. That said the 2 outcome variables employed for the investigation of Romer stage 1 are:

i. New Product which equals to 1 if the firm introduced a new product or service in the last 3 years and equal to 0 if otherwise.
ii. R&D Expenditure which equals to 1 if the firm spent on R&D both within firm and with other firms in the last 3 years and equal to 0 if otherwise.

The input variables (Xni) are those variables in the dataset which relate to human capital, taxes, rent and capital as well as control variables. Specifically, the following human capital variables are employed as inputs to know the extent to which human capital contributes to R&D. Among these variables are dummy variables and these variables are specified in parenthesis. These related human capital variables are as follows:

i. Log of number of permanent full-time non-production workers
ii. Log of number of female permanent full-time production workers
iii. Log of number of skilled production workers
iv. Log of number of full-time seasonal or temporary workers
v. Log of years of education of a typical permanent full-time production worker
vi. Log of percentage of full-time permanent workers who completed secondary school
vii. Log of number of full-time permanent production employees trained

Three (3) variables related to rent and capital as well as to capital leakages are included in the analysis to capture Romer rent and thus explain the impact of ploughed back revenue, loans and payments on product and service innovation as well as R&D expenditure. Two more variables meant to capture the effects of labour regulations and insufficient educating are included. The variables as incorporated into the model of Romer stage 1 is as follows:

i. Internal Funds or retained earnings which is equals to 1 if 50% or more of working capital is financed by internal or retained earnings and equals to 0 if otherwise
ii. Line of credit or loan which equals to 1 if firm had a line of credit or loan from a financial institution and equal to 0 if otherwise
iii. Tax which equals to 0 if tax rates pose a moderate obstacles to firm operations, equals to -1 if tax rates pose a minor obstacle, equals to -2 if tax rates pose no obstacles, equals

to 1 if tax rates pose major obstacles and equals to 2 if tax rates poses severe obstacles respectively.

iv. Labour regulations which equals to 0 if labour regulations pose a moderate obstacles to firm operations, equals to -1 if labour regulations pose a minor obstacle, equals to -2 if labour regulations pose no obstacles, equals to 1 if labour regulations pose major obstacles and equals to 2 if labour regulations poses severe obstacles respectively.

v. Inadequately educated workforce which equals to 0 if inadequately educated workforce pose a moderate obstacles to firm operations, equals to -1 if inadequately educated workforce pose a minor obstacle, equals to -2 if inadequately educated workforce pose no obstacles, equals to 1 if inadequately educated workforce pose major obstacles and equals to 2 if inadequately educated workforce poses severe obstacles respectively.

Finally, control variables are included to avoid the incidence of omitted variable effects which will render the results and analyses endogenous and unreliable. The study therefore controls for the following:

i. The city of the firms whether it is a capital city of not (dummy variable = 1 if yes and 0 if no)

ii. The size of the firm which equals to 1 or 2 or 3 if the firm is small, medium or large respectively

iii. Whether the firm is part of a larger firm (subsidiary) or not (dummy variable = 1 if yes and 0 if no)

iv. Domestic ownership of the firm which equals to 1 if 50% or more of the owners are private domestic individuals, companies, or organizations and equal to 0 if otherwise

v. Female ownership which equals to 1 if there are females among the owners of the firm and equals to 0 if otherwise

vi. Female manager which equals to 1 if the top manager is female and equals to 0 if otherwise

The stage 1 of the Romer (1990) is estimated by means of the logit models for econometric reasons since the dependent variables or outcome variables; introduction of new products or services and R&D expenditure have a binary response so that the use of other estimation techniques will amount to coefficients outside the 0 and 1 range for all parameters and independent variables.

Following the choice of logit models, equation 1 is transformed into a logit model (equation 2) to allow for the estimation of the effect of the independent variables on the probability of success of the dependent variables.

$$\text{Logit}\,(P\,(Y = 1|Xi \ldots, X_K)) = (\beta 0 + \beta 1 Xi + \beta 2 X2 + \cdots + \beta n X n) \qquad (2)$$

Marginal effect after logit and odds ratio are estimated to provide more information about the effects of unit change in independent variables on the outcome variables and also the statistical significance of the independent variables.

The stage 2 of the Romer model which investigates how much R&D is used to produce to know the contribution that R&D makes towards output is estimated using ordinary least squared estimation method. This is because the dependent variable for stage 2 is continuous and not binary as in the case of stage 1. Equation 1 as shown above is estimated for different set of variables to establish the relationship between R&D and productivity or output with output being the dependent variable and R&D together with other control variables the independent variables.

$$Y_i = \beta_0 + \beta_1 X_i + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \cdots + \beta_n X_{ni} + \varepsilon_i \qquad (3)$$

Where:

Y_i = log of output produced in 2011 as a proportion of the maximum output possible at full employment

$X_i, \ldots, X_{24i}$ = R&D inputs and control variables

$\beta_1, \ldots, \beta_{24}$ = Coefficients to be estimated

ε_i = Error term

The R&D inputs and control variables which serve in this case as the independent variables are listed below. It should be noted that the output variables for stage 1 which measure the production of R&D as well as R&D expenditure both of which were used to determine the extent to which R&D is produced are included but mutually exclusive in 2 different estimations for the determination of the impact of R&D on productivity.

i. New Product which equals to 1 if the firm introduced a new product or service in the last 3 years and equal to 0 if otherwise.
ii. R&D Expenditure which equals to 1 if the firm spent on R&D both within firm and with other firms in the last 3 years and equal to 0 if otherwise. (mutually exclusive with new product in (i))
iii. Log of typical hours of operation in a week
iv. foreign licensed technology which equals to 1 if firm uses technology licensed from a foreign-owned company and equals to 0 if otherwise
v. New or improved process which equals to 1 if firm developed a new or improved process in cooperation with suppliers and equals to 0 if otherwise
vi. Cost reduction innovation activity which equals to 1 if firm took innovative measures to reduce production cost and equals to 0 if otherwise
vii. New managerial or administrative process which equals to 0 if firm uses no ICT to support innovation activity, equals to 1 if firm has some use of ICT to support innovation activity, equals to 2 if firm has heavy use of ICT to support innovation activity
viii. Log of total annual cost of labour including wages, salaries, bonuses, social security payments in Yuan
ix. Log of total annual cost of raw materials and intermediate goods used in production in Yuan
x. Log of number of permanent full-time non-production workers
xi. Log of number of female permanent full-time production workers
xii. Log of number of skilled production workers
xiii. Log of number of full-time seasonal or temporary workers

The estimation for stage 2 is made robust by the inclusion of fixed effects in the form of high dimension fixed effects (HDFE). The fixed effects included are region fixed effects, industry fixed effects and region-industry fixed effect. These fixed effects are included to control for unobservable factors that may correlate with the independent variables such as infrastructure, population, resource endowment, governance and other macroeconomic factors in the case of region fixed effects and boom or drop in supply and demand of inputs and outputs, price changes, and a lot more in the case of industry fixed effects. Lastly, Region-industry fixed effect will control for unobservable factors in specific regions that impact of specific industries. These factors may include market size or demand for the product from the industry, climate and natural resource endowment and a lot more.

