AUS4INNOVATION

Technological change in Vietnam

The contribution of technology to economic growth

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Hien Thu Pham,* Hoang Duc Nguyen,† Giang Hoang Nguyen,† Antonio Peyrache,‡ Shino Takayama,‡ Terence Yeo,‡ Manh Duc Pham,‡ Nhan Phan,‡ Alicia Cameron,* Phi Truong Nguyen,† Tung Son Tran,† Jessica Atherton,* Dat Hoang Vu§ (2021). Technological change in Vietnam – The contribution of technology to economic growth. CSIRO, Brisbane.

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A Steering Committee guided the production of this report. Members include Mrs, Huong Thi Thu Tran from Ministry of Science and Technology; Mr Tom Wood and Mrs Nguyen Hoang Ha Loan from Aus4Innovation program; and Dr Alicia Cameron from CSIRO.

An Advisory Board provided technical advice on the production of this report. Members include Dr Andy Hall from CSIRO, Dr. Minh Hong Nguyen from Central Institute for Economic Management Vietnam (CIEM) and Mr. Thuy Pham Dinh from General Statistic Office of Vietnam (GSO).

Several experts reviewed the report, including:

- Ms. Tran Thi Thu Huong, Ministry of Science and Technology
- Dr. Tran Thi Hong Minh, Director General of Central Institute for Economic Management Vietnam (CIEM)
- Dr. Shawn W. Tan, World Bank
- Dr. Can Van Luc, Chief of Economic Expert from BIDV
- Dr. Pham Thi Hong Yen; Vietnam Cooperative Alliance
- Mrs. Pham Chi Lan, Economic Expert
- Mr. Dao Minh Thang; Office of the Government
- Prof. Jonathan Pincus, UNDP Viet Nam
- Dr. Tran Toan Thang, National Center for Economic Forecast and Information
- Mr. Tomi Särkioja, ADB
- Dr. Vo Tri Thanh, Institute for Brand and Competitiveness Strategy – BCSI
- Dr. Tran Dinh Toan, Economic Expert
- Dr. Nguyen Tien Dung, Viet Nam Institute for Economic and Policy Research (VEPR)
- Prof. Don Scoot-Kemmis, University of Technology, Sydney
- Prof. Prerre Mohnen, Maastricht University
- Prof. Anthony Arundel, University of Tasmania
- Mr Le Trung Hieu, General Statistic Office of Vietnam
- Dr. Pham Dinh Thuy, General Statistic Office of Vietnam.

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* CSIRO staff.

† Ministry of Science and Technology of Vietnam staff.

‡ University of Queensland staff.

§ Vietnam Academy of Social Sciences staff.

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Foreword

Cooperation on security, economic growth, and knowledge and innovation are the three pillars that underpin the Strategic Partnership between Australia and Vietnam.

Since 2017, Aus4Innovation has helped to drive this knowledge and innovation relationship – strengthening the two countries' cooperation in science and technology and building lasting linkages between our innovation systems.

Delivered cooperatively by the Australian Department of Foreign Affairs and Trade, Australia's National Science Agency (CSIRO) and Vietnam's Ministry of Science and Technology, Aus4Innovation explores technology and digital transformation, trials new models of partnership between the public and private sectors, and enhances Vietnam's capabilities in strategic foresight, scenario planning, commercialisation, and innovation policy development.

Over the past four decades, as Vietnam has experienced rapid industrialisation, modernisation, and international integration, the country has achieved rapid economic growth and transformed into a lower middle-income economy. The pace of Vietnam's continued growth and progress toward high-income status will depend increasingly on science, technology, and innovation.

Lower-middle income countries that have successfully developed high-income economies in a comparatively short period of time have switched their focus from export market development and capital accumulation to increasing productivity across all industries. Rapid economic growth at this stage therefore requires a national focus on productivity improvement and technology development.

This report is the culmination of Technological change in Vietnam – The contribution of technology to economic growth, a project delivered by CSIRO's Data61 in collaboration with the State Agency for Technology Innovation. It will play an important role in shaping policies for Vietnam's technology development in the next phase of growth and provides insights supporting Vietnam's economic development models to 2030, with the vision to 2045.

As a component of Aus4Innovation's Policy Exchange, this work was based on key recommendations from the 2019 report Vietnam's Future Digital Economy toward 2030 and 2045. The foresight scenarios contemplated by the 2019 report, and other key recommendations from that project have been widely cited by experts in Vietnam and international partners including the World Bank, United Nations Industrial Development Organization and the Asian Development Bank.

Innovation projects like this demonstrate the power of science and technology relationships to strengthen the long-term strategic and economic relations between our countries. Together, Australia and Vietnam will continue to collaborate in innovation to overcome shared challenges and realise growth opportunities; contributing to the goals of the Vietnam-Australia Strategic Partnership signed by the two Prime Ministers in March 2018.

On behalf of Vietnam's Ministry of Science and Technology and the Australian Department of Foreign Affairs and Trade, we greatly appreciate the collaborative efforts made by the implementing agencies and pledge to continue promoting science, research and innovation collaboration between our two countries.

H.E. Prof. Dr. Huynh Thanh Dat
Minister of Ministry of Science and Technology

H.E. Ms. Robyn Mudie
Department of Foreign Affairs and Trade
Ambassador to Vietnam

Reviews

Mr. Le Trung Hieu, General Director of the System of National Account, General Statistic Office of Vietnam

Report on Technological change in Vietnam: the contribution of technology to economic growth was developed based on scientific research. The analysis and evaluation are clear and based on rich, detailed data.

Dr. Pham Dinh Thuy, General Director of Industrial Statistics Department, General Statistic Office of Vietnam

Report on Technological change in Vietnam: the contribution of technology to economic growth is a valuable report to inform the Vietnamese government in developing policies on economic development, innovation, and promoting technology adoption amongst businesses … The report highlights the importance of R&D and innovation in promoting production productivity and efficiency by quantifying the impact with detailed and valuable data. The report also proposes valuable policy recommendations to stimulate technology development in Vietnam

Dr. Tran Hong Minh, General Director of the Central Institute for Economic Management (CIEM)

The report was developed compressively to reflect the current situation of technological change in Vietnam and its contribution to Vietnam's economic growth. The highlights of the report are the two quantitative models (the conditional frontier model and the dynamic stochastic general equilibrium model) that was developed in an elaborate, rational, and scientific way.

Dr. Tran Toan Thang, Head of Department of Industrial and Business Forecast, National Center for Socio-Economic Information and Forecast

In general, the paper provided very good analytical and critical insights about the technology change in Vietnam and its contribution to the economy.

Dr. Vo Tri Thanh, Director of the Institute of Branding and Competition Strategy

This report provides valuable and supplementary information to other existing research in Vietnam on innovation. The report also contributes significantly to fostering innovation and the economic-development model transformation process in Vietnam.

Dr. Can Van Luc, Chief Economist, Bank for Investment and Development (BIDV)

The report was well developed to assess the technology progress and its contribution to GDP and productivity growth in the context of rapid digital transformation and Industry 4.0 acceleration in Vietnam. The report provides an important reference to policy development for the government.

Prof. Dr. Jonathan Pincus – Senior Economist – the United Nations Development Program Vietnam

This is an interesting and richly detailed study that provides useful information about and perspectives on technological change and economic growth… The study is critical of the standard model of FDI-driven innovation, finding that backward/forward linkages from FDI firms are not a significant source of technological innovation in domestic firms … This is an important conclusion that deserves further study…

Executive summary

Vietnam is rapidly growing and advancing economically. The country enjoys high gross domestic product (GDP) growth, averaging over 6.6% per year between 2000 and 2019.[1] This recent phase of economic development starting from 1986 has seen Vietnam open its borders to trade, attract foreign direct investment (FDI) and move quickly into manufacturing. This rapid shift elevated Vietnam from low income status to lower-middle income status by 2015 and has seen over 45 million people lifted out of poverty.

