9. Productivity, Innovation and China's Economic Growth

Yanrui Wu, Xiumei Guo and Dora Marinova

The role of productivity and innovation in China's economic growth is fiercely debated among economists.[1] With the economy currently progressing through the middle-income stages, China is forced to confront difficult areas of restructuring, and this has intensified that debate. Following the Global Financial Crisis (GFC), Chinese policymakers opted to make innovation and entrepreneurship new drivers of economic growth over coming decades.[2] This policy shift has merely intensified the debate about and research on productivity growth and innovation in China. This chapter presents an updated literature review and provides new estimates of productivity growth, innovation and efficiency changes in the Chinese economy. In addition, it explores what can be learnt from China's recent experience and how economic growth may be sustained through innovation and productivity improvement.

The chapter begins with a brief review of the literature on productivity growth analysis, before discussion of the literature on innovation and catch-up. Recent extensions in the field are investigated in the third section and new estimates of productivity growth at the sector level are reported in section four. Section five presents a comparison of productivity performance between coastal and non-coastal areas, while section six offers concluding remarks.

Productivity growth analysis

According to the traditional growth accounting framework, economic growth in a society arises as a result of changes in production inputs and technological progress (Solow 1957). The latter is also known as productivity or total factor productivity (TFP) growth. Consider the following Cobb–Douglas production function (Equation 9.1).

Equation 9.1

$$y = Ak^{\alpha}l^{\beta}$$

1 For comprehensive literature surveys, see Wu (2011); Tian and Yu (2012); and Zhang (2016).
2 For reviews of China's innovation capacity and development, refer to Wu (2012); and Fan (2014).

In Equation 9.1, it is assumed that capital (k) and labour (l) are employed to produce output (y) in the production process; α and β are the capital and labour income shares, respectively; and A provides a measure of productivity. Equation 9.1 can be converted into the following growth rate format (Equation 9.2).

Equation 9.2

$$\dot{y} = t\dot{f}p + (\alpha\dot{k} + \beta\dot{l})$$

In Equation 9.2, the superscript dot indicates the rate of growth and *tfp* is total factor productivity. Equation 9.2 implies that TFP growth is defined as the residual of output growth that is unexplained by input changes. Given this equation, conventionally, at least three terms—namely, TFP growth, technical change and technological progress—are used interchangeably by economists.

Many authors have followed this practice in their empirical analysis of the Chinese economy. For example, Wu (1993) presented a comprehensive survey of the relevant literature published up to and including 1992. A follow-up survey covering the period from 1993 reported 151 TFP growth estimates for the Chinese economy (Wu 2011). Wu (2011) observed substantial variation in the estimated TFP growth rates across the 74 studies reviewed, and derived a mean TFP growth rate of 3.62 per cent. That rate accounts for about one-third of China's average rate of economic growth during the period under study. Adopting a meta-analysis method, the study also demonstrated that the manufacturing sector in China outperforms agriculture in terms of TFP growth. An interesting additional observation by Wu (2011) was his claim that English-language journal articles tend to report relatively high TFP growth rates compared with those in Chinese.

Since the review by Wu (2011), more empirical studies have emerged in the literature. Zhu (2012) studied the period 1978–2007 and concluded that TFP growth was responsible for about 78 per cent of China's per capita gross domestic product (GDP) growth over those years. Morrison (2013) reported annual TFP growth rates rose from about 4 per cent in 2000 to a peak of around 9 per cent in 2007. From 2008 to 2012, however, Morrison (2013) found that TFP growth showed a sustained downward trend. International Monetary Fund (IMF) economists Anand et al. (2014) also observed this inverted-U shaped pattern of TFP growth in a comparative study of China, India and economies of the Association of Southeast Asian Nations Five (ASEAN-5). In particular, they considered capital utilisation. Their argument is that rapidly declining capital utilisation could lead to biased estimates of TFP growth. They identified that the observed inverted-U shape in the case without considering capital utilisation is much flatter than that with capital utilisation being adjusted.

Wang et al. (2013) estimated agricultural productivity growth using provincial data for the period 1985–2007 and found that TFP growth was responsible for more than 50 per cent of China's agricultural growth, with the coastal regions enjoying relatively faster productivity growth than non-coastal areas. They also found, however, that TFP growth showed a downward trend over time. Du et al. (2014) examined firm-level data for the period 1998–2007 and reported that TFP growth tended to decline over time, and approached zero at the end of their sample period. They argued that this situation was due to resource misallocation between the state and non-state sectors on the one hand, and reduction in technological progress in surviving firms on the other.