Stage 3 of the Romer model explains how much of the output due to R&D that firms manage to sell. The econometric specification of this stage follows exactly that of stage 2 which is a multiple linear regression model and thus estimated by the ordinary least square estimation technique. However, both the dependent variable and independent variables differ from those of stage 2 since they are related to sales rather than output. And just as it was done to boost the robustness of the stage 2 estimation, region, industry and Region-Industry HDFE are applied to control for specific unobserved characteristics related to sales that exist and impact on the determination of sales in regions and industries in China. Two separate regressions are estimated for stage 3 the difference being new product or service variable and R&D expenditure since the presence of both in the same estimation prevents or reduces the realization of their full effect and hence makes it impossible to determine their effect on total sales. The model thus is as follows:

$$Y_{\mathrm{i}} = \beta_0 + \beta_1 X_{\mathrm{i}} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \cdots + \beta_{\mathrm{n}} X_{\mathrm{n}i} + \varepsilon_i \qquad (4)$$

Where:

Y_i = log of last complete fiscal year's total sales for firm i

$X_i, \ldots, X_{\mathrm{n}i}$ = determinant of sales and control variables

$\beta_1, \ldots, \beta_{\mathrm{n}}$ = Coefficients to be estimated

ε_i = Error term

The input variables as used to estimate sales due to R&D are listed below:

i. Log of output produced in 2011 as a proportion of the maximum output possible at full employment
ii. Log of number of permanent full-time non-production workers
iii. Log of number of full-time permanent production employees trained
iv. Log of percentage of full-time permanent workers who completed secondary school
v. Log of number of skilled production workers
vi. Log of years of education of a typical permanent full-time production worker
vii. New Product which equals to 1 if the firm introduced a new product or service in the last 3 years and equal to 0 if otherwise.
viii. R&D Expenditure which equals to 1 if the firm spent on R&D both within firm and with other firms in the last 3 years and equal to 0 if otherwise.
ix. New or improved process which equals to 1 if firm developed a new or improved process in cooperation with suppliers and equals to 0 if otherwise
x. Cost reduction innovation activity which equals to 1 if firm took innovative measures to reduce production cost and equals to 0 if otherwise
xi. New managerial or administrative process which equals to 0 if firm uses no ICT to support innovation activity, equals to 1 if firm has some use of ICT to support innovation activity, equals to 2 if firm has heavy use of ICT to support innovation activity
xii. National sales which equals to 1 if 50% or more of output is sold within China and equal to 0 if otherwise
xiii. Log of number of days of inventory of most important input

4.0 Results

Stage 1: R&D Produced by Chinese Firms

To test the relationship between the Romer (1990) model predictions and Chinese firm performance in terms of their production of R&D or innovation, how much R&D is used to produce, and how much sales firms make due to the intermediate goods they produce from their invented R&D, equations 2, 3 and 4 are estimated using the appropriate econometric specification methodology.

Equation 2 which investigates stage 1 is estimated by the logistic regression methodology to examine how much R&D Chinese firms produce. This will give an idea of how much new designs are produced and the contribution of the different forms of human capital to the development of new designs and knowledge. It is important to recognize that only human capital contributes to the development of new designs. Other variables including those related to taxes and rents are controlled for to avoid any spurious relationship between R&D and human capital.

Appendix II shows results of the estimations for all three stages of the Romer (1990) model in relation to the R&D production, intermediate goods production and final sales of Chinese firms. Table 5 shows the results of the effects of knowledge induced human capital on Chinese firm's innovation proxied by the introduction of new products or services and R&D expenditure (Stage 1). Column (1) of table 5 shows the marginal effects of human capital, rents and payments on the new products or services produced by Chinese firms in 2012 all other factors being equal while column (2) gives the odds ratio which is a measure of statistical significance of the causal effects of the related input variables on R&D or innovation proxied by new products or services. Column (3) and column (4) show similar results as revealed by column (1) and column (2) respectively but with R&D expenditure as the dependent variable. In all a total of 376 firms are involved in the estimation of equation (2). This is several firms less than the total 2700 firms in the dataset. The reason for this shortfall is due to the extreme rates of missing values so that firms with missing values for respective variables are dropped from the estimation by the STATA statistical software version 14 which is the estimation software for the study.

With respect to column (2) of table 5, only full-time seasonal or temporal workers (0.05), permanent production employees trained (0.01), taxes as an obstacle (0.01), internal funds or retained earnings (0.05) and subsidiary (0.001) have had statistically significant effects on the probability of Chinese firms to produce a new product or service. By this, using the marginal effects (ME) as shown in column (2), a marginal change or to an extreme degree a 1 unit increase in the number of seasonal or temporary workers has increased the probability of Chinese firms to produce a new product or service by 8.4% all other factors being equal. By a great measure, since the seasonal or temporary workers seem to contribute significantly to the probability of producing a new product, these workers could be said to be specialized or highly skilled workers with higher levels of knowledge who are hired only on short term notices to render specialized or expertise services to Chinese firms in their quest to producing new products. The situation could be due to china's increased guest worker programmes that targets foreign born high skilled Chinese people, high skilled Chinese people resident overseas and also high skilled internationals such as doctoral students, researchers, master students on internships etc. who go to china to work on short term contract and temporary basis due to difficulties and restrictions in securing permanent resident visa's in china although there is great need for their services due to domestic skills shortage, demographic imperatives such as falling birth and fertility rates, research networks, and reverse migration (ILO & IOM, 2017).

