The approach to and challenges in measuring innovation in China

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Abstract

In China and elsewhere, innovation features strongly in government policy as a key driver of economic development. Being able to measure innovation performance is therefore important. This article analyses China's approach to measuring the country's innovation performance. In doing so and using documentary analysis, it evaluates the conceptualisation and data collection that underpin and support that measurement. The findings show that China focuses on a science and technology approach to measuring innovation. The weaknesses of this approach are identified: first, the conceptual scope is too narrow due to its exclusion of non-technological innovation; second, relatedly, data gathering is limited quantitatively and qualitatively in its coverage of types of innovation; and, third, the sample population is biased, acting to excluding a significant number of firms and employees. These weaknesses undermine understanding of innovation performance in China. With this analysis, this article provides the first evaluation of China's innovation conceptualisation and measurement and, based on the findings, provides suggestions to address these weaknesses and improve the measurement of innovation performance and which have applicability beyond China. For China and other countries such as those which are members of the OECD and EU, the evidence provided in this article suggests that there is a pressing need to adopt a broader policy approach and support it through the development of appropriate measures and data collection.

Keywords: China; innovation conceptualisation; innovation data; innovation measurement; innovation policy; non-technological innovation; technological innovation

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Introduction

Governments worldwide are being urged to develop their countries' innovation performance as a route to attaining economic growth and competitiveness (EC, 2010; OECD, 2010). China too has adopted this strategy as it looks to shift from a cost-competitive economy to one in which innovation is central to its economic development (State Council, 2011). Over the last twenty years China has introduced a series of policies to drive this shift. Both the Chinese government and firms attach high importance to innovation and are pursuing growth and competitiveness through it (Ding & Li, 2015; Yang, 2020). Given that improving innovation requires its measurement, China has also introduced a number of innovation measures. Significantly, not only has China adopted similar innovation policy positions as the OECD and EU countries, it has also adopted the same measures. This article examines and evaluates those measures and their supportive data.

The article draws on a documentary analysis of Chinese governmental policy documents. This documentary analysis of innovation policy and data collection in China reveals three weaknesses with its approach to innovation measurement: the scope of measurement is too narrow; the questions in the measurement are too blunt; and the range of organisations covered is too limited. The outcome is that current data collection fails to capture the full extent of innovation in China and hampers not only assessment of innovation performance but also policy actions that might improve innovation performance. Some of these weaknesses are specific to China, others however resonate with critiques made about current evaluation of innovation performance in the EU (e.g. Makó et al., 2016). As this article points out, the China-specific weaknesses can be remedied. However, given that China is not alone in its approach to measuring innovation, our findings confirm the need for a rethink from policymakers more widely. In the EU, for instance, the importance of workplace innovation has been highlighted as it not only plays a significant role in connecting different policy agendas such as economy, innovation, social dialogue and social rights, but also helps achieve best possible human potential along with technological innovation. Furthermore, it has been strongly argued that policymakers should not only enhance the awareness of workplace innovation but also expand the related measures in wider fields such as industry, employment and policy research. (Totterdill et al., 2022).

The next part of this article outlines the conceptual approach to innovation as expressed in and underpinning Chinese government policy. The following section then outlines the resulting measurement of innovation in China, including its supportive data collection. The subsequent section then considers how the weaknesses in China's innovation measurement might be addressed and improved. The article makes three contributes to understanding. First, it is a first evaluation of the innovation measurement in China that links conceptualisation and data collection. Secondly it makes suggestions about how data collection in China might be improved. Third, in its conclusion, it relates this evaluation and suggestions to approaches to measuring innovation beyond China.

China's approach to innovation from a policy perspective

According to the IMF (2022), China is now the world's second largest economy. Its economic development has been rapid and marked by clear policy stages, within which innovation has become a key part. China's policy support for innovation has also evolved as the country has passed through three stages of economic development: the state-led formative period (1949-1977), the market-oriented transition period (1978-2005), and the indigenous innovation-oriented development period from 2006 onwards (Ding & Li, 2015). In this latest stage, China has sought to develop a supportive institutional environment for innovation (Fu, 2015).

The first indication of the shift away from the cost-based economic growth and competitiveness that marked the second stage of development to innovation occurred in 2001. *The Tenth Five-Year Plan Outline* proposed building a national innovation system and innovation-delivering projects. The emphasis was explicitly science and technology focused. The Plan promoted technological upgrading generally and enterprises as the site of technological innovation implementation as the basis for sustainable economic development. It also urged the fostering of collaborations between industry, universities and research institutions. Since the launch of this Plan, scientific and technological innovation has been further promoted nationally, with China committed to building technological capacity to deliver indigenous innovation to support its economic transformation.

This support for indigenous innovation development is evident in two subsequent policy documents: *The Decision on Implementing the Outline of the Scientific and Technological Plan and Enhancing the Independent Innovation Capacity* and *The National Guideline for Medium and Long-term Plan for Science and Technology Development (2006-2020)*, both published in 2006. These documents regard science and technology as strategically fundamental to improving indigenous innovation and the core of China's competitiveness. The documents list "original innovation", "integrated innovation" and "re-innovation" as the three fundamental forms of indigenous innovation. Original innovation refers to basic research breakthroughs in leading-edge and core technologies. Integrated innovation means the creation of new products by utilising and integrating existing technologies. Re-innovation is defined as major innovation breakthroughs based on imported technology. These policies target science and technology intensive industries such as information, biology, new materials, aerospace, energy and oceanography. The documents further specify that the Chinese government would increase its financial investment in science and technology, with the ratio of it to GDP increasing annually: 2% by 2010 and over 2.5% by 2020. According to the Chinese National Bureau of Statistics, this ratio was 2.4% in 2020 then rose to 2.55% in 2022.