More recent studies include Yao (2015), H. Wu (2016) and Mallick (2017). Yao (2015) demonstrated that economic reform and the policy of opening up boosted China's productivity growth significantly, but this growth shows a declining trend over time and especially during the GFC. H. Wu (2016), on the other hand, found that TFP growth has played a minor role in China's economic growth, and TFP growth had even turned negative during the period 2007–12. Mallick (2017) compared China with India and showed that the contribution of TFP growth is substantial in China, but tends to decline over time.

Overall, research findings in the existing literature on the role of TFP in China's economic growth are mixed. But there is one consensus in the literature: most authors observed that China's TFP growth declined during the GFC. Maliszewski and Zhang (2015) drew comparison between this decline and that during the East Asian Financial Crisis in the 1990s. Lai (2015) claimed this productivity slowdown was responsible for China's slow economic growth in recent years.

Innovation and catch-up

The conventional concept of TFP growth has been extended to distinguish between innovation or technological progress and efficiency change or catch-up since the work of Aigner et al. (1977), Meeusen and van den Broeck (1977) and Battese and Corra (1977), to cite a few. In the extended framework, innovation refers to the shift of the production frontier while efficiency change captures movement towards best practice or the production frontier (Nishimizu and Page 1982; Lau and Brada 1990). The sum of the rates of technological progress and efficiency change gives the rate of TFP growth. In other words, TFP growth is decomposable into two components: technological progress and efficiency change. Since the 1980s, a large pool of literature has adopted this concept. Lovell (1996) and Greene (1997) provide reviews of that literature. The decomposition method has also been applied to analyse productivity growth in the Chinese economy. Wu (1995) was one of the earlier studies to use China's regional data, and showed technological progress to be the main driver of TFP growth in farming and rural and urban industries. He also observed variations across sectors as well as among China's three regions—namely, the coastal, central and western regions. Wu (2011) reviewed the earlier literature.

Recently, Li et al. (2011) investigated the source of TFP growth in Chinese agriculture and found significant productivity growth since the 1980s. They pointed out that since the 1980s this growth has been driven mainly by technological progress. Ma et al. (2013) derived a similar conclusion by analysing micro-level data. You and Sarantis (2013) observed that rural transformation or efficiency improvement has made an important contribution to TFP growth; however, its importance has declined over time and that of technological progress has increased. Gao (2015) adopted a data envelopment analysis approach and examined agricultural TFP by using regional data for the period 1992–2012, reaching a conclusion that confirms the findings by Li et al. (2011) and Ma et al. (2013).

Wang and Szirmai (2013) found that efficiency changes dominated industrial productivity growth in the 1980s while technological progress played the major role in the 1990s. This is consistent with the conclusion about China's rural sector by You and Sarantis (2013). Zhang et al. (2014) drew attention to the declining trend in the contribution of TFP to economic growth during the period 1978–2012, and raised the important related question of the sustainability of economic growth in China.

More recently, Han and Shen (2015) adopted the data envelopment method and showed an annual TFP growth rate of 5.9 per cent over the period 1990–2009. This growth is dominated by the rate of technological progress: 5.5 per cent. However, Yu et al. (2015) argued that China's catch-up process is characterised by 'creative restructuring' (or efficiency improvement) rather than 'creative destruction' (or innovation). Curtis (2016) argued that relocation of resources could account for 21.5 points of TFP growth during 1992–97. In sum, the views of the research community as to the role of technological progress and efficiency changes are varied overall. However, more evidence appears to support the idea that technological progress has dominated TFP growth in the Chinese economy in recent decades and that TFP growth tends to decline over time, particularly during the GFC.

Extensions

New growth theory recognises the role of non-traditional production factors such as human capital and research and development (R&D) spending in the growth process. A stream of literature has adopted new growth theory ideas in case studies on the Chinese economy. Wang and Yao (2003) were probably the first to provide human capital estimates for the period 1952–99 with incorporated human capital growth accounting. They found that rapid human capital accumulation and related productivity growth that arose during China's reform period (1978–99) made a positive contribution to economic growth. Ding and Knight (2011) found a positive impact of human capital formation on economic growth. Wei and Hao (2011) examined the role of human capital in China's TFP growth and found a significantly positive effect from human capital on provincial TFP growth during 1985–2004. The effect of human capital, however, is found to vary between the coastal, central and western regions. Luckstead et al. (2014) showed that human capital accounted for an average 24 per cent of TFP growth over the period 1952–78 and 42 per cent for the period 1979–2000. Chen and Funke (2013) explained how a sequencing of physical capital accumulation, human capital accumulation and innovation has driven China's growth since the 1980s.