Vietnam is currently entering the next phase of economic development. While the previous phase was based on market development and a shift from reliance on agricultural output to manufacturing, the next phase will need to focus on efficiency gains. Between 2018 and 2019 Vietnam rose 10 places on the Global Competitiveness Index (GCI) published by the World Economic Forum and is now ranked 67th in the world.[2] These are remarkable gains, however, further economic development will require a greater focus on lifting labour productivity through technological change. This change will need to include both technology adoption and technology creation.

To achieve greater productivity across all industries, the government and industry itself need reliable, up-to-date and accurate measures of technology adoption, and how technological adoption in Vietnam compares to other countries over time.

Reliable measures for technological adoption and its contribution to GDP are important for several reasons:

1. **The next economic phase depends on the adoption of new technologies.** Vietnam's productivity, despite having relatively high average growth in recent periods, is still low compared to its peers. Some analysts have expressed concern that most of the recent periods of labour productivity growth in Vietnam can be attributed to capital deepening (investment) with a much smaller contribution coming from improvements in industrial efficiency. Productivity gains across Vietnamese industry through technology adoption are crucial if the country is to avoid the 'middle income trap' and progress to higher income status.[3]

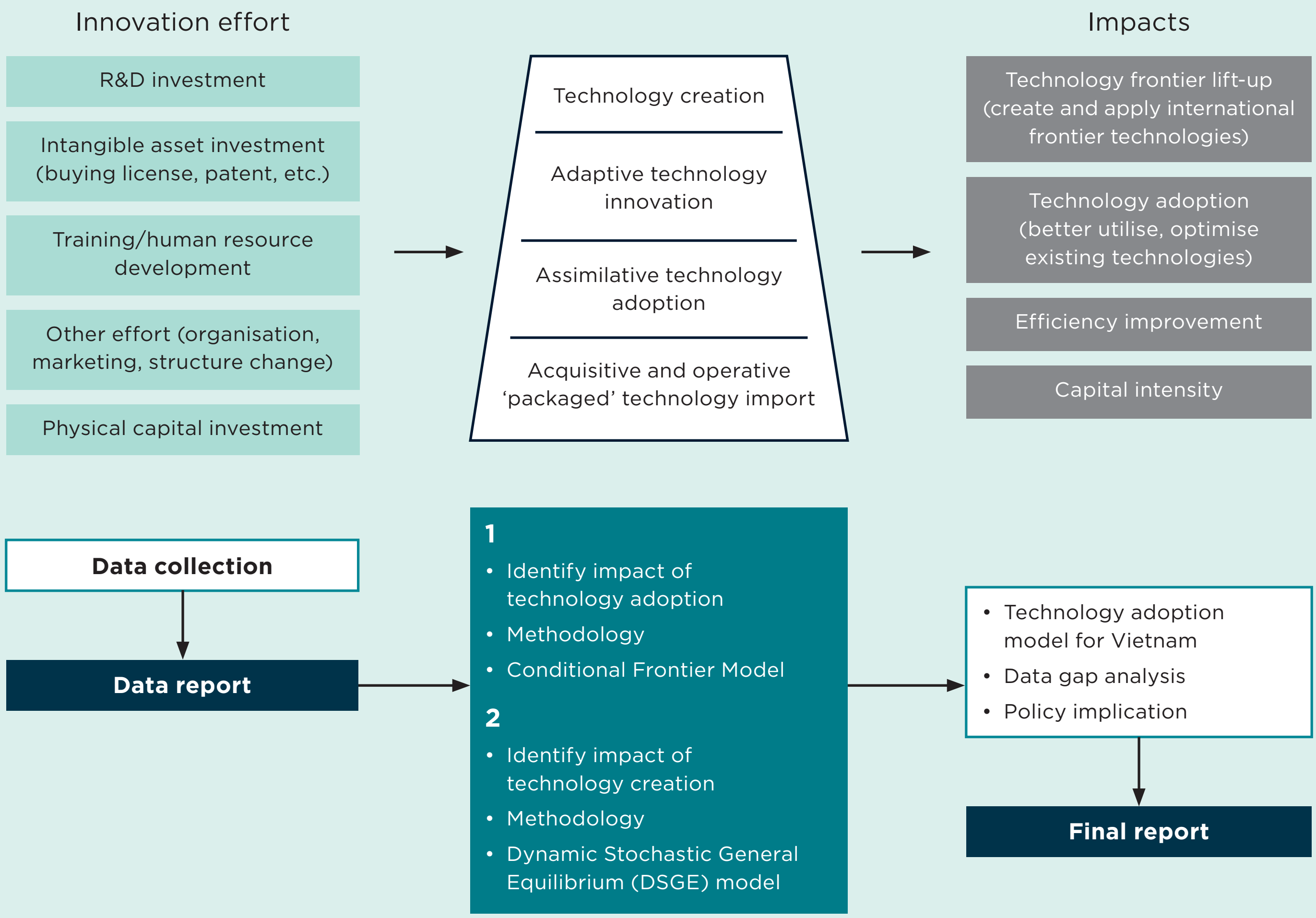
2. **Reliable indicators will create the confidence to invest in Vietnam's industry and research and development (R&D).** Investment in science and technology is low in Vietnam compared to its ASEAN peers. Low levels of investment and a lack of investor confidence may come from the belief that the productivity gains from technology adoption and creation have been low. The direct and indirect impacts of low R&D investment in Vietnam on productivity, GDP and economic growth are still speculative. There are currently no reliable indicators to measure or track technological progress and the impact of science and technology on productivity improvement. The lack of reliable data may be affecting R&D investment.

3. **The government needs more evidence to develop effective policies.** The Vietnam Government views technological progress and adoption as critical to continued growth and prosperity. Its commitment is seen in the number of policies, master plans and directives published over the last 30 years that have stressed the need to invest in critical infrastructure, skills and adoption of technology as a means of lifting productivity.[4,5] However, the lack of reliable indicators limits the ability of the government to further develop evidence-based policies and evaluate the results of public investments or investment from foreign aid. The report *Vietnam's Future Digital Economy* identified the need for measures to monitor "… innovation development across existing industries and enterprises to provide data, inform further investment and provide feedback to policy makers."[3]

METHODOLOGY OF THIS PROJECT

This project is a joint venture between Vietnam's Ministry of Science and Technology and CSIRO Data61. The project aims to better understand the current stage of technological development in Vietnam as well as the contribution of different technology creation and adoption activities to technological change and thus to Vietnam's economic growth.

Data availability is crucial in evaluating the stage of technological development across industry in Vietnam, as well as the impact of technological development on growth. The project's *Data Report* summarises and describes the database collected by the project team to evaluate technological adoption. This database was used to model the impacts of technology creation and technology adoption on economic growth in Vietnam.



Methodology of this project

CURRENT STAGE OF TECHNOLOGY DEVELOPMENT IN VIETNAM

R&D investment is relatively low and scattered, however Vietnam ranks well compared to other nations in certain R&D outputs

International benchmarks indicate that R&D resource allocation in Vietnam remains comparatively low in both regional and global terms, although it has improved in recent years.

There are, however, signals that Vietnamese businesses are actively participating in R&D in terms of localising foreign technologies and through creating incremental innovations to existing systems and technologies.

There is also impressive improvement in R&D outputs in Vietnam. According to the Global Innovation Index 2020, Vietnam scores relatively well in the registrations of trademarks and industrial designs by origin (ranking 20 and 43, respectively), while in registrations of patents by origin it ranks relatively lower, at 65.[6]

Vietnamese firms are increasingly turning to technology adoption as a means of improving efficiency and competitiveness

Vietnam's firms are lagging in technology adoption compared to countries at a similar developmental stage. As in many other developing countries, Vietnamese firms acquire and adapt technologies through the importation of capital goods. Another channel of technology transfer in Vietnam has been through labour mobility. Interestingly, Vietnamese firms do not consider technology acquired through backward/forward linkages within the supply chain to be an important channel for the adoption of technologies, particularly for overseas firms transferring knowledge to local companies.