To guide and accelerate China's innovation, *The Twelfth Five-Year National Indigenous Innovation Capacity Building Plan* was issued in 2013. It is so far the most comprehensive innovation policy to date in China and outlines five key objectives. First, to enhance construction of critical national infrastructure in, for example, energy, life, environmental and materials sciences as well as space sciences and engineering. Second, to promote technological innovation capacity in key industries including agriculture, manufacturing, strategic emerging industries, and energy and transportation. Third, to increase technological innovation capacity amongst business enterprises and research institutions, and build a number of world-class research institutions. Fourth, to establish a regional innovation system covering the country's eastern, central and western regions and to exploit each region's potential based on their distinctive resource advantages. Fifth, to improve the environment for innovation, including support for talent teams and protection of intellectual property rights and patents.

The Thirteenth Five-Year National Plan (2016-2020) and the recently released *Fourteenth Five-Year Plan (2021-2025)* show continued emphasis on improving the national innovation system through strengthened basic research, cross-disciplinary collaboration, enterprise innovation capability, and cooperation between academia and industry. *The Fourteenth Five-Year Plan* made it clear that science and technology independence is the core driver for indigenous innovation development and re-emphasised the importance of enhancing the technological innovation capability of enterprises as the route to a sustainable economy. It announced that China would establish a series of national innovation laboratories in strategic areas such as quantum information, artificial intelligence, biomedicine, modern energy systems.

To ensure effective implementation of its innovation policies, the Chinese government strengthened its guidance, improved laws and regulations, refashioned industrial and fiscal policies, increased government investment, and introduced a new supervision and evaluation system (State Council, 2013). For example, innovative enterprises enjoy favourable tax policies and privileges, and research institutions can retain all income to reward researchers and fund future research projects. In 2015, the Central Committee of the Communist Party and the State Council co-published a document called *Opinions of the CPC Central Committee on Deepening the Reform of the Institutional Mechanisms to Accelerate the Implementation of Innovation-Driven Development Strategy*. It stated that by 2020 an institutional and legal framework conducive to innovation-driven development would be established, allowing free movement of talent, capital, technology and knowledge across the country. This policy is intended to increase the efficiency of resource allocation and encourage coordinated innovation across regions (Gov.cn, 2015).

China has thus attached new, strategic importance to innovation as a driving force for its economic development and has moved through a series of policies intended to improve the innovation performance of the country. Its approach to building an innovation-led country is reflected in both national policy and infrastructure development. At the core of both lie the promotion of science and technology as the driver of innovation (Schot & Steinmueller, 2018). This conceptualisation of innovation as driven by science and technology in turn has shaped data collection to measure innovation performance in China.

Measuring innovation in China

China conducted its first nationwide innovation survey in 2007. It was based on the EU's *Oslo Manual*-influenced (OECD, 2005) Community Innovation Survey (CIS), though it included some China-specific questions about the behavior of enterprises in the Chinese economic and policy context. The Oslo Manual outlines two types of innovation: technological and non-technological. These two types are each broken down into two further types – within technological there are product and process innovations, and within non-technological there are organisational and marketing innovations. The Chinese survey, however, focused only on technological innovation and three industries. The brief focus on non-technological innovation that features in the CIS in the EU (see Makó et al., 2016) was ignored. Data collection was subsequently revised to extend the scope of the survey and to establish the architecture for regular innovation surveys (Statistics Sweden, 2008; Schaaper, 2009).

From 2013, the *National Innovation Investigation, Monitoring and Assessment System* was adopted that measures innovation at three levels – national, regional and enterprise – as well as innovation-intensive industries and localities (Ministry of Science and Technology, 2013). The purpose of this system is to establish the innovation capability of China compared to other countries at the national level while also assessing regional differences in innovation capability within China at the regional level. The enterprise data collection focuses on firms' innovation activities. The focus on innovation-intensive areas ranges from typically innovative industries to high-tech zones and innovation cities.

The measurement of innovation has three features: first, statistical investigation of innovation activities; second, innovation capability monitoring; and, third, innovation capability assessment (Ministry of Science and Technology, 2017). The statistical investigation collects data of innovation activities at the three levels – national, regional and enterprise. The monitoring phase then focuses on the input and output of innovation as well as overall innovation capability at national, regional, enterprise levels and innovation-intensive industries and localities. Finally, the assessment analyses and compares innovation capabilities at the respective levels. Measurement at the different levels involves different assessment frameworks and uses different data sources. Details of the data sources are presented in Appendix A.

Following the *Oslo Manual* guidelines, China adopts a range of innovation indicators for the different levels of measurement. The Chinese National Innovation Capability assessment comprises 33 indicators across five main categories: innovation resources, knowledge creation, enterprise innovation, innovation performance and innovation environment (see Appendix B). The Regional Innovation Capability assessment has 53 indicators ranging from innovation environment, innovation resources, enterprise innovation, innovation outputs to innovation effects (see Appendix C). The Enterprise Innovation Capability assessment includes 24 indicators divided into four areas: innovation inputs, collaborative innovation, intellectual property rights and innovation incentives (see Appendix D). The three-level assessment has different foci: while all three cover enterprise innovation, the regional and national-level assessments also measure wider social and macroeconomic items as well as the policy instruments relating to innovation, thus enabling an evaluation of innovation performance and effectiveness in wider context.

Despite these differences, as the appendices show, the indicators used in the three levels of assessment only relate to technological innovation, focusing on indicators such as R&D, human resources and expenditures, patents applications, scientific papers and publications, and science and technology activities and collaborations with various aspects of R&D, technology and patents commonly measured. They are what Taques et al. (2021) call input and output indicators. Indicators of non-technological innovation, either marketing or organisational, are not included in national and regional data collection.