A secondary body of research explores how additional variables have affected China's TFP growth. For example, Jiang (2011) found a negative relationship between regional openness and TFP growth. Later, however, Yu (2015) found tariff reduction was responsible for at least 14.5 per cent of China's economy-wide productivity growth. Lin et al. (2011) explored the relationship between foreign direct investment (FDI) and regional productivity, concluding that the overall effect of FDI on productivity is positive, especially in coastal regions. Hong and Sun (2011) support this finding. Choi et al. (2015) considered environmentally sensitive productivity growth, the rate of which is found to be low and relatively constant in China. They also observed that related productivity growth has been driven mainly by innovation.

Hu (2001) analysed firm-level data and found a strong link between private R&D and firm productivity. Ljungwall and Tingvall's (2015) meta-analysis of the literature on the effects of R&D spending on economic growth in a large number of economies, however, finds that R&D spending in China has weaker impacts on economic growth than it does in other economies—both Organisation for Economic Co-operation and Development (OECD) and non-OECD countries—covered in the literature. Their finding is supported to some extent by Boeing et al. (2016), who provided micro-level evidence in their finding that a strong increase in patent stock is linked with a falling positive or even vanishing influence on TFP in listed Chinese firms. Boeing et al. (2016) are, however, disputed by Fang et al. (2016), who also used firm-level data. The latter analysis used propensity-score matching methods to demonstrate the link between intra-firm increases in patent stock and TFP growth.

Finally, scholars have also derived estimates of intangible capital in China and examined the related contribution to productivity growth. Intangible capital generally refers to knowledge embedded in intangible products or processes (Li and Wu forthcoming). Examples include software, R&D, designs and advertising. Hulten and Hao (2012) were probably the first to derive these, and they showed that about one-sixth of productivity growth was due to intangibles during 2000–08.

Li and Wu (forthcoming) looked at the role of intangible capital at the provincial level and concluded that TFP growth estimates would be biased if intangibles were not considered. They observed the decline in TFP growth during the GFC; however, Li and Wu also noticed that both human capital deepening and intangible capital deepening played a greater role during the GFC than before it. Fleisher et al. (2015) presented evidence at the micro level that showed that investment in knowledge capital is productivity enhancing among domestically owned and foreign-invested firms.

Growth accounting estimates

To identify new evidence on productivity growth and technological progress using the latest statistics at both the sector and the regional level, we study productivity and economic growth sources using a growth accounting framework. The framework we adopt takes Equations 9.1 and 9.2 and extends them with the inclusion of a time trend in the production function. The coefficient (δ) of the time trend measures the rate of technological progress. The difference between TFP growth rates and δ gives an indication of efficiency changes ($\dot{ec}$). The underlying model is essentially a deterministic one (Aigner and Chu 1968). Given this definition, Equation 9.2 expands as follows (Equation 9.3).

Equation 9.3

$$\dot{y} = \delta + \dot{ec} + (\alpha\dot{k} + \beta\dot{l})$$

To estimate the right-hand side components of Equation 9.3, panel data from 31 Chinese provinces covering the period 1991–2015 are compiled. The raw data are sourced from China's *Statistical Yearbook*s (NBS various issues). Output (y) is measured by value added in three sectors—agriculture, manufacturing and services—at the provincial level. Capital stock (k) estimates are described in Y. Wu (2016), who adopted region-specific and sector-specific rates of capital depreciation. Both output and capital stock are expressed in constant prices. Labour (l) is measured by the year-end employment numbers because information for the actual hours worked is not available.

In the empirical exercises, period-specific dummy variables are included in the production function to capture possible variations in the values of δ, α and β over three subperiods: the 1990s, the 2000s and the period of the GFC. This division is to ensure that the subsamples have approximately equal size. In addition, the three eight-year subperiods coincide with major reform campaigns—starting in 1992 with Deng Xiaoping's 'southern tour', China's accession into the World Trade Organization (WTO) in December 2001 and the period including and following the GFC (since 2008). These major events or policy changes may have led to structural changes in the Chinese economy during the relevant periods. In effect, the inclusion of the dummy variables allows for different production frontiers for the three subperiods. The computation results use the first set of regression outcomes (not reported here due to space limitations) and are summarised in Table 9.1.