By the same measure, permanent production employees trained, since it is statistically significant at 0.01 alpha level, a unit change or increase in the number of permanent production employees trained has reduced the probability of firms to produce new products or services by 38.7%. The situation could be economically explained by the law of diminishing marginal returns which explains that an extra unit of labour input all other factors being equal will lead to final output reducing after a point. Thus Chinese firms have gotten to the point where they no longer need to hire more trained production workers or put in extra resources towards training non-skilled production workers but rather invest those resources into developing the competences of non-production workers who are carriers of knowledge in so as to increase their probability of inventing more new products or services.

With reference to column (2), Internal funds or retained earnings which is a dummy variable is statistically significant at 5% significance level so that the marginal effect of 0.199 as recorded in column (1) under new product or services would mean that Chinese firm's decision to rely on internal funds or retained earnings rather than otherwise to finance their operations has increased their probability to introduce new products or services by 0.199. As pointed out by Yang & Pan (2018), there exist a situation of capital market imperfections in china such that private firms, small and young firms encounter a lending bias problem so that they face high premiums for external finance and hence rely extensively on internal finance for R&D investment. Zhang et al. (2009)

explain the preference for internal funds, in that "internal funding overcomes the problem of information asymmetries with regards to the quality of the innovation, potential market applications, and commercialisation but internal funding is available only to entrepreneurs and firms with sufficient cash. Bassey et al. (2016) adds to this by stating that internal funds do not confer obligations on the firms as they do not have to pay transaction and other cost associated with external funds. This and many other reasons account for the choice for internal funds to support innovation in Chinese firms.

When the measure of knowledge, R&D or innovation is proxied by R&D expenditure as shown in table 5 columns (3) and (4), then one more measure of human capital: workers who completed secondary school, becomes statistically significant at 5% if reference is made to the odds ratio results in column (4). As a result, if the number of workers with a secondary school diploma increases by 1 extra unit, there will be an instantaneous positive rate of change of R&D proxied by R&D expenditure, a predicted probability of 0.151. This is to say that secondary school attendance and the completion of it thereof contributes to the probability of firms engaging in R&D and producing innovative ideas via R&D. Indeed, education is a way to transmit knowledge, facilitate learning, and inspire innovation, is essential for individual and societal development (Guo et al., 2019). However, innovation education and its accompanying activities occur more especially at levels of post-secondary education in china that post secondary education should contribute more to R&D than secondary education in China.

Contrary to the case of production of new products and services, when it comes to R&D expenditure, it is line of credit facilities or loans that contributes to R&D and not internal funds or retained earnings. With reference to column (4) line of credit or loans is statistically significant at 5% significance level so that by use of the marginal effect as listed in column (3), the decision of Chinese firms to resort to line of credit from banks or resort to loans from financial institutions rather than otherwise will increase their probability to produce R&D by 0.202. So then, bank loans contribute to R&D development in Chinese firms just as retained earnings and internal funds do. Hanley et al. (2011) in their paper "Financial Development and Innovation in China: Evidence from the Provincial Data" support this finding regarding access to loans and lines of credit with the outcome of their study which is that, financial depth of a region has significantly positive effect on regional innovation (patenting) performance.

Two input variables that are statistically significant regardless of the R&D output proxy are subsidiary and taxes as an obstacle. When new product is used as the R&D proxy, taxes as an obstacle is significant at 0.01 alpha level while when R&D expenditure is used as the R&D proxy, taxes as an obstacle becomes statistically significant at 0.001 alpha level. If that is the case, then with reference to columns (1) and column (3), the marginal effect of no obstacle, minor obstacle, major obstacle and very severe obstacle to operations all due to tax rates are 0.100 and 0.115 respectively. Therefore the predicted probabilities of these 4 categories relative to taxes being a moderate obstacle are 0.100 and 0.115 respectively so that an if taxes pose any sort of obstacle to business operations rather than it being moderate, the production of R&D will increase by a probability of 0.100 while R&D expenditure will increase by a probability of 0.115. Subsidiary, which is the other variable is statistically significant at 0.001 significance level for new product and service and 0.01 significance level for R&D expenditure. All other factors being equal, Chinese firms that are subsidiary firms or part of a bigger firm increase their probability of producing a new product or service and R&D expenditure by 0.423 and 0.285 respectfully.

Stage 2: R&D Used in the Production of intermediate Goods

Table 6 provides the results of the stage 2 regression and shows the quantity of R&D and the component of R&D that goes into production. The results for the baseline OLS regression is shown in columns (1) and (5) for the inputs new products or services and R&D expenditure respectively while those of the various combinations of HDFE are shown in columns (2) (3) and (4) for new products or services and columns (6) (7) and (8). In both models with new products or services, and R&D expenditure, the constant which explains the mean value of intermediate goods when all the other independent variables are zero or absent are 4.331 and 4.267 respectively. Hence, when there are no R&D and other related inputs, Chinese firm's intermediate produce as a proportion of maximum output ranges between 4.331% and 4.267%. In the model with new products or services, only new products or services is significant across all 4 levels of estimation. New process in cooperation with suppliers, cost of labour, non-production workers as well as the constant are all significant at the respective significant rate when estimated with the OLS estimator.

That said, new products or services contributes positively to firms output so that if the number of new products or services increases by 1unit, Chinese firms output increase by rates of 5.6% and

6.6% across the various levels of estimation. R&D expenditure which is the other important R&D variable in the model as indicated in columns (5) (6) (7) and (8) is significant at 5% significance level for the OLS estimation and the last HDFE which has a combination of regional, industrial and regional-industrial fixed effects. For the OLS estimation, the decision of Chinese firms to make expenditure towards R&D increases output by 3.7%. This increases to 6.6% when factors related to the regional location, industry and regional-industry interactions are controlled for.

Surprisingly, new or improved process developed in cooperation with suppliers which is a measure of R&D reduces output when estimated with the OLS for both the model with new product or service and R&D expenditure. It is negative and significant at 0.01 significance level and 0.05 significant level for the 2 models respectively so that firms that introduced such innovations reduced their output by 3.9% and 3.3%. Cost of labour which includes wages, salaries, bonuses, social security payments to employees contributes positively to output at 0.01 significance level for both models so that a 1% increase in cost of labour increases output by 2.5%. This suggests that most of the investment made in labour are made in skilled and non-production workers whose work contribute more to output than otherwise. Non-production workers which is an important measure of knowledge is significant at 5% significance level but negative for both the model with new products or services and R&D expenditure all at the OLS estimation. For the 2 estimations, a 1% increase in the number of non-production workers reduces output by a significant 3.5% and 3.4% significantly. A possible explanation of these negative contribution to production could be that they are inefficient in terms of cost and output so that there is the need for a higher input ratio in terms of funding and material inputs in other to produce and this adversely affects output so that it reduces rather than increase.