In terms of the data sources, the national measurement draws mainly on data from the National Bureau of Statistics which covers economic, scientific, technological and societal aspects. Other data includes scientific papers and patents to enable international comparisons. Data sources for regional measurement are more concentrated, mainly from the *China Science and Technology Statistical Yearbook* and *China Statistical Yearbook*. By contrast, enterprise level measurement draws on both existing secondary data and an enterprise level survey. The existing data comes from the *Statistics Yearbook on Science and Technology Activities of Industrial Enterprises* and *China Industry Statistical Yearbook*, while the new data is generated through the *China Enterprise Innovation Survey* (CEIS).

The CEIS was first conducted in 2014 and since 2016 has been conducted annually. It comprises two parts with two separate questionnaires. The first part collects basic background information on the enterprise (e.g. employee numbers, financial turnover, sector), innovation activities and the four types of innovation: product, process, marketing and organisational. The second part focuses on the employer, collecting information on their background (e.g. gender, age, education), impact of innovation on their enterprises and factors for successful innovation (Chinese Academy of Science and Technology for Development & School of Economics in Central University of Finance and Economics, 2016). While other levels' data collection focuses exclusively on technological innovation, a distinctive feature of the CEIS is that it covers both technological innovation and non-technological innovation. Nonetheless, technological innovation remains the main focus of the CEIS, asking detailed questions on product and process innovation such as innovation activities and expenditures, sources of information for product and process innovation, the mode and the importance of partnership in innovation cooperation, factors hampering product and process innovation, and intellectual property rights protection. By contrast, questions on non-technological innovation are very limited in number and nature. A single 'yes/no' question asks only if enterprises have marketing or organisational innovation. As a result, the survey captures only the percentage of enterprises reporting having such innovation (either marketing or organisational, or both) and their distribution by industry and region.

China's approach to measuring innovation thus involves data collection at three levels but which almost exclusively focuses on technological innovation. The exception is the CEIS at the enterprise level which includes both technological and non-technological innovations, though data collection and measurement of the latter is very limited.

Weakness in the measurement of innovation in China and how it might be improved

The conceptualisation and measurement of innovation in China has resulted in three weaknesses in data collection. This section outlines those weaknesses and offers suggestions as to how they might be addressed.

The first weakness is that the scope of measurement is too narrow. Reliance on input and output indictors alone as measures of innovation has been criticised as too narrow by Taques et al. (2021). We argue that this narrowness stems from the conceptualisation of innovation in Chinese policy. Jensen et al. (2007) distinguish between two modes: Science, Technology & Innovation (STI) and 'Doing, Using and Interacting' (DUI). China's measurement rests on the first mode, which is based on 'know what', regarding the driver of innovation as 'the production and use of codified scientific and technical knowledge' (p.680). It assumes that innovation is linear, passing through various stages of scientific discovery, development, production and marketing (Fagerberg, 2005). The result is an emphasis on measuring technological innovation – the product and process innovations outlined in the Oslo Manual (OECD, 2005). Although limited data is collected through the CEIS on non-technological innovation at enterprise level, the dominant focus at all three levels of assessment reflects the STI mode.

The problem for China is that this emphasis on technological innovation is neither efficacious – it fails to capture the range of innovation in China – nor delivering the expected benefits for China. With respect to the first issue, and reflecting its focus on input and output variables, measurement of product innovation as a type of technological innovation uses, for example, patents as an indicator of innovation performance. While patents and R&D data tend to be useful in reflecting innovations in manufacturing industries, these technological innovation indicators lack the capacity to capture innovations in the service industries which emphasise marketing or organisational investments over formal R&D investments (Taques et al., 2021). This problem is particularly poignant for China as it is transitioning from a manufacturing-heavy economy to a service-led economy. The aspiration is to build an economy in which the tertiary sector contributes most to economic output (as measured by GDP) and most employment compared to the primary (e.g. agriculture) and secondary (e.g. construction and manufacturing) sectors (National Bureau of Statistics, 2021). With respect to the second issue, Chinese firms struggle to lever growth and competitiveness through new product innovation. In 2021, the total number of invention patents applications in China rose to 1.6 million and utility model patent applications increased to 2.9 million, of which 55 per cent were approved and awarded (China National Intellectual Property Administration, 2022). However, the rate of patent conversion to commercial use in China is less than 10 per cent (China National Intellectual Property Administration, 2019; State Council, 2019a). In the US it is around 40-50 per cent (National Science Board, 2018). These figures would suggest a low return on investment in technological innovation in China. Such figures reveal that the STI mode alone has created low returns on innovation investment.

It is not that China does not recognise non-technological innovation. As we note, the Oslo Manual covers two types of innovation – technological and non-technological – and China draws on this Manual in its measurement of innovation. The problem is that China places overwhelming emphasis on only one type – technological. Accepting both types means accepting the broader conceptualisation of innovation that includes the DUI mode. This mode of innovation relies on informal processes of learning and experience-based know-how and know-who which is often highly localised (Jensen et al., 2007). In this mode innovation is fostered by building structures and relationships which promote learning. Innovation performance can then be enhanced by organisational practices such as project teams, problem-solving groups and job and task rotation (Lundvall & Nielsen, 1999; Michie & Sheehan, 1999; Laursen & Foss, 2003; Lorenz at al., 2004; Lorenz & Valeyre, 2006). Crucially, as Jensen et al. point out based on their Danish research, innovation performance is improved by strategies that combine the STI and DUI modes. Controlling for sector, firm size and ownership, firms combining the STI and DUI modes are more innovative than firms biased toward one mode. Recent research not focused on China shows that a full return on investment is unlikely to be achieved by organisations unless they considered both technological innovation and workplace innovation, a mechanism that can embrace and maximise technological innovations through synergies with human potential (Totterdill et al., 2022). New empirical research indicates that versions, at least, of DUI exist and do make a difference to innovation performance at enterprise level in China (Yang, 2020; see also Wang et al., 2019). Moreover, Yang (2020) also notes, deteriorating working conditions in China have triggered a growing need for improvements in job quality, and practices associated with good job quality often overlap with DUI practices. Consequently, China would benefit from better recognition and inclusion of both STI and DUI modes and the innovation potential in their dual use, not only because doing so would provide a more comprehensive understanding of the range of innovation in China but also highlight the points where intervention policies can be implemented to improve innovation performance and capability, as well as employees' wellbeing – if that wellbeing is a function of job quality (see Muñoz de Bustillo et al., 2011). As such, it would help policy development and a more efficient allocation of state resources.