From Table 9.1, it is evident that TFP growth has been the dominant driver of economic growth in China since the 1990s. This relates to the fact that the share of TFP growth over output growth ranges from 63 per cent to 93 per cent (column 'TFP/Output' in Table 9.1). The contribution of TFP to economic growth is highest in agriculture, followed, in turn, by services and manufacturing in recent years. This presents a sharp contrast to the findings of H. Wu (2016) and Hoffman and Polk (2014), with the main difference in the latter being their assumption of constant returns to scale by following the conventional growth accounting framework proposed by Solow (1956) and Swan (1956). In fact, the sum of the estimated output elasticity with respect to labour and capital in Table 9.1 is well below one. Since this implies decreasing returns to scale in all three sectors, growth accounting with assumptions of constant returns to scale would in this case inflate the contribution of production inputs and hence underestimate the role of TFP growth.

Table 9.1 Calculated growth rates, shares and returns to scale (per cent, unless otherwise noted)

Period	Output	TFP	TP	EC	TFP/Output	Scale*
Agriculture						
1	5.17	3.90	4.24	–0.33	75.48	0.46
2	4.40	4.05	4.25	–0.19	92.25	0.46
3	4.32	3.90	3.41	0.49	90.30	0.49
Manufacturing						
1	13.45	10.87	9.98	0.89	80.82	0.55
2	14.42	11.31	10.56	0.75	78.43	0.53
3	13.74	8.68	8.09	0.59	63.17	0.56
Services						
1	13.26	10.95	9.92	1.03	82.58	0.26
2	11.89	9.76	9.19	0.57	82.04	0.25
3	10.77	7.73	7.57	0.16	71.77	0.29

* 'Scale' reports the estimated returns to scale and has no unit.

Notes: Period 1 refers to the years 1992–99, period 2 is the second subperiod (2000–07) and period 3 is the third subperiod (2008–15). The values in the columns represent average growth rates of provincial value added (output), TFP, technological progress (TP) and efficiency change (EC). The numbers in the 'TFP/Output' column are shares of TFP growth over output growth. The sum of TP and EC may not be equal to TFP due to rounding.

Source: Authors' own work.

The results in Table 9.1 suggest that technological progress plays a dominant role in productivity growth in all three sectors. The data also suggest that TFP growth in China slowed during the GFC, although growth remains relatively high. Other researchers have also observed this downward trend (e.g. Wang et al. 2013; Yao 2015; Mallick 2017). The implications of this slowdown are worth monitoring as the global economy recovers incrementally. It is also noted in Table 9.1 that the estimated returns to scale in the service sector are much smaller than those in the manufacturing sector. Given that services generated more than 50 per cent of China's total GDP in 2016, Liu and Yang (2015) have argued that China's future growth relies on improvement in the performance of productivity growth in the service sector. Lee (2016) made a similar argument by examining Korea's economic growth and catch-up process. Lee reckons Korean productivity growth was affected by the poor performance in services and China should avoid this by improving productivity in the service sector.

Finally, it is interesting to note that the relatively high rates of TFP growth estimated in this study are consistent with the findings of others (Table 9.2). Examples include Zhu (2012), who reported similar estimates for the Chinese economy, and Gao (2015), who investigated the agricultural sector. Brandt et al. (2012) and Ding et al. (2016) focused on the manufacturing sector.

Table 9.2 Selected estimates of TFP growth and its share in output growth (per cent)

Sources	Years	Growth	TFP/ Output	Sectors
This study	1992–2015	8.9	77.1	Economy wide
	1992–2007	9.4	81.1	Economy wide
	2000–2015	8.7	75.5	Economy wide
	2008–2015	7.9	69.0	Economy wide
Zhu (2012)	1978–2007		78.0	Economy wide
Morrison (2013)	2000–2012	6.0*		Economy wide
Han & Shen (2015)	1990–2009	5.9		Economy wide
Ding et al. (2016)	1998–2007	9.6		Manufacturing
Brandt et al. (2012)	1978–2007	8.0		Manufacturing
Yang (2015)	1998–2009	3.8		Manufacturing
Gao (2015)	1992–2012	3.1	79.2	Agriculture

* This growth rate is estimated by using Figure 3 in Morrison (2013).