Stage 3: Sales that Accrue to Chinese Firms due to R&D Produced in China

The stage 3 of this study which investigates the third and final sector of the Romer endogenous technological model postulates that intermediate goods produced in stage 2 from the R&D developed in stage 1 are used to produce final goods which are then sold to consumers or stored as inputs for further production. This is investigated by estimating how much of the final goods firms manage to sell. Special attention is paid to the proportion of the final goods sold domestically. Tables 7 and 8 show the results of the estimations for stage 3 of the endogenous technological change model. New products or services and R&D expenditure are used mutually exclusively in table 7 and table 8 respectively.

Column 1 in both tables show the baseline OLS estimation while columns 2, 3 4 also in both tables show the results controlled for by HDFE. For the first 2 estimations (column 1 and column 2) in table 7 and table 8, the number of firms involved are 663. This number reduces to 660 when industry fixed effects are included to already existing fixed effects. It reduces even further to 572 when region-industry fixed effects are added. The R-squared from both estimations gradually increases after successive fixed effects are included. This improves our model and makes it reliable as about 76% of the variation of the relationship with total sales is explained by the model. With reference to the constant or intercept for the estimations regarding sales, all other factors being equal, without the presence of the sales inducing input variables, Chinese firms record sales averaging between 7.882 and 7.945 Yuan. This could also be interpreted as the contribution made by other factors that are not included in the model.

From column 1 of table 7 and table 8, Output at full capacity utilization which is an important variable is significant at 0.05 significance level and positively related to total sales. This is true in all estimations in tables 7 and 8. The estimation level (either OLS or with HDFE) notwithstanding for both models with new products or services and R&D expenditure, output at full capacity utilization contributes between 81.9 % and 143% of the input to total sales when output increases by 1%. The most significant contribution of non-production workers, who are the embodiments of knowledge is seen on its effects on total sales. In that, a 1% increase in these knowledgeable workers that firms employ increase total sales by 80.5%, 76.3%, 77.7% and 71% when they are employed in the presence of new products or services. In the estimation with R&D estimation, a 1% increase in non-production workers increases total sales by rates between 66.5% and 75.8%.

R&D expenditure and new managerial and administrative process are the other R&D measures that have significant effects on the sales made by Chinese firms. From table 7, new managerial and administrative process is positive and significant at 0.05 and 0.01 significance level for the estimations in columns (1) and (2) and columns (3) and (4) respectively. So that the ability of a Chinese firm to develop leads to a 13.5%, 15.5%, 17.2% and 24.5% increase in total sales having controlled for regional, industrial, and regional-industrial fixed effects respectfully. These effects as derived following the inclusion of new products or services in the model is slightly reduced by a probably insignificant margin when R&D expenditure replaces new products or services in the model. That said, the effects of new managerial or administrative innovation on total sales reduces to 13.2%, 15.2%, 16.6% and 23.5% respectively. R&D expenditure, one of the main R&D definitions for this study is consistently significant at 0.001 significance level at all levels of estimation. It's effects on total sales is second only to that of non-production workers among the R&D measures such that Chinese firms that spend on R&D increase their sales by 42.3% and up to 51% when unobserved effects in the determination of sales are controlled for via HDFE.

Apart from non-production workers, two more human capital measures that significantly contribute to Chinese firm's total sales are skilled production workers which is significant at all levels of estimation even for both mutually exclusive models and average years of education of production workers which is significant in both mutually exclusive models at all levels except in columns 4 when region-industry HDFE are added.

Skilled production workers is statistically significant at 0.05 and 0.01 alpha levels for the mutually exclusive model with new product or service and this depends on the respective presence and combination of fixed effects. Meanwhile, in the model with R&D expenditure, as shown in table 8, skilled production workers is consistently significant at 0.01 alpha level regardless of the absence or presence of the HDFE as used for the study. That said, a 1% increase in skilled production workers in Chinese firms has increased their total sales by 10.3% when estimated by OLS and by 15.6%, 14.9% and 18.6% when specific factors in regions and industries including those that interact are controlled for in the form of HDFE. The effects of a percentage increase in skilled production workers on total sales is enhanced even more when determined in the presence of R&D expenditure as its contribution to total sales increases to 13.1% when estimated under OLS and 17.5%, 16.7%, 20.6% when the respective HDFE are included.

Although skilled production workers is significant and positive with respect to its effects on total sales, average years of education of production workers has a higher effects on the total sales of Chinese firms. In that, a 1% increase in the average years of education of production workers in

Chinese firms, leads to a 106.5% increase in total sales of these firms. This effect is decreased slightly to 81.9% and 87.9% when region and industry HDFE are included. Regardless, the effects are still greater than those made by skilled production workers.

National sales which depicts the sales made by firms that sell more than 50% of their produce within the boundaries of China is significant even after controlling for the various unobserved factors that determine sales using HDFE. It is positive and significant at 0.01 and 0.05 significance levels for the first two estimations involving OLS and region HDFE and industry and region-industry HDFE respectfully. This means that Chinese firms that tend to sell more than 50% of their produce in China increase their total sales by rates between 37.3% and 39.2% when estimated in the presence of new products or services and 29% and 31.4% if R&D expenditure, all other factors being equal.

4.1 Discussion of Results

The results of the study as shown above show the relevance of the endogenous technological change theory as formulated by Romer (1990) in China's R&D creation, production structure and output changes as well as sales. However, the results reveal specific details that are not contained in the original model since the model aggregated most variables together and analyzed them in a macro sense. Since the study uses a more micro and disaggregated data to examine the role of the Romer (1990) model on China's economic and structural change, specific details regarding types of human capital, and R&D are seen to be more relevant for the predictions of the endogenous technological change theory than others.