Broadening conceptual understanding of innovation would have implications for data collection. The second weakness is that, even when included in the CEIS, the questions used to collect data on non-technological innovation are currently limited quantitatively and qualitatively, disabling detailed understanding of this type of innovation. As a consequence, the CEIS generates limited understanding of non-technological innovation. The sole question about each form of non-technological innovation simply reveals the number and proportion of enterprises that report having marketing or organisational innovations in China. Even basic, but what would still be useful, information on what kind of marketing innovation or organisational innovation is present in these enterprises is absent. Consequently, China needs to expand the scope of its data capture of non-technological innovation.

Taken together the two limitations create a significant understanding deficit about the types, nature and extent of innovation in China. More and better questions related to the DUI mode and marketing and organisational innovations are needed, particularly at enterprise level. In developing these new questions, it would be important to draw on existing theoretical and empirical research. In the case of DUI and organisational innovation, there is much research, past and more recent, about levering innovation in workplaces (e.g. Burns & Stalker, 1961; Lorenz et al., 2004; Exton & Totterdill, 2019; Putnik et al., 2019). In addition, there are useful literature reviews focused on this type of innovation (e.g. Armbruster et al., 2008; Kesselring et al., 2014; Kibowski et al., 2019; Alasoini, 2022). Some of this literature advocates the concept of 'workplace innovation' to provide better detail to what is argued to be the poor operationalisation of organisational innovation (Coriat, 2000). This concept rests, as Kesselring et al. (2014) state, with human resource management and organisational development functions within workplaces (see also Pot et al. 2016) and is not unlike the DUI mode of innovation outlined by Jensen et al. (2007). Referencing it would help develop new measures of organisational innovation within Chinese enterprises or, better perhaps, replace organisational innovation with workplace innovation. Likewise, in the case of marketing innovation, there is research showing innovations achieved through different marketing methods such as market research, orientation and segmentation, and more recently, consumer behaviors and digital marketing (e.g. Doyle & Bridgewater, 2012; Gong et al., 2021; Saura, 2021). Again reference to this literature would help develop indicators of this type of innovation and generate more and better data on it within Chinese enterprises. Theoretical and empirical resources thus already exist from which China might draw to help improve its measurement of non-technological innovation.

The third weakness is the biased sample population. The innovation data released by the Chinese government (see Appendix A), including the *Chinese Statistical Yearbooks* and the CEIS, focuses only on those enterprises 'above a certain scale' (Statistics Division of Social Science and Cultural Industry of the National Bureau of Statistics, 2016, p.449). This scale typically refers to a particular level of revenue or employee headcount. For revenue, the level can vary by sector – more than 20m yuan per annum for enterprises in the industrial and wholesale sectors, more than 10m yuan for service sector enterprises (or more than 50 employees) and more than 5m yuan for retail sector enterprises – but which, in each case, classifies these enterprises as medium-sized for that sector. Thus, given this threshold, only medium to large sized enterprises are included in the data collection in China. This sample presents a representativeness problem because small enterprises dominate the Chinese economy both in terms of the number of enterprises and employees. In some regions, the number of small enterprises is double that of large and medium-sized enterprises (National Bureau of Statistics, 2021). Data from the National Bureau of Statistics show that China's micro, small and medium-sized enterprises (MSMEs) contribute more than 50 per cent of the country's tax revenue, more than 60 per cent of GDP, more than 80 per cent of urban employment and more than 90 per cent of new jobs. Amongst MSMEs, the contribution of small and micro enterprises is particularly salient. Small and micro enterprises account for more than 97 per cent of all enterprises and provide 54 per cent of all jobs (Fudan-Ping An Research Institute for Macroeconomy, 2020). It could be argued therefore that, on a general level, these smaller enterprises are the main driver of national economic development in China. Nonetheless, they are ignored in the measurement of innovation.

It is recognised that smaller firms generally, are less likely to innovate (Taques et al. 2021), a situation that also holds for China. In China, most small enterprises are in industries with a relatively low level of technology, have smaller scale investment, less clear market prospect and less fast cycles of return on investment. As such they lack the incentives and capacities to innovate (Xie et al., 2013; Newman et al., 2015; Naradda Gamage et al., 2020). As a consequence, most small enterprises rely on importing rather than innovating technology (Wonglimpiyarat, 2015; Alqahtani, 2016; Chu & Tan, 2019). For these reasons and in the absence of supportive policy, it is difficult to release the innovation potential of small firms in China.

Recently, the China State Council (2019b) has at least acknowledged micro and small enterprises as the new driver of economic development and employment and the important potential source of innovation. It would make sense therefore to include these firms in innovation measurement. In doing so, China would be able to capture their current innovation performance and identify how it might improve that performance. In not doing so, China is likely to be left with a long tail of under-performing enterprises and employees which might then constrain further economic growth and competitiveness. Data collection therefore needs to be more comprehensive in China and include smaller enterprises to reveal their contribution to and potential for innovation.