Coastal versus non-coastal regions

A major policy focus in China is to reduce regional disparity—in particular, unbalanced development between the coastal and the non-coastal provinces. It is therefore of policy relevance to evaluate and contrast the role of TFP growth in these two broad regions. For this purpose, the above exercises are repeated to allow for regional variations in technology—different values of δ, α and β in Equation 9.3—for the three sectors and the two regions (coastal and non-coastal). This is achieved through the use of both period-specific and regional dummy variables. The estimation results are not listed due to space limitations. Instead, the computational findings are summarised in Table 9.3.

Table 9.3 Computational results: Coastal versus non-coastal regions (per cent)

	Coastal			Non-coastal		
Period	Output	TFP	TFP/Output	Output	TFP	TFP/Output
Agriculture						
1	4.89	3.64	74.53	5.31	4.32	81.40
2	3.69	3.60	97.55	4.73	4.62	97.61
3	2.71	3.08	113.66	5.09	4.81	94.52
Manufacturing						
1	15.84	15.27	96.38	13.40	11.35	84.67
2	14.09	10.64	75.51	14.58	12.24	83.99
3	10.27	4.41	42.96	13.27	8.82	66.51
Services						
1	14.07	12.83	91.19	12.88	9.55	74.14
2	12.32	11.06	89.82	11.69	8.86	75.79
3	10.49	8.48	80.90	10.91	7.38	67.65

Note: See the notes to Table 9.1.

Source: Authors' own work.

Table 9.3 adds weight to our earlier findings that TFP has played an important role in China's growth in recent decades. Both TFP and economic growth have, as also earlier noted, slowed over time. Here we identify, however, that this downward trend is much more serious in the coastal regions than in non-coastal areas. The coastal areas, China's traditional manufacturing heartland, recorded the largest fall in TFP growth. In contrast, the non-coastal regions have maintained strong growth in manufacturing and in turn outperformed the coastal areas in all three sectors during the GFC. This is bad news for the coastal regions but good news for the reduction of regional disparity in the country. For the coastal regions, however, it is interesting to note that the service sector has outperformed the manufacturing sector since the onset of the GFC. Since the service sector dominates coastal economies, relatively fast growth in services may help economic restructuring in these regions and hence contribute to sustainable economic growth.

Conclusion

Understanding the role of productivity and innovation in economic growth in the case of China is controversial. The debate has attracted more attention since the GFC and as China's economy attempts to shift to new sources of growth. From the various methods adopted to analyse related Chinese data at the macro, regional and firm levels, the dominant view in the existing literature appears to support the notion that TFP has made a significant and positive contribution to economic growth in recent decades. Most studies also agree that the rates of both TFP and economic growth have slowed in recent years. Whether this downward trend continues has important implications for China's economic development.

This study has presented some new evidence about TFP and economic growth by examining the latest regional and sectoral statistics from China. Our estimates concur with the existing literature in finding that productivity growth has made a positive contribution to economic growth in China. It is specifically found that productivity growth is the main driver of economic growth in all three sectors: agriculture, manufacturing and services. It is also found that technological progress is primarily responsible for TFP growth.

Though TFP growth tended to fall during the GFC, there are otherwise encouraging developments in the Chinese economy. First, the extensive non-coastal areas have maintained high growth and have outperformed the coastal regions in all three sectors. This is good for the reduction of regional disparity, which has been a major policy focus in China for many years. Second, while manufacturing seems to suffer the most in the coastal areas, growth in the service sector fell only slightly, and, in particular, TFP growth in this sector is still very strong. Since services generate more than 50 per cent of the value added in the coastal areas, strong TFP growth may help these regions sustain economic growth in the future. Finally, the decline in manufacturing and rise in less resource-intensive services may also be a positive development for the environment in the coastal areas of China.

References

Aigner, D. J. and Chu, S.-F. (1968), On estimating the industry production function, *The American Economic Review* 58(4): 826–39.

Aigner, D. J., Lovell, C. A. K. and Schmidt, P. J. (1977), Formulation and estimation of stochastic frontier models, *Journal of Econometrics* 6(1): 21–37. doi.org/10.1016/0304-4076(77)90052-5.

Anand, R., Cheng, K. C., Rehman, S. and Zhang, L. (2014), *Potential growth in emerging Asia*, IMF Working Paper WP/14/2, International Monetary Fund, Washington, DC.