There are also encouraging signs that Vietnam is increasingly adopting digital technologies. A survey on Industry 4.0 readiness in Vietnam showed that in 2018 around 15.1% of firms were applying cloud computing to their business operations, 12.4% were connecting machinery to digital equipment and 9.8% had installed digital sensors in their factories.[7] These levels of adoption, although small, are not much below the levels found in developed countries.

The COVID-19 pandemic has also underscored the importance of technology as businesses have rushed to adopt or develop digital technologies to address both the health and economic effects of the outbreak in Vietnam.

MEASURING THE IMPACTS OF TECHNOLOGY ADOPTION AND CREATION

The project utilises two economic models to measure technology adoption and creation:

- The **conditional frontier model** was used to assess the impact of technology adoption on economic growth by decomposing the output per worker growth of the economy/ sector into different components:
  - capital deepening
  - the impact of technology frontier lift-up
  - the impact of technology adoption effort
  - the impact of efficiency improvement effort
- The **dynamic stochastic general equilibrium model** was used to assess the impact of R&D investment on economic growth. The model was used to forecast Vietnam's long-term growth, driven by the adoption of new technologies developed by R&D investment. This general equilibrium model assumes that total factor productivity (TFP) does not grow exogenously but is dependent on two factors:
  - the creation of new technologies via R&D
  - the speed at which businesses adopt technologies

IMPACTS OF TECHNOLOGY ADOPTION

The conditional frontier model shows that from 2001–2019, technology adoption has been the main engine of growth in Vietnam

In the early 2000s, capital intensity played an important role in economic growth while TFP contributed only a small portion of the growth in output per worker. The increasing investment in technology-related activities among businesses in Vietnam in recent years, however, has lifted the contribution of TFP to the growth in output per worker and thus economic growth in Vietnam.

In the latest period, from 2015 to 2019, technology adoption has overtaken capital deepening as the main driver of growth in output per worker. The modelling results suggest that technology adoption efforts contributed 3.25% of the 5.64% average annual growth in output per worker. However, this period also showed issues related to technical efficiency improvement in Vietnam. Among other factors, firms found it hard to keep up with the rate of technological change in terms of organisational structure and management.

The contribution of components to output per worker growth differs across sectors

Over the last two decades, agriculture, forestry and fisheries were among the industries with the lowest output per worker in absolute levels. These sectors, however, enjoyed a relatively high growth rate over the period. Capital deepening was the only contributor to growth in agriculture while the fisheries sector relied more on technology adoption to boost growth in output per worker.

Similarly, most of the analysed service sectors have relied more on capital deepening to drive growth in output per worker. However, some service sectors such as transport, healthcare, and computers and related services enjoyed relatively high output per worker in large part due to improvements in technology adoption and efficiency.

Among manufacturing sectors, high-tech manufacturing sectors experienced the highest average growth in output per worker. Besides capital deepening, firms in this sector benefitted the most from investing in technologies to lift up the technology frontier of the sector. In medium-high and medium-low technology sectors, although there were significant impacts of leading firms lifting up the technology frontier and technology adoption investment, firms' stagnancy in technical efficiency improvement caused the limited contribution of TFP to output per worker growth in these sectors. The low-tech manufacturing sector, which is the largest manufacturing sector in terms of employment, experienced much lower average output per worker growth and is a low adopter of advanced technologies. The source of growth for the sector, besides capital deepening, is the increase in technical efficiency through adoption of quality management tools, production process improvement and peer learning.

Across firm types

The efforts of leading firms to lift the technology frontier have been the main source of growth for FDI firms, beside a capital deepening effect. On the other hand, the main source of growth in output per worker for private local firms in the last five years besides capital deepening was technology adoption effort. Our model results show that private firms are more efficient than others in converting technology adoption to growth in output per worker.

Output per worker growth decomposition across time in Vietnam

PERIOD	OUTPUT PER WORKER Million dong /labor/year	OUTPUT PER WORKER GROWTH	TECHNOLOGY FRONTIER LIFT-UP	EFFICIENCY IMPROVEMENT	TECHNOLOGY ADOPTION EFFORT	CAPITAL INTENSITY	TOTAL FACTOR PRODUCTIVITY
2001–2007	46.41	4.47%	1.03%	-0.05%	0.70%	2.79%	1.68%
2008–2014	60.89	1.30%	0.56%	-0.12%	-0.13%	0.99%	0.31%
2015–2019	73.17	5.64%	0.63%	-1.31%	3.25%	3.06%	2.58%

IMPACTS OF TECHNOLOGY CREATION

The dynamic stochastic general equilibrium model shows that R&D investment has long-term positive impacts on economic growth

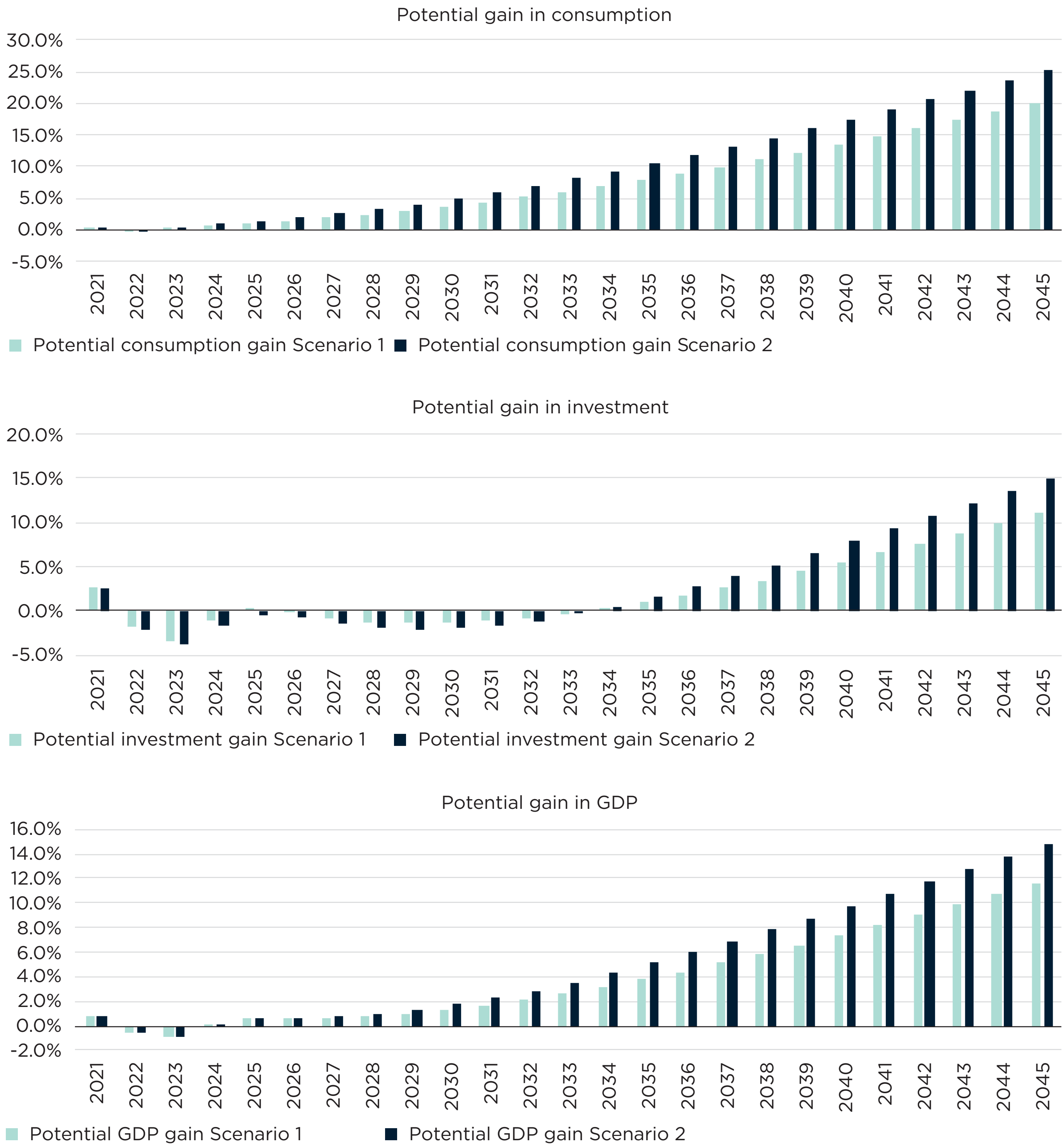
The increase in R&D investment not only directly contributes to GDP growth but also has an indirect impact on stimulating structural change in the economy. The indirect impacts occur through encouraging and upskilling human resources, facilitating technology adoption activities as well as incentivising investment in production across the economy.