Although from 2016 the CEIS survey sought to include small enterprises, limitations still exist in terms of industry coverage and questions compared to medium and large enterprises. Small enterprises in the construction, wholesale and retail industries are omitted from the survey population. Moreover, the questions for small enterprises are shortened, again only covering product and process innovations. However, and echoing the findings of Jensen et al. (2007), recent research by Zhang (2022) indicates that the performance of small and medium-sized enterprises (SMEs) in China improves when organisational innovation is introduced simultaneously alongside the above-mentioned technological innovations, thus suggesting the importance of using and combining different types of innovation within SMEs. The exclusion of non-technological innovation questions for small enterprises in the current CEIS generates a knowledge gap in fully capturing and understanding the innovation capability of small enterprises in China. Further improvements are therefore needed in the collection of innovation data from these small enterprises.

These three weaknesses matter: they created a skewed dataset that disables comprehensive evaluation of China's innovation performance, capability and potential. Not recognising these weaknesses also hampers China's policy aim to improve innovation and thereby improve the country's economic growth and competitiveness.

Concluding remarks

As with many other countries worldwide, China's economic development and competitiveness has shifted to emphasise innovation. A range of policies now support the improvement of innovation capacity in China. This article has outlined how that innovation is measured, examining that measurement's underpinning conceptualisation and supportive data collection. The document analysis identified three resulting weaknesses in China's approach to innovation measurement. These weaknesses mean that understanding of China's innovation performance is limited. However, as this article has argued, the measurement of innovation in China can be improved by, firstly, widening the scope of measurement beyond the STI mode to recognise and include the DUI mode of innovation; secondly and relatedly, by extending the collection of data on technological innovation to improved data collection of non-technological innovation; and, thirdly, by better reflecting China's enterprise and employment composition and thereby capturing data on innovation in small enterprises.

We note though that the weaknesses in China's conceptualisation and measurement of innovation are not China specific, which is not surprising given that China's measures of innovation are drawn from the OECD's *Oslo Manual* (OECD, 2005). Because it too adopts the Oslo Manual, the first two limitations that we identify in China's measure of innovation also exist in EU innovation measurement. Whilst both China and the EU recognise the four types of innovation as outlined in the *Oslo Manual*, their approaches to measuring innovation both privilege the STI mode and so are dominated by a focus on technological innovation. Even where they are included, survey questions and statistical indicators of non-technological marketing innovation and organisational innovation are weak and need to be better developed and given more prominence in analysis of innovation (for an evaluation of EU innovation measurement, see Makó et al., 2016). Non-technological innovation needs to be given more attention. In order to boost innovation, it is not sufficient to target higher levels of R&D expenditure at national level, Arundel et al. (2007) argue. Instead, more attention needs to be paid, they state, to organisational (or, we suggest, workplace) innovation at the enterprise level for two reasons: one, it is easier to affect and, two, it provides greater effect. Studies show that failure to implement such innovation is associated with a lack of knowledge and relevant skills, rigid organisational structure, short-term low road company strategy and market failure (Totterdill et al., 2022). Finland, a leading innovator, has adopted a 'broad-based innovation policy', which incorporates this approach, 'expanding the target of innovation policy to give more significance to non-technological innovations and increasing the positive joint impacts of technological and non-technological innovations' (Alasoini, 2013: 1). For China and other countries such as those which are members of the OECD and EU, the evidence suggests that there is a pressing need to adopt this broader policy approach and support it through the development of appropriate measures and data collection.

The argument for China and other countries continued use of existing measures is that they enable cross-country and, in the case of China, within-country cross-regional comparisons.

Whilst international comparisons based on conceptual commensurability are undoubtedly useful, what is captured by this conceptualisation and measurement is partial at best and, at worst, generates data bias because of the innovation within any country and its firms is overlooked and unrecorded. Although devising new innovation measures based on broader conceptualisation will not be a trivial task, it is a task that is urgently needed (Taques et al. 2021). Without better measurement that incorporates the DUI mode and non-technological innovation, not only is understanding of innovation performance impaired but policy development is also likely to falter in its objective to improve innovation performance. In this regard China is emblematic of both current innovation measurement more widely and how that measurement might be improved. If the example of China has resonance elsewhere, having that more comprehensive understanding and measurement of innovation will help other countries, not just China, develop better policy and interventions within their national innovation systems that will improve the efficiency of resource allocation as well as innovation conversion rates.

References

Alasoini, T. (2013) 'Promoting employee-driven innovation: putting broad-based innovation policy into practice', paper for the International Helix Conference, Linköping, Sweden.

Alasoini, T. (2022). Promoting Workplace Innovation in an Innovation Policy Context. *European Journal of Workplace Innovation*, *7*(1), pp.4-19.

Alqahtani, K.M. (2016). Challenges of Innovation for Chinese Small and Medium-sized Enterprises: Case Study in Beijing. *International Business Research*, Vol. 9, No. 12, 165-171.

Armbruster, H., Bikfalvi, A., Kinkel, S., & Lay, G. (2008). Organisational innovation: the challenge of measuring non-technical innovation in large-scale surveys. *Technovation*, 28, 644-657.

Arundel, A., Lorenz, E, Lundvall, B.-Å. and Valeyre, A. (2007). 'How Europe's economies learn: a comparison of work organization and innovation mode for the EU-15, Industrial and Corporate Change, 16(6), 680-93.

Burns, T., & Stalker, G.M. (1961). *The management of innovation*. Tavistock, London.

China National Intellectual Property Administration. (2019). China patent research report 2019. http://www.cnipa.gov.cn/module/download/down.jsp?i_ID=40213&colID=88.

China National Intellectual Property Administration. (2022). *China Annual Report 2021*. https://english.cnipa.gov.cn/module/download/down.jsp?i_ID=176467&colID=2936.

Chinese Academy of Science and Technology for Development, & School of Economics in Central University of Finance and Economics. (2016). Assessment report on the innovation capability of Chinese enterprises. Scientific and Technical Documentation Press, Beijing.