Battese, G. E. and Corra, G. S. (1977), Estimation of a production frontier model: With application to the pastoral zone of eastern Australia, *Australian Journal of Agricultural Economics* 21(3): 169–79. doi.org/10.1111/j.1467-8489.1977.tb00204.x.

Boeing, P., Mueller, E. and Sandner, P. (2016), China's R&D explosion: Analyzing productivity effects across ownership types and over time, *Research Policy* 45(1): 159–76. doi.org/10.1016/j.respol.2015.07.008.

Brandt, L., Biesebroeck, J. V. and Zhang, Y. (2012), Creative accounting or creative destruction? Firm-level productivity growth in Chinese manufacturing, *Journal of Development Economics* 97: 339–51. doi.org/10.1016/j.jdeveco.2011.02.002.

Chen, X. and Funke, M. (2013), The dynamics of catch-up and skill and technology upgrading in China, *Journal of Macroeconomics* 38: 465–80. doi.org/10.1016/j.jmacro.2013.07.002.

Choi, Y., Oh, D.-H. and Zhang, N. (2015), Environmentally sensitive productivity growth and its decompositions in China: A metafrontier Malmquist–Luenberger productivity index approach, *Empirical Economics* 49(3): 1017–43. doi.org/10.1007/s00181-014-0896-5.

Curtis, C. C. (2016), Economic reforms and the evolution of China's total factor productivity, *Review of Economic Dynamics* 21: 225–45. doi.org/10.1016/j.red.2015.02.005.

Ding, S. and Knight, J. (2011), Why has China grown so fast? The role of physical and human capital formation, *Oxford Bulletin of Economics and Statistics* 73(2): 141–74. doi.org/10.1111/j.1468-0084.2010.00625.x.

Ding, S., Guariglia, A. and Harris, R. (2016), The determinants of productivity in Chinese large and medium-sized industrial firms, 1998–2007, *Journal of Productivity Analysis* 45(2): 131–55. doi.org/10.1007/s11123-015-0460-0.

Du, J., Liu, X. and Zhou, Y. (2014), State advances and private retreats? Evidence of aggregate productivity decomposition in China, *China Economic Review* 31: 459–74. doi.org/10.1016/j.chieco.2014.03.002.

Fan, P. (2014), Innovation in China, *Journal of Economic Surveys* 28(4): 725–45. doi.org/10.1111/joes.12083.

Fang, J., He, H. and Li, N. (2016), *China's rising IQ (innovation quotient) and growth: Firm-level evidence*, IMF Working Paper WP/16/249, International Monetary Fund, Washington, DC.

Fleisher, B. M., McGuire, W. H., Smith, A. N. and Zhou, M. (2015), Knowledge capital, innovation and growth in China, *Journal of Asian Economics* 39: 31–42. doi.org/10.1016/j.asieco.2015.05.002.

Gao, F. (2015), Evolution trend and internal mechanism of regional total factor productivity in Chinese agriculture, *Journal of Quantitative and Technical Economics* 32(5): 3–19.

Greene, W. H. (1997), Frontier production functions, in M. H. Pesaran and P. Schmidt (eds), *Handbook of Applied Econometrics II: Microeconomics*, pp. 81–166, Oxford: Blackwell.

Han, J. and Shen, Y. (2015), Financial development and total factor productivity growth: Evidence from China, *Emerging Markets Finance and Trade* 51(Supp. 1): S261–S274. doi.org/10.1080/1540496X.2014.998928.

Hoffman, D. and Polk, A. (2014), *The long soft fall in Chinese growth: Business realities, risks and opportunities*, Conference Board Research Report, US–China Business Council, Washington, DC, and Beijing. Available from: www.uschina.org/china-hub/report-long-soft-fall-chinese-growth.

Hong, E. and Sun, L. (2011), Foreign direct investment and total factor productivity in China: A spatial dynamic panel analysis, *Oxford Bulletin of Economics and Statistics* 73(6): 771–91. doi.org/10.1111/j.1468-0084.2011.00672.x.

Hu, A. G. (2001), Ownership, government R&D, private R&D, and productivity in Chinese industry, *Journal of Comparative Economics* 29(1): 136–57. doi.org/10.1006/jcec.2000.1704.