Assuming that the R&D expenditure growth rate follows a different pathway depending on different governmental policies and market forces, the model assessed the impact of R&D investment on macro-economic indicators in Vietnam. In particular, we investigated two scenarios:

- **Scenario 1.** By 2030, social investment in R&D activities will comprise 2% of total GDP (meeting the target set by the Vietnamese Ministry of Science and Technology in the *Scheme on Mechanism to Attract Social investment to Science, Technology and Innovation*)
- **Scenario 2.** The average annual growth rate in R&D expenditure per GDP is assumed to be 24.2% per annum for 10 years till 2030 (i.e. a scenario that reflects a growth trajectory for R&D investment in Vietnam similar to South Korea in the period 1981–1991).

In both scenarios, R&D investment initially leads to a crowding-out effect in both social capital investment and investment in technology adoption activities. These investments, however, show significant impact on all macro indicators of Vietnam including GDP, and consumption and investment in the long run. The impact is more apparent after a 10-year period.

The model also shows that improvement in R&D efficiency can result in positive economic outcomes. R&D efficiency can be increased through improving the R&D workforce or links among research institutes. As the R&D sector becomes more efficient, there is a positive impact on real GDP as well as consumption and investment over the longer term. Unlike the impacts arising from the increase in R&D investment, the impacts from R&D efficiency on real GDP are seen much sooner (i.e. five years, instead of 10 years as mentioned in the previous paragraph).



Impact of R&D investment across scenarios by 2045

IMPLICATIONS FOR POLICY

The actions listed in this report are designed to provide insights for policy makers and industry leaders in Vietnam around future investment decisions for the next phase of development.

Technology adoption and creation is the key for Vietnam to maintain rapid and sustainable growth and leapfrog through the next phase of development. Strong leadership and institutions will be key for Vietnam to leverage these opportunities and unblock bottlenecks for further economic development.

These findings provide insights for future policy directions in the following five areas:

1

Improve technology adoption among businesses

- Develop sectoral strategies for technology adoption
- Accelerate digital transformation and Industry 4.0 technology adoption
- Improve 'spillover' effects and forward and backward linkages

2

Improve technical efficiency amongst businesses

- Accelerate the implementation of programmes to develop skills and expertise of managers
- Increase the awareness and adoption of efficiency/ productivity enhancement tools for management and business

3

Promote R&D and emerging industries to lift up the technology frontier

- Monitor innovation and technology adoption and identify clusters and emerging industries
- Strengthen IPR protection through increasing IPR consultancy and IPR management
- Select leading technology performers as technology models to showcase and build competitiveness
- Incentivise R&D from the private sector

4

Develop human resources

- Attract foreign researchers/experts, especially Vietnamese experts who are currently living in foreign countries
- Enhance the skills of the S&T labour force

5

Develop policy instruments and implementation mechanisms to synthesise and stimulate technology development efforts

- Undertake foresight exercises
- Develop a database on technology adoption and creation and a systematic methodology to prioritise investment
- Further improve the two models developed in the project using new data available

1 Technology adoption, technology creation and the interlink for development

Technology has always been at the centre of socio-economic development. The promotion of technological change through the introduction and utilisation of new technologies has become a critical component of development strategies throughout the world. There are also intensive studies into the process of technological change: how technology is created, diffused, adapted and implemented to generate economic outcomes. Many studies confirm the impact of technology creation and adoption in determining the aggregate productivity growth of an economy. In particular, productivity can be boosted by the ability of new technology to leverage existing capabilities and resources, cut costs and reach un-tapped demand and markets.

Technology development, however, can have a different meaning when used in reference to developing countries as opposed to developed countries. Altenburg (2009) highlights five main structural differences between developed and developing countries in terms of the adoption of new technologies.[8] Developing countries have:

1. A less developed industrial base (i.e. less diversified sectoral compositions)
2. Low levels of specialisation and interaction among the firms in an industry
3. Widespread informal arrangements and a large informal sector (informal technology transfers, informal loans, etc.)
4. More importance placed on the informal sector (i.e. the majority of businesses are organised informally)
5. Foreign-funded sectors playing a dominant role in total fixed capital formation and technology transfer.

Accordingly, these differences need to be considered in how technology adoption and creation are conceptualised in a developing country like Vietnam.

In this report we mainly focus on technology adoption and creation in the private sector. The private sector in Vietnam holds the greatest potential for efficiency or productivity improvement and the formation of national competitive advantage.

Put simply, the process of technology development in the private sector in Vietnam can be achieved through independent research and development (R&D) or technology creation and technology adoption.