In stage 1, the study reveals that non-production workers, the kind of workers who produce R&D, irrespective of how much or how few they are do not contribute to the production of R&D in anyway. Likewise, skilled production workers, years of formal education accumulated by production workers do not in any way contribute to R&D production China even after unobserved effects are controlled for. Instead, what counts the most in the production of R&D in the Chinese context are secondary school education, training of production workers, female ownership and the hiring of seasonal and temporary workers. These are the main human capital components contained in the Chinese World Bank enterprise survey 2012 that contribute significantly to the production of R&D and not the broad sense of human capital as postulated by the endogenous technological change theory. Apart from human capital related variables, being a subsidiary, which is being part of a larger firm in china as well as ploughing back earnings and having access to credits and loans boost Chinese firm's chances of producing R&D.

Stage 2 examines the extent to which the R&D produced in China is used in the production of intermediate goods. The study ensures the robustness of this relationship by controlling for unobserved characteristics in the immediate environment of Chinese firms such as the location and industry of Chinese firm's that affects the production of these firms in order to extract the real contribution of R&D to the production. The results show that the R&D produced in stage one of the Romer sectors namely R&D expenditure and new products or services significantly contribute to the production of intermediate goods by Chinese firms proxied by their output when they operate at full capacity. However, the ability of Chinese firms to produce new products or services aids their production of intermediate goods more than a mere expenditure towards R&D. What this means is that Chinese firm's investment in R&D, even those made together with other firms does not produce efficient R&D to boost output if it does not lead to the creation of a new product or service. The contribution of new products or services and R&D expenditure to output notwithstanding, other forms of R&D namely new process with suppliers and non-production workers negatively affect the production of intermediate goods of Chinese firms. Spending on these therefore deprive the firms of other inputs including effective human capital that they need to produce efficiently and effectively since they have to sacrifice those in so as to spending on these.

Stage 3 which looks at the final output produced and how much of these output Chinese firms manage to sell provides results that are highly reliable owing to a relatively high R-squared. The results reveal output at full capacity utilization which is a proxy variable for the production of intermediate goods by Chinese firms which are then used to produce final goods to extremely contribute positively and significantly to total sales. This positive and significant contribution to total sales is seen in the effects of specific R&D contributors and measures such as non-production workers, years of education, skilled production workers, new managerial and administrative processes and R&D expenditure. So then, since several R&D related variables positively and significantly contribute to total sales in China, it can be concluded that Chinese firms, by their involvement in R&D can and have boosted the total sales that accrues to them. Since the variable, national sales is positive and significant, the conclusion can be extended, in that, Chinese firms boost their the sale of their R&D aided products when they sell at home to domestic consumers.

5 Conclusion

The study sought to examine the role of the endogenous technological change model on China's economic miracle by testing the relationship between the endogenous technological change model and Chinese firm performance to ascertain the extent to which the model and its predictions have influenced Chinese economic policy in terms of R&D and human capital development, the production of R&D led blueprints for further production and the total sales that accrues to Chinese firms due to the use of these blueprints in the production of final goods and services for consumer use.

By use of the World Bank enterprise survey data collected from Chinese firms and published in 2012, the study finds evidence that are largely consistent with the predictions of the endogenous technological change model but with varying intensities and more decomposed R&D effects. In that, although R&D as produced in China by Chinese firms contribute significantly to their production of intermediate goods and final goods, only specific types of R&D make the predictions of the model possible and relevant and not the general sense of R&D. Therefore, the null hypothesis of the study is rejected, and the alternative hypothesis accepted so then it is concluded that there is a significant relationship between the predictions of the Romer (1990) endogenous technological change model and Chinese firm performance. That said, there is enough evidence to suggest that the Chinese have managed to transition from reliance on economic and machine capital as postulated by the Solow model to properly executing the Romer (1990) model of endogenous technological change in their quest for economic growth and development.

The study encountered 2 main limitations without which the outcome in terms of results would have been better. The first limitation to this study is the extreme rate of missing values of variables in the dataset. This prevented the study from employing certain variables that are relevant for the objectives of the study since the frequency of missing values are too high such that it led to the dropping of the observations of other variables when used together. Also, it prevented the full impact of the variables used from being realized as the absence of certain values reduced the contribution of those related variables on respective output variables. As a result, the generated results or findings could be biased and underestimated. The second source of limitation to the study is the lack of specific variables such that the researcher resorted to the use of proxies to define certain variables. The problem presented by this use of proxies is that of measurement problem so that certain variables are incorrectly measured. This makes the results of the study endogenous and hence biased.

China, as open as it has become in these last 2 decades tell a story of the interdependence and importance among several economic factors such as globalisation. Furthermore, knowledge as was used in the formulation of the endogenous technological change model has greatly evolved since 1990 when the model was propounded to include new dimensions such as artificial intelligence. Human capital induced knowledge does not exist in isolation then and this calls for the need to investigate the effect of these on knowledge and how they contribute to the predictions of the endogenous technological change model in China. The findings will go a long way to shape policy geared towards achieving growth developing countries including China.

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Appendix I: Descriptive Statistics

Table 1: Summary Statistics of Selected Key Variables

Variables	Obs.	Mean	SD	Min	Max
	Stage 1				
Introduction of new products or service	2,692	0.47	0.499	0	1
R&D expenditure	1,667	0.43	0.495	0	1
Permanent full-time non-production workers	1,664	62.33	451.1	0	15000
Skilled production workers	1,654	95.04	463.6	0	11000
Female permanent full-time non-production workers	1,557	17.89	64.27	0	1200
Full-time (FT) seasonal or temporary workers	2,548	12.48	53.29	0	1600
Years of education of typical production worker	1,557	10.15	1.891	0	18
FT permanent workers who completed sec. sch. (%)	2,548	60.22	30.25	0	100
FT permanent production employees trained (%)	1,348	91.99	18.33	0	100
Internal funds or retained earnings	2,349	0.24	0.425	0	1
line of credit or a loan from a financial institution?	2,420	0.29	0.452	0	1
	Stage 2				
Output as a proportion of the maximum output (%)	1,409	86.69	10.88	0	100
Weekly hours operated	1,409	57.73	23.86	20	168
Foreign licensed technology	1,408	0.23	0.422	0	1
New or improved process developed with suppliers	1,247	0.33	0.470	0	1
New innovative measures to reduce production cost	1,409	0.76	0.425	0	1
New managerial process due to ICT	2,341	0.44	0.693	0	2
	Stage 3				
Total annual sales	2,299	1.36e+08	1.24e+09	100	4.00e+10
Domestic Selling Firms	2,255	0.139246	0. .34628	0	1
Days of inventory	1,372	33.18	37.21	0	360