Hulten, C. R. and Hao, J. X. (2012), *The role of intangible capital in the transformation and growth of the Chinese economy*, NBER Working Paper No. 18405, National Bureau of Economic Research, Cambridge, Mass. doi.org/10.3386/w18405.

Jiang, Y. (2011), Economic environment, technology diffusion, and growth of regional total factor productivity in China, *Journal of Chinese Economic and Business Studies* 9(2): 151–61. doi.org/10.1080/14765284.2011.568684.

Lai, P. (2015), Growth slowdown in China since 2008: Will there be a hard landing in the near future? *China and World Economy* 23(3): 42–58. doi.org/10.1111/cwe.12113.

Lau, K.-T. and Brada, J. C. (1990), Technological progress and technical efficiency in Chinese industrial growth: A frontier production approach, *China Economic Review* 1(2): 113–24. doi.org/10.1016/1043-951X(90)90001-5.

Lee, J.-W. (2016), Korea's economic growth and catch-up: Implications for China, *China and World Economy* 24(5): 71–97. doi.org/10.1111/cwe.12175.

Li, G., You, L. and Feng, Z. (2011), The sources of total factor productivity growth in Chinese agriculture: Technological progress or efficiency gain? *Journal of Chinese Economic and Business Studies* 9(2): 181–203. doi.org/10.1080/14765284.2011.568686.

Li, Q. and Wu, Y. (forthcoming), Intangible capital in Chinese regional economies: Measurement and analysis, *China Economic Review*.

Lin, C.-H., Lee, C.-M. and Yang, C.-H. (2011), Does foreign direct investment really enhance China's regional productivity? *The Journal of International Trade & Economic Development* 20(6): 741–68. doi.org/10.1080/09638190903294866.

Liu, H. and Yang, T. (2015), Explaining the productivity growth gap between China and India: The role of structural transformation, *Developing Economies* 53(2): 100–21. doi.org/10.1111/deve.12071.

Ljungwall, C. and Tingvall, P. G. (2015), Is China different? A meta-analysis of the growth-enhancing effect from R&D spending in China, *China Economic Review* 36: 272–8. doi.org/10.1016/j.chieco.2015.10.001.

Lovell, C. A. K. (1996), Applying efficiency measurement techniques to the measurement of productivity change, *Journal of Productivity Analysis* 7: 329–40. doi.org/10.1007/BF00157047.

Luckstead, J., Choi, S. M., Devadoss, S. and Mittelhammer, R. C. (2014), China's catch-up to the US economy: Decomposing TFP through investment-specific technology and human capital, *Applied Economics* 46(31–3): 3995–4007.

Ma, H., Huang, J. and Oxley, L. (2013), Capital formation and agricultural growth in China, *Asian Economic Papers* 12(1): 166–90. doi.org/10.1162/ASEP_a_00200.

Maliszewski, W. and Zhang, L. (2015), *China's growth: Can Goldilocks outgrow bears?* IMF Working Paper WP/15/113, International Monetary Fund, Washington, DC.

Mallick, J. (2017), *Structural change and productivity growth in India and the People's Republic of China*, ADBI Working Paper No. 656, Asian Development Bank Institute, Tokyo.

Meeusen, W. and van den Broeck, J. (1977), Efficiency estimation from Cobb–Douglas production functions with composed error, *International Economic Review* 18(2): 435–44. doi.org/10.2307/2525757.

Morrison, W. M. (2013), *China's economic rise: History, trends, challenges, and implications for the United States*, CRS Report for Congress 7-5700 RL33534, Congressional Research Service, Washington, DC.

National Bureau of Statistics of China (NBS) (various issues), *China Statistical Yearbook*, Beijing: China Statistics Press.

Nishimizu, M. and Page, J. M. (1982), Total factor productivity growth, technological progress and technical efficiency change, *Economic Journal* 92: 920–36. doi.org/10.2307/2232675.

Solow, R. M. (1956), A contribution to the theory of economic growth, *Quarterly Journal of Economics* 70(1): 65–94. doi.org/10.2307/1884513.

Solow, R. M. (1957), Technical change and the aggregate production function, *Review of Economics and Statistics* 39(3): 312–20. doi.org/10.2307/1926047.

Swan, T. W. (1956), Economic growth and capital accumulation, *Economic Record* 32(2): 334–61. doi.org/10.1111/j.1475-4932.1956.tb00434.x.