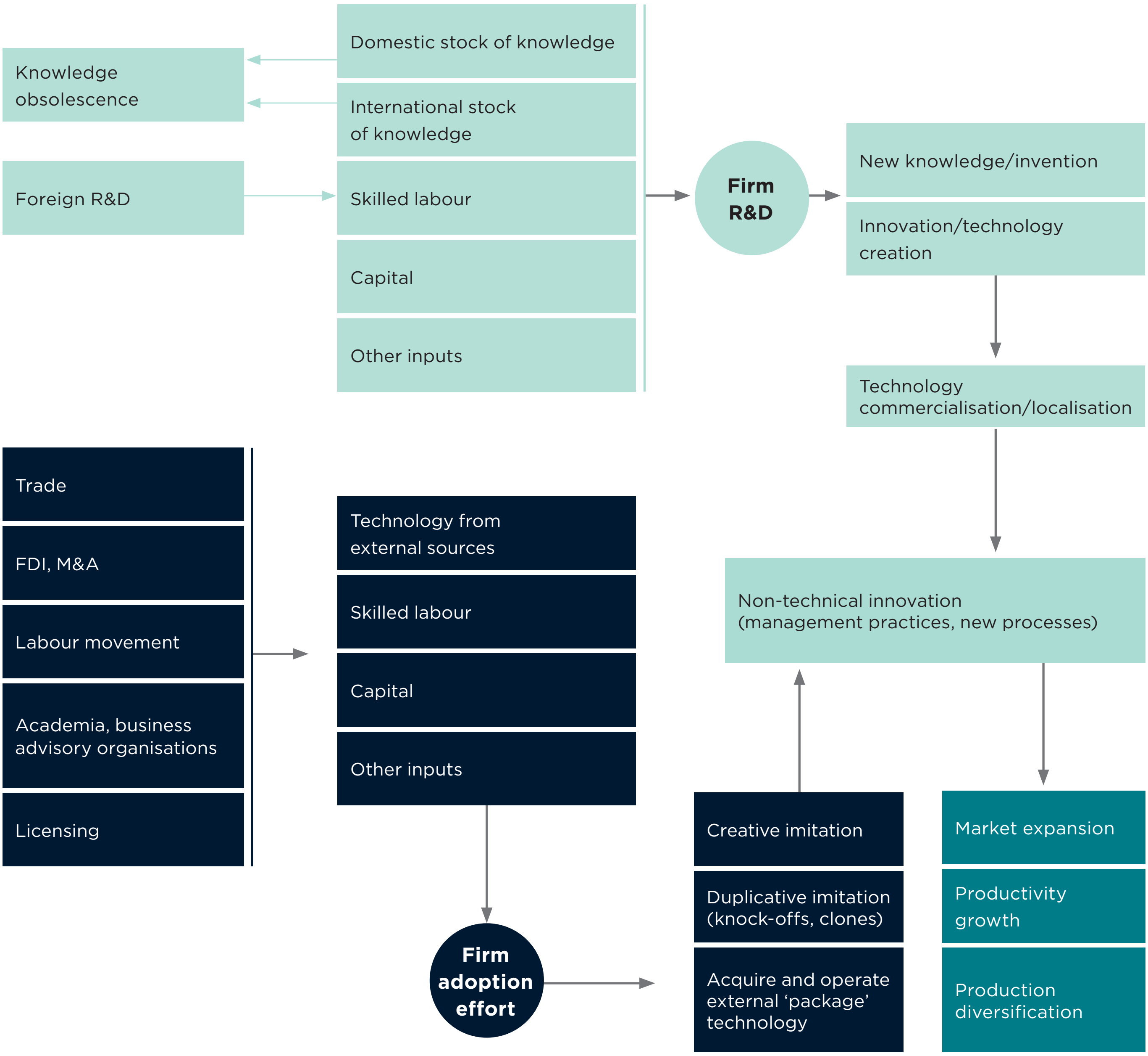


Figure 1. Technology adoption and creation in businesses

1.1 R&D AND TECHNOLOGY CREATION

Given the level of development, R&D in developing countries mainly focuses on creating products/processes that are either new to the market/country or new to the industry, rather than new to the world

In terms of business development, R&D is the accumulation and creation of knowledge and/or technology. In particular, firms use the existing stock of knowledge (domestic or foreign) together with other inputs (capital, labour and other inputs) to create outputs of new knowledge and new inventions (technology creation), as seen in Figure 1. Given the level of technology development in developing countries, the R&D activities mainly focus on creating knowledge and inventions that are either new to the market/country or new to the industry, rather than new to the world.

R&D activities tend to result in radical innovations that can involve significant and disruptive changes to products and processes offered by the firm; including changes that are based on new scientific or technological knowledge, or highly novel combinations of existing science and technology. The activities also increase the possibility of achieving a higher standard of technology in firms and regions, and this in turn may result in much higher levels of productivity, market expansion and production diversification.

R&D can occur in all fields of science and technology (natural sciences, engineering, social sciences and humanities), and covers three main activities: basic research, applied research and experimental development. However, in the private sector, most activities involve engineering and applied research.

In many developing countries, the business sector tends to perform much less R&D than the government and higher education (public) sectors. R&D activities captured in the business sector are normally conducted by a handful of high-profile, large-scale enterprises. In some cases, these enterprises may create 'independent' R&D institutes with significant R&D budgets and R&D human resources.

The lower participation in R&D activities by the business sector may reflect structural issues. For example, small and medium-sized enterprises (SMEs), which are dominant in developing countries, may primarily serve the local market and experience reduced competitive pressure, making systematic R&D the exception rather than the rule. R&D, therefore, is normally commissioned on an ad hoc basis to deal with production issues only. However, there is also a class of start-ups and high-growth firms who are agile, dynamic, innovative and actively conduct R&D to be competitive in international markets. Such high-growth firms and start-ups are increasing their role in technology creation in developing and developed countries.

To create impact from new technologies generated from the R&D process there must be a sturdy commercialisation process. Clearly, the generation of innovative ideas is not sufficient for technology deployment. Technology needs to be transferred to the market in order to actually create value.

Technology commercialisation is a difficult process, however. According to Lee et al. (2015), the success rate of technology development in South Korea is 96% while the success rate of commercialisation is only 47%.[9] Companies attempting to commercialise new technology can go through a phenomenon cited in the literature as the 'valley of death'. This refers to the disconnect between the technology developed in the R&D process and a viable commercialised product.

Lastly, while R&D is the foundation for technology creation, there is also non-technological innovation or process innovation (e.g. in management and organisational arrangements, service innovations, business model innovations). These kinds of innovations improve the efficiency and effectiveness of the firm. The combination of both technology and non-technical innovation will result in improvements in economic outcomes in market expansion, productivity growth and production differentiation.

1.2 TECHNOLOGY ADOPTION

Technology adoption is the process of internalising new technologies that are already available in the market. Although inventions and new technologies offer the possibility to leapfrog older technologies and make significant gains in productivity in much of the developing world, it is the diffusion and internalisation of these new technologies that determine the pace of economic and productivity growth.

In the context of a developing country, technology adoption depends critically on the country's links to the rest of the world. International trade, foreign direct investment (FDI), joint ventures, mergers and acquisitions, licensing contracts and international expert mobility are major channels for the acquisition of foreign technologies. However, although technology access is necessary, access to the technology alone is not sufficient to ensure technology adoption. Equipment and technology packages can be imported from abroad; however, the ability to make effective use of these packages cannot be transferred in the same way. This is because knowledge has tacit elements.

Strategies toward FDI for foreign technology acquisition

Countries around the world follow different strategies to develop their capabilities to adopt technologies. According to Lall (2001) there are four main sets of strategies:[10]

'Autonomous': to develop capabilities of domestic firms and encourage export through comprehensive policies relating to trade, finance, training, technologies and industrial structure. This strategy also includes selective restrictions to FDI, and encouraging technology transfer through other channels such as equipment import, expert mobility or licensing. The prime examples of countries using this strategy are South Korea and Taiwan.

'Strategic FDI dependent': to attract and upgrade FDI, especially from multi-national corporations (MNCs) to higher value-added activities and induce domestic affiliates to improve their capabilities as well. This strategy includes policies relating to skill creation, institution building, infrastructure development and R&D investment. The prime example of a country using this strategy is Singapore.

'Passive FDI dependent': to attract FDI by relying more on market forces to upgrade the economic structure. This strategy includes policies such as FDI-attraction initiatives, special economic zones, export initiatives, infrastructure development and a cheap and trainable workforce. Skill development and R&D are negligible, and the domestic sector tends to develop in isolation from the export sector. The prime examples of countries using this strategy are Malaysia, the Philippines, Thailand and Mexico.

'ISI restructuring': to promote export from well-established import-substituting industries (ISIs). This strategy includes policies relating to trade liberalisation and export initiatives together with developing supplier networks. This strategy differs from the 'autonomous' strategy in that it lacks clear, co-ordinated policies to develop competitiveness through upgrading skills, technology, institution and infrastructure. The prime examples of countries using this strategy are India and Latin American economies.

Developing countries are also struggling to employ/adopt technologies with the same degree of intensity as developed countries. Even as new technologies have quickly become available to all countries, it takes longer for them to be as productive and widely used as in developed countries.

Absorptive capabilities of firms within a country will be key to determining the level and rate of the technology adoption process. Different firms have different capabilities to increase their 'productivity' or ability to transform knowledge activities or inputs into innovation outputs.

There are different activities that firms in developing countries normally engage in to develop technology. Their engagement in these activities depends on their size and technology adoption capabilities. These capabilities include:

- **Ability to acquire and operate imported equipment/machinery or 'packaged' technology under the instruction of foreign experts.** This is where firms merely work on assembling parts and components of foreign origin, and the technological focus of the company is essentially the technologically efficient implementation of the production process. No or little effort is made to introduce technological changes.
- **Duplicative imitation.** This is where firms try to clone products or create new products that are identical to those of their competitors. Reverse engineering at this stage refers to the process of extracting the knowledge and design blueprints from anything man-made.[11] Reverse engineering aims to understand the structure and function of a product to produce a similar product by copying it, modifying it or improving on it.
- **Creative imitation.** This is where firms conduct creative improvement to existing products or technologies by adapting the existing ideas to new applications or generating truly new solutions inspired by the competitors' supply. This can also include the modification or localisation of the original technology to better fit local conditions.