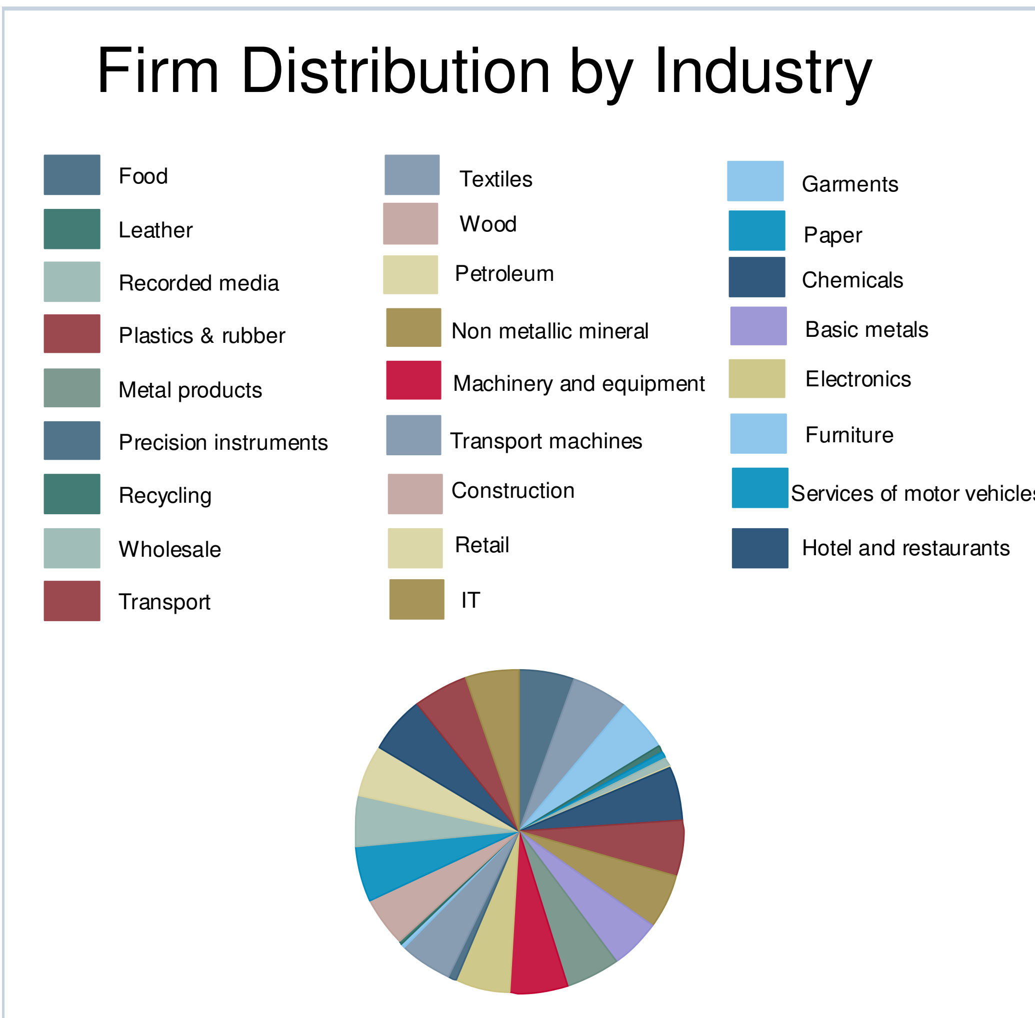
Source: World Bank Enterprise Survey, China (2012)

Table 2: Sectoral Distribution of Firms

Sector	Frequency	Percentage	Cumulative Percentage
Manufacturing	1,692	62.67	62.67
Retail	158	5.85	68.52
Other Services	850	31.48	**100.00**
Total	**2700**	**100.00**	

Source: World Bank Enterprise Survey, China (2012)

Figure 1: Distribution of Firms by Industry



Source: World Bank Enterprise Survey, China (2012)

Table 3: Distribution of Firms by Size

Firm Size	Frequency	Percentage	Cumulative Percentage
Small >=5 and <=19	991	36.70	36.70
Medium >= 20 and <=99	950	35.19	71.89
Large >=100	756	28.11	**100.00**
Total	**2700**	**100**	

Source: World Bank Enterprise Survey, China (2012)

Table 4: A Cross-Tabulation of Firm sizes in Relation with External Larger Firms

	Firm Size			
Part of a Larger Firm	Small	Medium	Large	**Total**
Yes	82	121	155	358
No, a firm on its own	909	829	604	2,342
Total	**991**	**950**	**759**	**2,700**

Appendix II: Estimation Results

Table 5: The Effects of Human Capital Measures on Innovating New Products and R&D Expenditure

	(1) New Product ME/P	(2) New Product Odds/P	(3) R&D Expenditure ME/P	(4) R&D Expenditure odds/P
Permanent full-time non-production workers	0.099	1.491	0.077	1.366
	(0.167)	(0.167)	(0.285)	(0.285)
Skilled production workers	-0.014	0.946	-0.044	0.836
	(0.719)	(0.719)	(0.250)	(0.250)
Female permanent production workers	-0.088	0.700	-0.012	0.951
	(0.176)	(0.176)	(0.848)	(0.848)
Full-time seasonal or temporary workers	0.084*	1.405*	0.045	1.197
	(0.010)	(0.010)	(0.165)	(0.165)
Years of education of production worker	0.091	1.445	-0.117	0.623
	(0.714)	(0.714)	(0.645)	(0.645)
Workers who completed secondary school	0.018	1.075	0.151*	1.843*
	(0.780)	(0.780)	(0.030)	(0.030)
Permanent production employees trained	-0.387**	0.210**	-0.157	0.529
	(0.002)	(0.002)	(0.122)	(0.122)
Taxes as an obstacle	0.100**	1.499**	0.115***	1.593***
	(0.003)	(0.003)	(0.001)	(0.001)
Internal funds or retained earnings	0.199*	2.237*	0.084	1.402
	(0.024)	(0.028)	(0.350)	(0.350)
Line of credit or loan	0.115	1.591	0.202*	2.270*
	(0.196)	(0.198)	(0.021)	(0.024)
Labour regulations as an obstacle	0.033	0.145	0.070	1.329
	(0.545)	(0.545)	(0.211)	(0.211)
Inadequately educated workforce	-0.044	0.835	0.062	1.283
	(0.360)	(0.360)	(0.216)	(0.215)
Firm size	-0.052	0.810	0.022	1.093
	(0.308)	(0.308)	(0.661)	(0.661)
Capital city	0.101	1.509	0.068	1.319
	(0.132)	(0.135)	(0.311)	(0.312)
Subsidiary	0.423***	7.021***	0.285**	3.298**
	(0.000)	(0.000)	(0.003)	(0.009)
Female	-0.111	0.638	-0.284***	0.311***
	(0.119)	(0.121)	(0.000)	(0.000)
Domestic ownership	0.079	1.376	0.099	1.488
	(0.535)	(0.536)	(0.450)	(0.452)
Female manager	0.156	1.882	0.193	2.193
	(0.146)	(0.157)	(0.066)	(0.079)
Constant		139.152		6.502
		(0.072)		(0.446)
Pseudo R-squared		0.241		0.252
observations	376	376	376	376