Chung, L., & Tan, K.H. (2017). The unique Chinese innovation pathways: Lessons from Chinese small and medium sized manufacturing firms. *International Journal of Production Economics*, 190, 80-87.

Coriat, B. (2000). Organisational Innovation in European Firms: A Critical Overview of the Survey Evidence in D. Archibuggi and B. Lundvall (Eds), The End of Fordism and the Rise of the knowledge Economy, Oxford University Press, Oxford.

Ding, X.D., & Li, J. (2015). Incentives for innovation in China: building an innovative economy. Routledge, London.

Doyle, P., & Bridgewater, S. (2012). Innovation in marketing. Routledge, London.

European Commission. (2010). About Innovation Union. http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=intro.

Exton, R. and Totterdill, P., (2018). Unleashing workplace innovation in Scotland. European Journal of Workplace Innovation, 4(1), pp.45-53.

Fagerberg, J. (2005). Innovation: a guide to the literature, in: Fagerberg, J., Mowery, D. C., & Nelson, R. R. (Eds), The Oxford Handbook of Innovation. Oxford University Press, Oxford.

Fu, X. (2015). China's path to innovation. Cambridge University Press, Cambridge.

Fudan-Ping An Research Institute for Macroeconomy. (2020). China's SMEs amid the pandemic: facing cash cow problems and awaiting government aid. http://www.pingan.cn/app_upload/file/official/SMEReport2020.pdf.

Gong, Q., Tang, Z., & Xu, B. (2021). Trading behaviors on knowledge of price discovery in futures markets. Journal of Innovation & Knowledge, 6(3), 191-195.

Gov.cn. (2015). China eyes innovation in face of economic 'new normal'. http://english.gov.cn/policies/latest_releases/2015/03/24/content_281475076695559.htm.

International Monetary Fund (IMF). (2022). World Economic Outlook Database, April 2022. https://www.imf.org.

Jensen, M.B., Johnson, B., Lorenz, E., & Lundvall, B. A. (2007). Forms of knowledge and modes of innovation. Research Policy, 36, 680-693.

Kesselring, A., Blasy, C., & Scoppetta, A. (2014). Workplace Innovation: Concepts and indicators. European Commission, Directorate-General Enterprise and Industry, Brussels.

Kibowski, F., Baguley, T., Totterdill, P. and Karanika-Murray, M., 2019. A new measure of workplace innovation. European Journal of Workplace Innovation, 5(1).

Laursen, K., & Foss, N. (2003). New HRM practices, complementarities, and the impact on innovation performance. Cambridge Journal of Economics, 27, 243-263.

Lorenz, E., & Valeyre, A. (2006). Organisational forms and innovative performance, in: Lorenz, E., & Lundvall, B.A. (Eds), How Europe's economies learn: coordinating competing models. Oxford University Press, Oxford.

Lorenz, E., Wilkinson, F., & Michie, J. (2004). HRM complementarities and innovative performance in French and British industry, in: Christensen, J.L., & Lundvall, B.A. (Eds), Product innovation, interactive learning and economic performance. Elsevier, Amsterdam.

Lundvall, B.A., & Nielsen, P. (1999). Competition and transformation in the learning economy. Revue d' Economie Indstrielle, 88, 67-90.

Makó, C., Illéssy, M., & Warhurst, C. (2016). The evolution of EU innovation policy relevant to job quality and employment. QuInnE Working Paper 2, www.quinne.eu.

Michie, J., & Sheehan, M. (1999). HRM practices, R&D expenditure and innovative investment. Industrial and Corporate Change, 8, 211-234.

Ministry of Science and Technology. (2013). National Innovation Investigation, Monitoring and Assessment System. http://www.most.gov.cn/tztg/201312/t20131204_110716.html.

Ministry of Science and Technology. (2017). Illustration of "Measures for the Implementation of The National Innovation Investigation System". http://www.most.gov.cn/xxgk/xinxifenlei/fdzdgknr/fgzc/zcjd/202106/t20210625_175428.html.

Muñoz de Bustillo, R., Fernández-Macías, E., Esteve, F. and Antón, J. (2011). Measuring more than money. Edward Elgar, Cheltenham.

Naradda Gamage, S.K., Ekanayake, E.M.S., Abeyrathne, G.A.K.N.J., Prasanna, R.P.I.R., Jayasundara, J.M.S.B., & Rajapakshe, P.S.K. (2020). A review of global challenges and survival strategies of small and medium enterprises (SMEs). Economies, 8(4), 79.

National Bureau of Statistics. (2021). China Statistical Yearbook 2021. China Statistics Press, Beijing.

National Science Board. (2018). Science & engineering indicators 2018. https://www.nsf.gov/statistics/2018/nsb20181/report/sections/invention-knowledge-transfer-and-innovation/invention-united-states-and-comparative-global-trends#global-patent-trends-and-cross-national-comparisons.

Newman, A., Gao, Y., & Zheng, J. (2015). Overcoming the innovation challenge: examining the determinants of new product innovation in Chinese SMEs. In Developments in Chinese entrepreneurship (pp. 33-57). Palgrave Macmillan, New York.

OECD. (2005). Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data. OECD, Paris.

OECD. (2010). The OECD innovation strategy. OECD, Paris, https://doi.org/10.1787/9789264083479-en.

Pot, F., Totterdill, P. and Dhondt, S. (2016). Workplace innovation: European policy and theoretical foundation, World Review of Entrepreneurship, Management and Sustainable Development, 12(1), 13-32.

Putnik, K., Oeij, P., Dhondt, S., Van der Torre, W., De Vroome, E. and Preenen, P., 2019. Innovation adoption of employees in the logistics sector in the Netherlands: The role of workplace innovation. European Journal of Workplace Innovation, 4(2), pp.176-192.

Saura, J.R. (2021). Using data sciences in digital marketing: Framework, methods, and performance metrics. Journal of Innovation & Knowledge, 6(2), 92-102.