Innovation

Technology creation and adoption as defined in this report are closely linked to the broad definition of innovation. In particular, our definition encompasses both innovation as the 'invention' of new products and processes and as the 'diffusion and adoption' of existing technologies and practices that enable firms to undertake new and more effective modes of production.

According to the Organisation for Economic Cooperation and Development's (OECD's) *Oslo Manual*, an innovation is 'a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)'.[12]

In the context of a developing country like Vietnam, innovation has not always been 'new to the world', but is more often 'new to the market' and 'new to the firm'. Innovations that are new only to the firm can be interpreted as resulting from the diffusion, adoption and use of already-existing technologies and practices. The firm's innovation activities represent all efforts that lead to a significant improvement to the firm, which may include upgrading processes and imitating other existing products.

A firm can innovate its six business functions: (i) production of goods or services; (ii) distribution and logistics; (iii) marketing and sales; (iv) information and communication systems; (v) administration and management; and (vi) product and business process development. Innovation can be done internally with the firm's own capacity or it can borrow, buy or copy from external sources including foreign sources, domestic research institutions or other domestic firms.

The technology adoption and creation effort, however, applies more to product/process-related innovations. Non-technical innovations, such as marketing and organisation or administration, will also be analysed under the efficiency improvement effort.

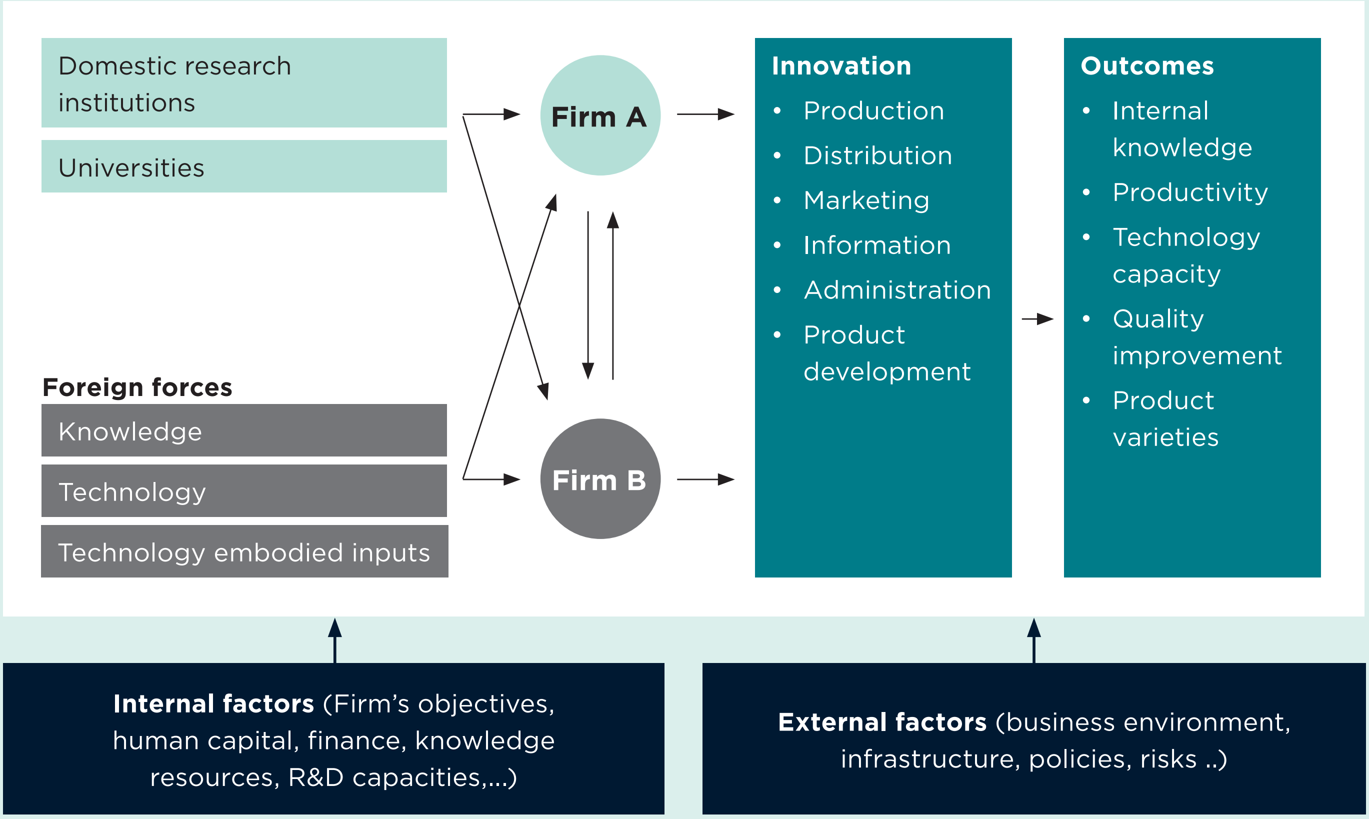


Figure 2. An innovation framework

Source: Authors' adaptation from models of OECD/Eurostat (2018), Global Innovation Index (2020).[2,12]

2 Technology adoption and creation in Vietnam – current situation

2.1 R&D AND TECHNOLOGY CREATION

Vietnam has a relatively low level of R&D investment

International benchmarks indicate that, though R&D resource allocation in Vietnam has improved in recent years, it remains comparatively low in both regional and global terms (see Figure 3). In 2019, Vietnam's expenditure on R&D equaled 0.53% of total GDP, a relatively low level compared to its regional peers. Only Indonesia and the Philippines had notably lower R&D intensity.

Vietnam's low R&D capacity is not surprising. In spite of its impressive economic growth, Vietnam remains a lower-middle income country. Given pressing needs in other areas, devoting resources to developing new-to-the-world innovations can be hard to justify.

The impact of the low level of R&D resources is apparent in the number of researchers per million population. Although Vietnam has a relatively average number of R&D personnel per million inhabitants (896 per million inhabitants in 2018), the R&D workforce size has remained stagnant in recent years.[13] Over the 2014–2018 period, the accumulated growth rate of the R&D workforce in Vietnam was 1.2%, compared to 63% in Thailand, 12% in China, and 15% in Korea.[13] Overall, the proportion of R&D labour per population in Vietnam is relatively low, compared to other countries. The proportion is approximately 20% of the average level in the European Union, 8% of that in Korea, 30% of that in Malaysia and 58% of that in Thailand.[13] Also, human resources for R&D in Vietnam were mainly distributed in the state sector (84%), while the non-state sector accounted for 13.8%.[14]

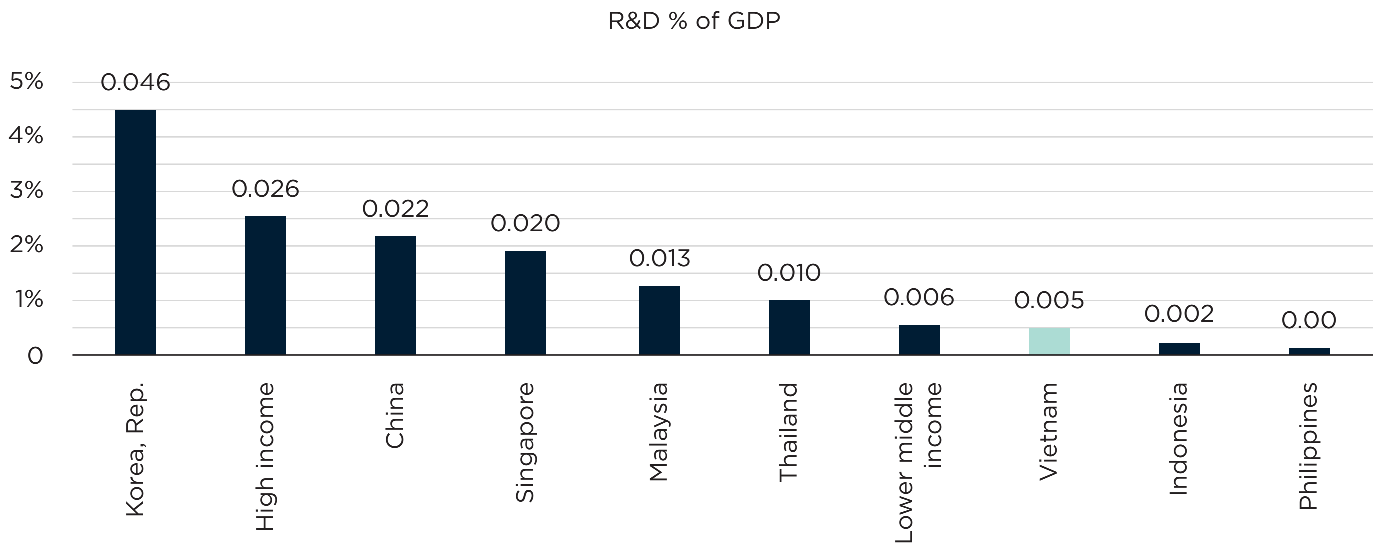


Figure 3. Research and development expenditure as a percentage of gross domestic product, selected countries