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: World Bank Enterprise Survey, China (2012)

Table 6: The Effects of R&D Measures on Productivity

	(1) Output OLS 1	(2) Output HDFE 1	(3) Output HDFE 2	(4) Output HDFE 3	(5) Output OLS 2	(6) Output HDFE 1	(7) Output HDFE 2	(8) Output HDFE 3
New Product or service	0.056***	0.056***	0.060***	0.066**				
	(0.02)	(0.02)	(0.02)	(0.02)				
Foreign licensed Technology	-0.003	-0.014	0.001	0.018	0.001	-0.008	0.007	0.014
	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)	(0.03)
Operating Hours	-0.035	-0.020	-0.017	-0.059	-0.021	-0.005	-0.000	-0.026
	(0.02)	(0.03)	(0.03)	(0.05)	(0.02)	(0.03)	(0.03)	(0.04)
New process with suppliers	-0.039**	-0.012	-0.003	0.018	-0.033*	-0.007	0.001	0.022
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)
Cost reduction Innovation	0.044	-0.020	-0.009	0.026	0.046	-0.009	0.002	0.033
	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)
New managerial Process	0.013	0.009	0.006	0.002	0.016	0.011	0.007	0.008
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Cost of Labour	0.025**	0.013	0.005	0.004	0.025**	0.015	0.006	0.001
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Cost of Raw material	-0.007	-0.001	0.002	-0.001	-0.007	-0.001	0.002	0.002
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Non-production workers	-0.035*	-0.023	-0.021	-0.020	-0.034*	-0.025	-0.021	-0.029
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)
Skilled Production workers	-0.003	0.002	0.008	-0.000	-0.001	0.003	0.010	-0.001
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Female permanent production workers	0.024	0.010	0.005	0.015	0.019	0.009	0.002	0.024
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)
Seasonal or temporary workers	0.002	0.003	0.003	-0.002	0.003	0.005	0.005	-0.005
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
R&D expenditure					0.037*	0.022	0.033	0.066*
					(0.02)	(0.02)	(0.02)	(0.03)
Constant	4.331***				4.267***			
	(0.12)				(0.12)			
Region	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Industry	No	No	Yes	Yes	No	No	Yes	Yes
Region x Industry	No	No	No	Yes	No	No	No	Yes
R-squared	0.135	0.393	0.436	0.625	0.114	0.370	0.413	0.624
Observations	328.000	328.000	323.000	245.000	328.000	328.000	323.000	245.000

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: World Bank Enterprise Survey, China (2012)

Table 7: Effects of R&D and Innovation on Firm's Total Sales (New Product or Service as input)

	(1) Total Sales OLS	(2) Total Sales HDFE 1	(3) Total Sales HDFE 2	(4) Total Sales HDFE 3
Output at full employment	0.819*	0.900*	0.996*	1.435**
	(0.39)	(0.43)	(0.44)	(0.54)
Non-production workers	0.805***	0.763***	0.777***	0.710***
	(0.06)	(0.06)	(0.06)	(0.07)
Permanent production employees trained	0.070	0.037	0.052	0.012
	(0.10)	(0.11)	(0.11)	(0.13)
Workers who completed secondary school	-0.095	-0.086	-0.148	-0.197
	(0.09)	(0.10)	(0.10)	(0.13)
Skilled production workers	0.103*	0.156**	0.149*	0.186**
	(0.05)	(0.06)	(0.06)	(0.07)
Average years of education of production workers	1.065**	0.819*	0.879*	0.609
	(0.35)	(0.37)	(0.38)	(0.46)
New product or service	0.162	0.175	0.138	0.084
	(0.09)	(0.10)	(0.10)	(0.12)
National sales	0.373***	0.347**	0.311**	0.392**
	(0.11)	(0.11)	(0.11)	(0.13)
Days of inventory	-0.038	-0.024	-0.018	0.030
	(0.04)	(0.05)	(0.05)	(0.06)
New process with suppliers	-0.093	-0.046	-0.056	-0.093
	(0.09)	(0.10)	(0.10)	(0.12)
Cost reduction Innovation	0.184	0.050	0.022	0.288
	(0.14)	(0.15)	(0.15)	(0.18)
New managerial Process	0.135*	0.155*	0.172**	0.245***
	(0.06)	(0.06)	(0.06)	(0.07)
Constant	7.882***			
	(1.89)			
Region	No	Yes	Yes	Yes
Industry	No	No	Yes	Yes
Region x Industry	No	No	No	Yes
R-squared	0.556	0.585	0.610	0.756
observations	663.000	663.000	660.000	572.000

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: World Bank Enterprise Survey, China (2012)

Table 8: Effects of R&D and Innovation on Firm's Total Sales (R&D Expenditure as input)