Schaaper, M. (2009). Measuring China's innovation system: National specificities and international comparisons. OECD Science, Technology and Industry Working Papers 2009/01, OECD, Paris.

Schot, J., & Steinmueller, W.E. (2018). Three frames for innovation policy: R&D, systems of innovation and transformative change. Research Policy, 47(9), 1554-1567.

State Council. (2006). The Decision on Implementing the Outline of the Scientific and Technological Plan and Enhancing the Independent Innovation Capacity. http://www.gov.cn/gongbao/content/2006/content_240241.htm.

State Council. (2006). The National Guideline for Medium and Long-term Plan for Science and Technology Development (2006-2020). http://www.gov.cn/gongbao/content/2006/content_240244.htm.

State Council. (2011). Twelfth Five-Year Plan (2011-2015) for National Economic and Social Development. China's National People's Congress, Beijing.

State Council. (2013). "Twelfth five-year" national indigenous innovation capacity building plan. http://www.gov.cn/zhengce/content/2013-05/30/content_5186.htm.

State Council. (2019a). Audit report of the State Council on the implementation of the central budget and other fiscal revenues and expenditures in 2019.

State Council. (2019b). Reducing innovation and entrepreneurship costs and enhancing the development of small and micro sized enterprises. http://www.gov.cn/zhengce/2019-01/19/content_5359180.htm.

Statistics Division of Social Science and Cultural Industry of the National Bureau of Statistics. (2016). Statistics of enterprise innovation survey. China Statistics Press, Beijing.

Statistics Sweden. (2008). S&T and Innovation Statistics in China. Presented at the 2008 meeting of the OECD Working Party of National Experts on Science and Technology Indicators (NESTI), Secretariat working document, OECD, Paris.

Taques, F.H., López, M.G., Basso, L.F., & Areal, N. (2021). Indicators used to measure service innovation and manufacturing innovation. Journal of Innovation & Knowledge, 6(1), pp.11-26.

Totterdill, P., Pot, F., Dhondt, S. and Warhurst, C. (2022). Workplace Innovation: Europe's Competitive Edge. A manifesto for enhanced performance and working lives. European Journal of Workplace Innovation, 7(1), pp.132-141.

Wang, Y.X., Yang, Y.J., Wang, Y., Su, D., Li, S.W., Zhang, T. and Li, H.P., (2019). The mediating role of inclusive leadership: Work engagement and innovative behaviour among Chinese head nurses. Journal of nursing management, 27(4), pp.688-696.

Wonglimpiyarat, J. (2015). Challenges of SMEs innovation and entrepreneurial financing. World Journal of Entrepreneurship, Management and Sustainable Development, Vol. 11 No. 4, 295-311.

Xie, X., Zeng, S., Peng, Y., & Tam, C. (2013). What affects the innovation performance of small and medium-sized enterprises in China? Innovation, 15(3), 271-286.

Yang, J. (2020). Exploring the relationship between innovation and job quality: evidence from China. PhD thesis, University of Warwick.

Zhang, H. (2022). Does combining different types of innovation always improve SME performance? An analysis of innovation complementarity. Journal of Innovation & Knowledge, 7(3), 100192.

Appendices

Appendix A. China's approach to measuring innovation

Framework		Data sources
National	Assessment framework of national innovation capability	*China Statistical Yearbook; China Science and Technology Statistical Yearbook; Statistical Bulletin on National Economy and Social Development; Statistics and Analysis of Chinese Science and Technology Paper; Annual Report of Patent Statistics; World Development Indicators; Main Science and Technology Indicators; IP statistics; Global Competitiveness Report; Science and Engineering Indicators; SCI Journal Database;* National Science Library, Chinese Academy of Sciences; China Research Institute for Science Popularization; Torch High Technology Industry Development Center, Ministry of Science and Technology; Overseas Institutes of the Ministry of Science and Technology.
Regional	Assessment framework of regional innovation capability	*China Science and Technology Statistical Yearbook; China Statistical Yearbook; Statistics and Analysis of Chinese Science and Technology Paper; China Torch Statistical Yearbook; China Statistics Yearbook on High Technology Industry.*
Enterprise	Assessment framework of enterprise innovation capability	*CEIS; Statistics Yearbook on Science and Technology Activities of Industrial Enterprises; China Industry Statistical Yearbook.*

* Authors' summary.

Appendix B. Assessment Framework of China's National Innovation Capability

1st level indicators	2nd level indicators
Innovation resources	1. R&D expenditure input intensity
	2. R&D human resource input intensity
	3. Scientific human resource training level
	4. Information development level
	5. The ratio of R&D expenditure to that of the world
Knowledge creation	1. Number of citations of scientific paper funded by over one million R&D expenditure
	2. Number of scientific papers per ten thousand scientific researchers
	3. Number of internet users per one hundred people
	4. Number of patent applications per one hundred million USD economic output
	5. Number of patent authorisations per ten thousand researchers
	6. The ratio of scientific papers to that of the world
	7. The ratio of trilateral patents to that of the world
Enterprise innovation	1. The ratio of enterprise R&D expenditure and industrial value added
	2. Number of PCT patents per ten thousand enterprise researchers
	3. Autonomy rate of comprehensive technology
	4. The ratio of new product revenue to enterprise' main business revenue
	5. The ratio of high-tech industry value added to whole manufacturing
Innovation performance	1. Labour productivity
	2. Economic output per unit energy consumed
	3. Life expectancy
	4. The ratio of high-tech industrial exports to manufacturing exports
	5. The ratio of knowledge services value added to GDP
	6. The ratio of knowledge-intensive industry value added to that of the world
Innovation environment	1. Protection of IPR
	2. Governmental regulation impact on enterprise's burden
	3. Macroeconomic environment
	4. Professional research and training service
	5. Effectiveness of antitrust policy
	6. Relation between employee's income and performance
	7. Difficulty level of enterprise innovation project receiving venture capital support
	8. Development of industrial cluster
	9. Coordination level between enterprise and university
	10.Impact of government procurement on technological innovation

Source: National Innovation Capability Assessment System (2013).