Note: The figure shows the most recent data available. All country and income group data are from 2018, except for Singapore (2017), Thailand (2017) and the Philippines (2015).
Source: UNESCO Institute for Statistics[13]

Several bottlenecks in the supply of human resources were identified as a key issue for Vietnam in the OECD Southeast Asian Economic Outlook.[15] The bottlenecks include, but are not limited to, low and unequal participation, and mismatches between education and the labour market. For example, the proportion of population between ages 18 and 29 attending universities is 28.3%, which is amongst the lowest in the world. Vietnam is likely to continue to struggle to grow its R&D workforce.[16]

There are signals for active participation of businesses in R&D in terms of localising foreign technologies and incremental innovations

Interestingly, though still limited in absolute terms, businesses contribute a significant proportion of national R&D investment in Vietnam. Figure 4 shows that Vietnam's businesses contributed around 64% to national R&D, a share comparable to that of Singapore (52%), Korea (77%) and China (77%).[¶]

According to the report *Analysing Vietnam's labour productivity based on the survey on business productivity*, only a limited number of businesses conducted R&D activities.[17] The proportion of businesses that are involved in R&D activities over the total number of businesses in the sector is: 17% for electric equipment manufacturing; 15% for chemical product manufacturing; 9% for food processing; 7% for rubber and plastic manufacturing; and 5% for textiles.

However, in recent years more businesses in Vietnam have expanded their R&D activities. For example, Military Telecom Corporation (Viettel) established its own research institute in 2010 following the R&D model of major corporations around the world. Viettel has deducted 10% of their pre-tax profit for the Science and Technology (S&T) Development Fund, equivalent to VND 2,500 bil. Another example is the National Oil and Gas Group, which co-operated with the Ministry of Science and Technology (MoST) to manufacture new-generation drilling rigs for oil and gas exploitation activities. With the efforts of domestic scientists, the company has designed and mastered technologies for manufacturing drilling rigs, putting Vietnam in the top ten in the world and the top three Asian countries capable of manufacturing 90-metre and 120-metre jack-up rigs in 2009.[18]

Some of the success of domestic R&D in Vietnam has flowed from international technology transfer activities. However, Coe et al. (1997) found that while developing countries benefit significantly from the R&D efforts of their trading partners, the magnitude of the benefit depends on the extent to which the developing countries do R&D themselves.[19] This paper provides evidence on the possible linkage between extensive international technology transfer and domestic R&D performance across businesses in Vietnam.

Another important source of R&D is the government. Over the past decade, Vietnam has developed an array of public research institutes, which have a dominant position in both the amount of public R&D expenditure and the size of the R&D workforce. In 2020, there were 652 research organisations in Vietnam. However, unlike their Taiwanese and South Korean counterparts, from the 1970s onwards, these research organisations have had limited linkages/collaboration with private enterprises and universities.

The majority of R&D investment in Vietnam is in engineering and technologies (see Figure 5). These priorities are also reflected in the following analysis of international scientific publications. Bibliometric data show that Vietnam has a specialisation above the world average in mathematics and statistics, agriculture, fisheries and forestry, and biology, though these areas still have lower than world average impact. Other areas such as environmental science, clinical medicine, built environment and design are also areas of competitive advantage for Vietnam. The dominant role of applied research in Vietnam (representing 69% of total research studies) is likely to continue to lift innovation and productivity growth for Vietnam in industries with high R&D investment.

¶ The business enterprise sector comprises:
- All resident corporations, including not only legally incorporated enterprises, regardless of the residence of their shareholders. This group includes all other types of quasi-corporations, i.e. units capable of generating a profit or other financial gain for their owners, recognised by law as separate legal entities from their owners, and set up for purposes of engaging in market production at prices that are economically significant.
- The unincorporated branches of non-resident enterprises are deemed to be resident because they are engaged in production on the economic territory on a long-term basis.
- All resident non-profit institutions (NPIs) that are market producers of goods or services or serve business.
- This sector comprises both private and public enterprises.

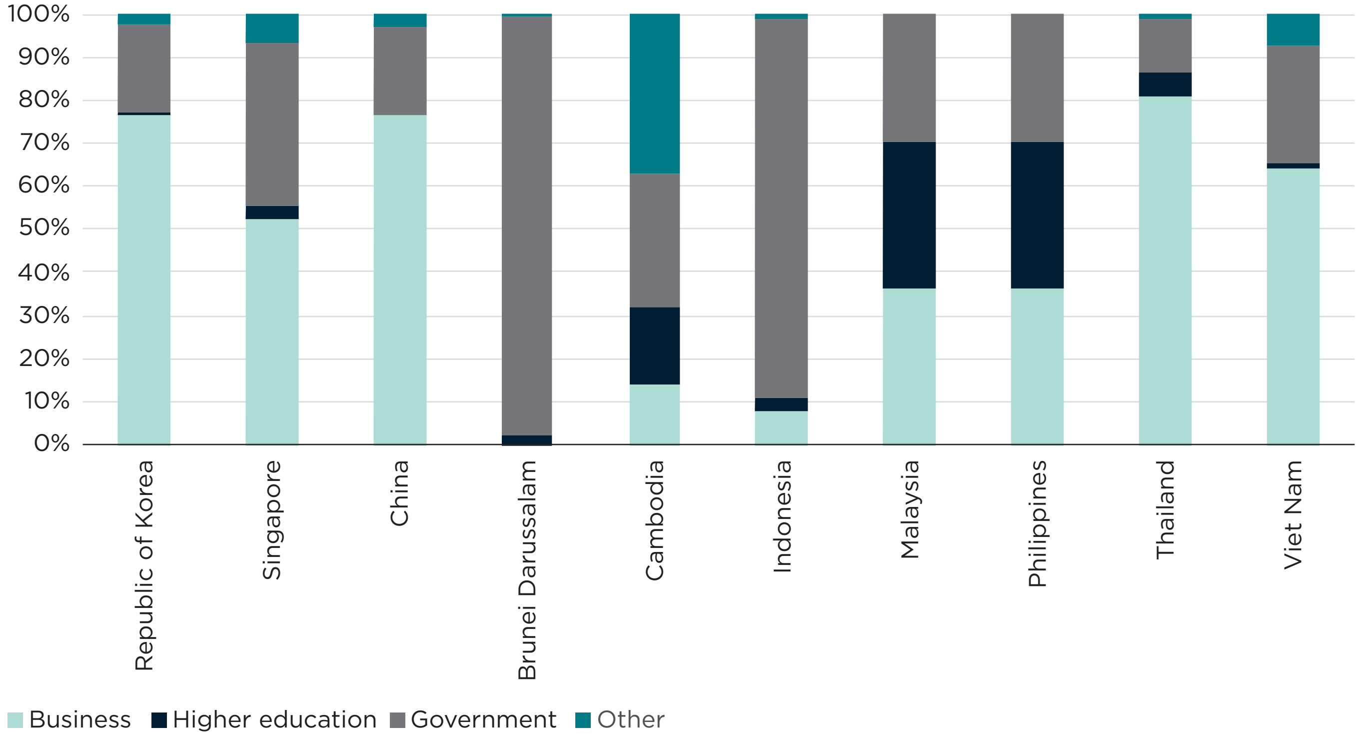


Figure 4. Share of R&D expenditure by source, selected countries in 2017

Source: UNESCO Institute for Statistics[13]