	(1) Total Sales OLS	(2) Total Sales HDFE 1	(3) Total Sales HDFE 2	(4) Total Sales HDFE 3
Output at full employment	0.822*	0.927*	0.969*	1.317*
	(0.38)	(0.42)	(0.43)	(0.53)
Non-production workers	0.758***	0.726***	0.740***	0.665***
	(0.06)	(0.06)	(0.06)	(0.07)
Permanent production employees trained	0.105	0.069	0.088	0.073
	(0.10)	(0.11)	(0.11)	(0.12)
Workers who completed secondary school	-0.090	-0.094	-0.142	-0.186
	(0.09)	(0.10)	(0.10)	(0.12)
Skilled production workers	0.131**	0.175**	0.167**	0.206**
	(0.05)	(0.06)	(0.06)	(0.07)
Average years of education of production workers	0.966**	0.769*	0.809*	0.404
	(0.34)	(0.37)	(0.37)	(0.45)
R&D expenditure	0.423***	0.433***	0.416***	0.510***
	(0.09)	(0.10)	(0.10)	(0.12)
National sales	0.290**	0.292**	0.259*	0.314*
	(0.11)	(0.11)	(0.11)	(0.13)
Days of inventory	-0.034	-0.029	-0.025	0.023
	(0.04)	(0.05)	(0.05)	(0.06)
New process with suppliers	-0.092	-0.069	-0.076	-0.126
	(0.09)	(0.10)	(0.10)	(0.12)
Cost reduction Innovation	0.105	-0.033	-0.067	0.154
	(0.13)	(0.15)	(0.15)	(0.17)
New managerial Process	0.132*	0.152*	0.166**	0.235***
	(0.06)	(0.06)	(0.06)	(0.07)
Constant	7.945***			
	(1.86)			
Region	No	Yes	Yes	Yes
Industry	No	No	Yes	Yes
Region x Industry	No	No	No	Yes
R-squared	0.569	0.595	0.619	0.766
observations	663.000	663.000	660.000	572.000

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: World Bank Enterprise Survey, China (2012)

Appendix III: Summary of Related Empirical Literature

Author(s)	Title	Objective	Methodology	Data	Findings
Li et al. (1998)	Testing the neoclassical theory of economic growth: Evidence from Chinese provinces	To examine the extent to which the growth process of china can be explained by the augmented Solow-Swan model	Cross-section and panel data estimation techniques	Chinese provincial data (1978-1995)	Growth rates of GDP per capital are higher in regions with lower population, greater openness, and higher physical and human capital
Ding & Knight (2009)	Can the augmented Solow model explain China's economic growth? A cross-country panel data analysis	To examine the extent to which the growth differences between China and other countries can be explained by the augmented Solow model.	Growth regression models estimated by general method of moments (GMM)	Penn world tables, WDI, and FAO data	High physical capital investment, conditional convergence gains, structural changes in employment and output, as wells as low population growth be responsible for China's economic growth
Ding & Knight (2009a)	Why has China grown so fast? The role of structural change	To attempt to explore some indirect determinants of China's growth success including the degree of openness, institutional change and sectoral change	Bayesian model averaging, automated general-to-specific approach, and panel data system GMM	China Compendium of Statistics and China Statistical Yearbook	Improvements in productive efficiency have been an important part of the explanation for China's remarkable rate of growth
Hooi Lean & Song (2009)	The domestic savings and economic growth relationship in china	To examine the relationship between the growth of domestic savings and economic growth in China	Cointegration and Causality tests		China's economic growth is found to have long run relationship with household savings and enterprise savings
Chow (1993)	Capital formation and economic growth in China	To measure the contribution of capital formation to the growth of sectors, the effects of the Great Leap Forward of 1958-1962 and of the Cultural Revolution of 1966-1976 on outputs, the impact of economic reforms since 1979 on growth, the rates of return to capital, and the effects of sectorial growths on relative prices.	Estimation of aggregate and sectorial Cobb-Douglas production function	Official data from the Chinese statistical state bureau via private communication and Statistical yearbook of China 1989	That technological progress was absent in China's economic growth between 1952-1980 and the great stock of capital accumulation reported by Chinese government in this did not lead to improved total productivity.
Romero-Ávila (2013)	Is physical capital the key to	To establish whether large permanent movements in the physical investment rate	Deterministic and Stochastic trend analysis,	China Compendiu	Trends in Chinese growth is consistent with the AK model. However, an

	China's growth miracle?	cause permanent movements in output growth	Autoregressive Distributed Lag (ADL) Growth Regressions	m of Statistics (1949-2008), Hsueh and Li data (1952-1995)	augmented AK model to allow for structural transformation, imbalances in factor endowments, and R&D-based technology transfer better describes China's growth miracle
Jiang (2011)	Structural change and growth in china under economic reforms: patterns, causes and implications	To investigates the patterns, causes, and implications of China's structural change and its contribution to China's regional growth	variance decomposition of output growth	Chinese statistical yearbooks (1980-2006)	Empirical analysis Chinese growth and structural analysis support the hypothesis of the theoretical model of this paper (Lucas (2009))
Li (2005)	China's economic growth: what do we learn from multiple-break unit root tests?	To investigate China's economic growth to identify the steady state and transitional growth paths of national and sectoral output and output per worker	Multiple break unit root tests		Growth behaviour of the Chinese economy is consistent with endogenous growth theory
Wei et al. (2011)	Endogenous innovation growth theory and regional income convergence in China	To test endogenous innovation growth theory for 27 provinces across China	Panel data, standardized "t-bar" test for unit roots	Chinese statistical yearbooks	Found evidence of convergence which supports the endogenous innovation growth model in which regional per capita can converge given technological diffusion, transfer, imitation.
Lai et al. (2006)	Technological spillover, absorptive capacity and economic growth	To establish an endogenous growth model with knowledge driven R&D by investigating the relationship between international technology spillovers, the host country's absorptive capacity and endogenous economic growth	Panel data estimation techniques	Chinese province level data (1996-2002)	Among other things, long-run growth is found to arise from improvements in absorptive capacity and higher human capital stocks
Hongyi Li & Huang (2009)	Health, education, and economic growth in China: Empirical findings and implications	To examine the augmented Mankiw, Romer and Wiel model which considers both health and education in human capital in the framework of Chinese economy	Panel data models including OLS, Fixed effects, and Random effects	Chinese provincial data (1978-2005)	Both health and education have positive significant effects on growth.

Ding & Knight (2011)	Why has China Grown So Fast? The Role of Physical and Human Capital Formation	To investigate if growth regressions help us to understand why China has grown so fast and to know the type of investment that explain Chinese growth	Panel data techniques	China Compendium of Statistics (1949–2004), China Statistical Yearbook (2005-2007)	Human and physical capital promote economic growth. Investment in innovation, private investment, secondary and higher education are important