Appendix C. Assessment Framework of China's Regional Innovation Capability

1st level indicators	2nd level indicators
Innovation environment	1. Population with higher than college degree per ten thousand people
	2. The ratio of enterprise R&D expenditure deducted in tax to that of whole country
	3. The ratio of fixed asset investments in Information transmission, computer services and software to total fixed asset investments
	4. Number of landline and mobile phone users per one hundred people
	5. Number of internet users per ten thousand people
	6. Number of trademarks per one million people
	7. Regional per capita GDP
Innovation resources	1. The ratio of R&D expenditure to regional GDP
	2. The ratio of financial education expenditure to regional GDP
	3. The ratio of local financial expenditure on S&T to local financial expenditure
	4. The ratio of local financial expenditure on S&T to regional GDP
	5. The ratio of national innovation funds to R&D expenditure
	6. The ratio of funds of national industrialization project to R&D expenditure
	7. The ratio of enterprise financial institution loan to enterprise R&D expenditure
	8. Number of R&D personnel per ten thousand people
	9. The ratio of tax deduction in high-tech enterprise to that in whole country
	10. The ratio of newly-added fixed assets in scientific research and comprehensive technical services to newly-added fixed assets in whole society
	11. Number of national papers per ten thousand people
	12. Number of international papers per ten thousand people
Enterprise innovation	1.The ratio of enterprise R&D expenditure to R&D expenditure
	2. The ratio of enterprise R&D expenditure to main business revenue
	3. The ratio of enterprise technology acquisition and improvement expenditure to enterprise main business revenue
	4. The ratio of enterprise trust fund investment to research institution and university R&D expenditure
	5. The ratio of enterprise scientific research expenditure to enterprise R&D expenditure
	6. The ratio of R&D expenditure from enterprise to R&D expenditure of university and scientific research institution
	7. Enterprise average trading volume of technology
	8. The ratio of enterprise R&D personnel to people employed
	9. The ratio of enterprise having R&D institution to total enterprises
	10. Number of patents per ten thousand enterprise employees
Innovation outputs	1. Number of patent applications per ten thousand people
	2. Number of patent applications funded by one hundred million CNY R&D expenditure
	3. Number of patent authorisations per ten thousand people
	4. Number of patent authorisations funded by one hundred million CNY R&D expenditure

	5. Number of patents per ten thousand people
	6. Technical contract turnover per ten thousand people
	7. The ratio of authorisation of new agricultural plants to value added in agriculture
	8. Technology international revenue per one million people
	9. The ratio of value added in high-tech industry to GDP
	10. The ratio of sales revenue of new products to main business revenue
Innovation effects	1. The ratio of commodity exports to regional GDP
	2. The ratio of exports of high-tech products to commodity exports
	3. The ratio of value added in tertiary industry to regional GDP
	4. The ratio of high-tech enterprise to industrial enterprise
	5. The ratio of employees in high-tech industry to those of whole society
	6. Labour productivity
	7. Capital productivity
	8. Gross production per unit energy consumption
	9. Proportion of days with air quality above level 2
	10. The percentage of complying with the oxygen emission legislation in waste water
	11. The percentage of complying with sulfur dioxide emission legislation
	12. The decreased rate of water usage per industrial production
	13. The percentage of complying with ammonia and nitrogen emission legislation in wastewater
	14. Comprehensive treatment rate of solid waste

Source: Regional Innovation Capability Assessment System (2013).

Appendix D. Assessment Framework of China's Enterprise Innovation Capability

1st level indicators	2nd level indicators	3rd level indicators
Innovation inputs	1. Innovation expenditures	（1） The ratio of innovation expenditure to main business revenue
		（2） The ratio of R&D expenditures to main business revenue
	2. Innovation human resources	（1） The ratio of R&D personnel to employed population
		（2） The ratio of doctorate graduates to employed population
	3. Research institutes	（1） The ratio of research institute's R&D expenditure to enterprise's R&D expenditure
		（2） The ratio of research institute's R&D personnel to enterprise R&D personnel
Collaborative innovation	Industry-university-Research cooperation	（1） The ratio of enterprises participating in industry-university-research cooperation to total enterprises
		（2） The ratio of R&D expenditure on university and research institutes to enterprise's external R&D expenditure
	5. Innovation resource integration	（1） The ratio of technology import expenditure to R&D expenditure
		（2） The ratio of technology digestion and absorption expenditure to technology import expenditure
	6. Innovation cooperation	（1） The ratio of enterprise with innovation cooperation to total enterprises
		（2） The ratio of collaborative patent applications to total patent applications
Intellectual property rights	7. IPR creation	（1） The ratio of enterprise patent applications to total patent applications
		（2） Number of patent applications funded by 100 thousand CNY (16 thousand USD equivalent) R&D spending
	8. IPR protection	（1） The ratio of enterprises having patent to total enterprises
		（2） Number of patents per 10 thousand employed population
	9. IPR utilisation	（1） The ratio of patents implemented to total patents
		（2） The ratio of revenues of patent licensing and transfer to sales revenues of new products
Innovation incentives	10. Innovation value realisation	（1） The ratio of marketing expenditure on new products to total marketing expenditure
		（2） The ratio of sales revenues of new production to main business revenues
	11. Market influence	（1） The ratio of PCT application to patent application
		（2） The ratio of enterprises with independent brands to total enterprises
	12. Economic and social development	（1） Labour productivity
		（2） Gross production per energy consumption

Source: Enterprise Innovation Capability Assessment System (2013).

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