Tian, X. and Yu, X. (2012), The enigmas of TFP in China: A meta-analysis, *China Economic Review* 23(2): 396–414. doi.org/10.1016/j.chieco.2012.02.007.

Wang, L. and Szirmai, A. (2013), The unexpected convergence of regional productivity in Chinese industry, 1978–2005, *Oxford Development Studies* 41(1): 29–53. doi.org/10.1080/13600818.2012.756464.

Wang, S. L., Tuan, F., Gale, F., Somwaru, A. and Hansen, J. (2013), China's regional agricultural productivity growth in 1985–2007: A multilateral comparison, *Agricultural Economics* 44(2): 241–51. doi.org/10.1111/agec.12008.

Wang, Y. and Yao, Y. (2003), Sources of China's economic growth 1952–1999: Incorporating human capital accumulation, *China Economic Review* 14: 32–52. doi.org/10.1016/S1043-951X(02)00084-6.

Wei, Z. and Hao, R. (2011), The role of human capital in China's total factor productivity growth: A cross-province analysis, *The Developing Economies* 49(1): 1–35. doi.org/10.1111/j.1746-1049.2010.00120.x.

Wu, H. X. (2016), Sustainability of China's growth model: A productivity perspective, *China & World Economy* 24(5): 42–70. doi.org/10.1111/cwe.12174.

Wu, Y. (1993), Productive efficiency in Chinese industry: A review, *Asian-Pacific Economic Literature* 7(2): 58–66. doi.org/10.1111/j.1467-8411.1993.tb00191.x.

Wu, Y. (1995), Total factor productivity growth, technological progress and technical efficiency change in China: A three sector analysis, *Journal of Comparative Economics* 21(2): 207–29. doi.org/10.1006/jcec.1995.9997.

Wu, Y. (2011), Total factor productivity growth in China: A review, *Journal of Chinese Economic and Business Studies* 9(2): 111–26. doi.org/10.1080/14765284.2011.568682.

Wu, Y. (2012), Trends and prospects in China's research and development sector, *Australian Economic Review* 45(4): 467–74. doi.org/10.1111/j.1467-8462.2012.00707.x.

Wu, Y. (2016), China's capital stock series by region and sector, *Frontiers of Economics in China* 11(1): 156–72.

Yang, R. (2015), Study on the total factor productivity of Chinese manufacturing enterprises, *Economic Research Journal* 50(2): 61–74.

Yao, Z. (2015), Productivity growth and industrial structure adjustment: An analysis of China's provincial panel data, *Chinese Economy* 48(4): 253–68. doi.org/10.1080/10971475.2015.1044848.

You, K. and Sarantis, N. (2013), Structural breaks, rural transformation and total factor productivity growth in China, *Journal of Productivity Analysis* 39(3): 231–42. doi.org/10.1007/s11123-012-0285-z.

Yu, M. (2015), Processing trade, tariff reductions and firm productivity: Evidence from Chinese firms, *Economic Journal* 125(585): 943–88. doi.org/10.1111/ecoj.12127.

Yu, X., Dosi, G., Lei, J. and Nuvolari, A. (2015), Institutional change and productivity growth in China's manufacturing: The microeconomics of knowledge accumulation and 'creative restructuring', *Industrial and Corporate Change* 24(3): 565–602. doi.org/10.1093/icc/dtv011.

Zhang, J., Jiang, C. and Wang, P. (2014), Total factor productivity and China's miraculous growth: An empirical analysis, Unpublished ms. Available from: papers.ssrn.com/sol3/papers.cfm?abstract_id=2456009. doi.org/10.2139ssrn.2456009.

Zhang, Y. (2016), *China's productivity: Past success and future challenges*, MPFD Working Paper No. WP/16/06, Macroeconomics Policy and Financing for Development Division, United Nations Economic and Social Commission for Asia and the Pacific, Bangkok. Available from: www.unescap.org/resources/mpfd-working-paper-chinas-productivity-past-success-and-future-challenges.

Zhu, X. (2012), Understanding China's growth: Past, present and future, *Journal of Economic Perspectives* 26(4): 103–24. doi.org/10.1257/jep.26.4.103.

This text is taken from *China's New Sources of Economic Growth: Human Capital, Innovation and Technological Change, Volume 2*, edited by Ligang Song, Ross Garnaut, Cai Fang and Lauren Johnston, published 2017 by ANU Press, The Australian National University, Canberra, Australia.

dx.doi.org/10.22459/CNSEG.07.2017.09