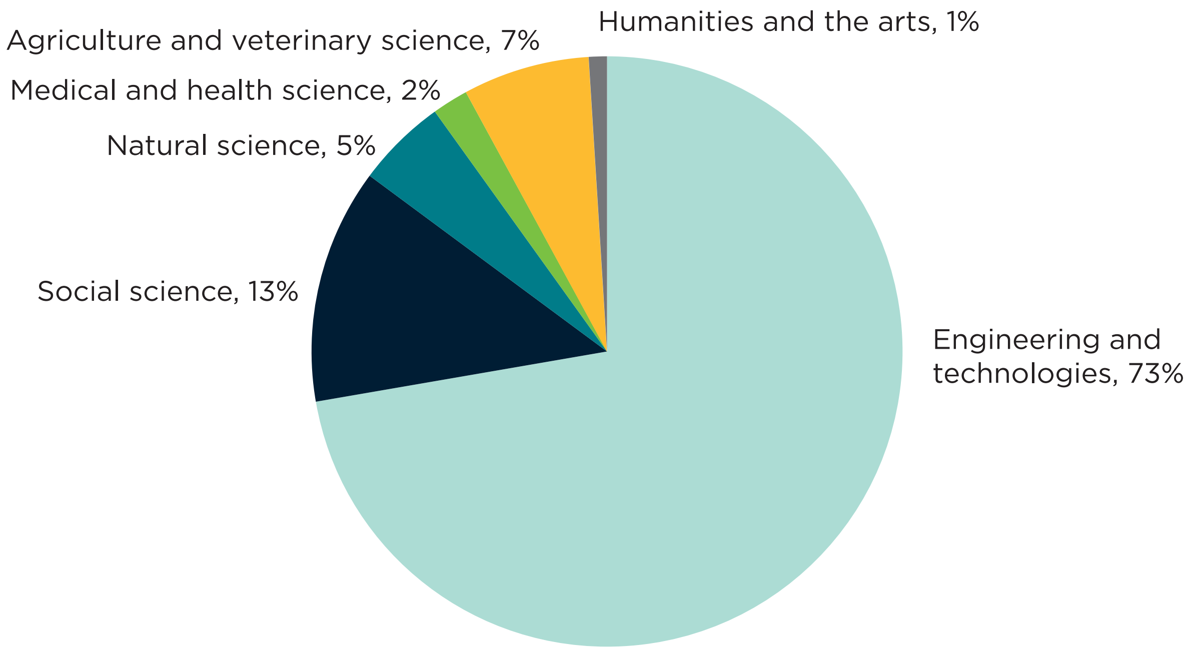


Figure 5. Vietnam R&D investment by sector in 2017

Source: UNESCO Institute for Statistics[13]

There is also much improvement in R&D outputs in Vietnam

In 2019, the Intellectual Property Office of Vietnam saw outstanding annual growth in the number of intellectual property right (IPR) applications received (75742, 26.7% growth), handled (65029, 51.7% growth) and granted (40715, 40.6% growth).[20] The vast majority of granted IPR protection titles are in the form of trademarks (see Figure 6). According to the Global Innovation Index 2020, Vietnam scores relatively well in trademarks and industrial designs by origin (ranked 20 and 43, respectively, out of 131) while patents by origin ranked relatively lower at 66.[2]

Like other intellectual property (IP) instruments, trademark applications may signify the generation of economically useful novelty and may therefore be used as a complementary indicator of innovation. Trademarks are especially relevant in the services sector and, compared to patents, are more representative of the activities of smaller firms and of non-technological innovation. Trademarks are also a proxy for activity that is closer to the commercialisation stage. In recent years, Vietnam has witnessed a steep rise in both resident and non-resident trademark registrations.

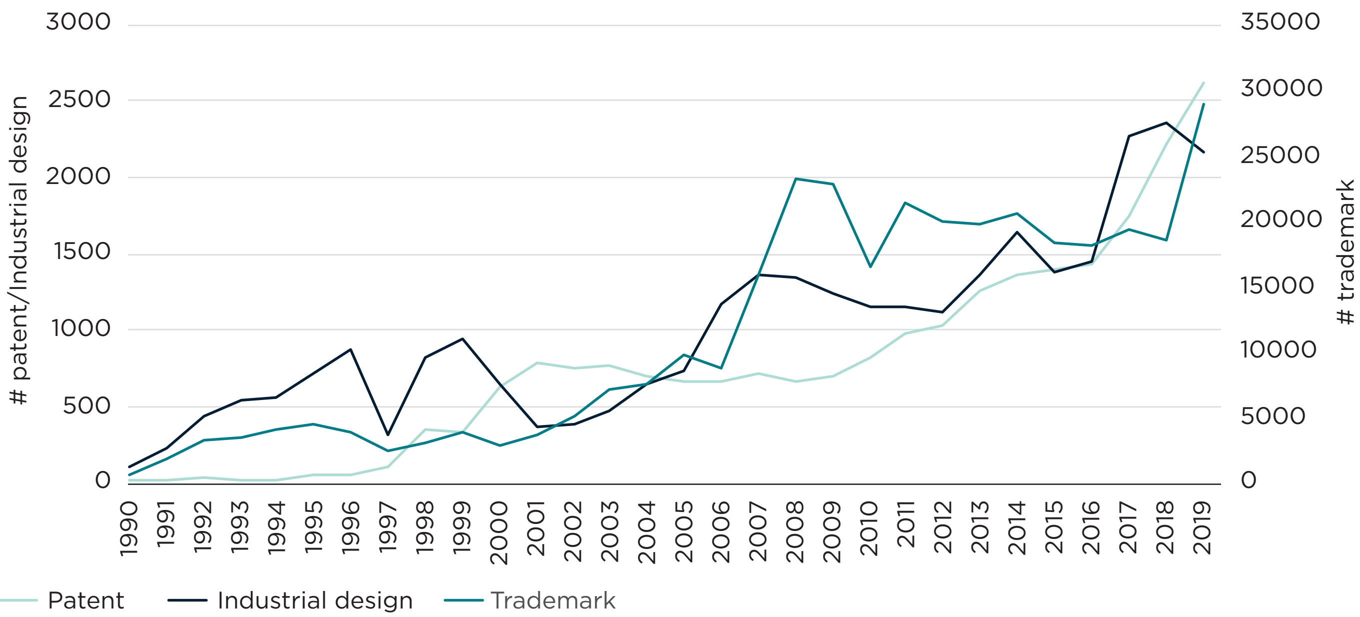


Figure 6. The number of granted Intellectual Property Rights in Vietnam in the 1990–2019 period

Source: Intellectual Property Office of Vietnam[20]

On the other hand, the number of patents granted in Vietnam is relatively low, especially those filed by local applicants. The reasons for the small number of patents granted locally may not necessarily reflect the low level of inventive activity. Rather, a large number of useful technologies do not qualify for patents mainly due to the stringent requirements of patentability: novelty, an 'inventive step' and industrial applicability.[21] Similar to other developing countries, most patent applications in Vietnam are filed by foreigners (see Figure 7).

Patents filed by foreign applicants seek to protect a foreign invention from imitation and production in and for the Vietnamese market. As such, the modest improvement in patent figures reflects the improvement of technological absorptive capacity in the country, as there is a high correlation between technological licensing arrangements, foreign patent applications and the technology transfer process.

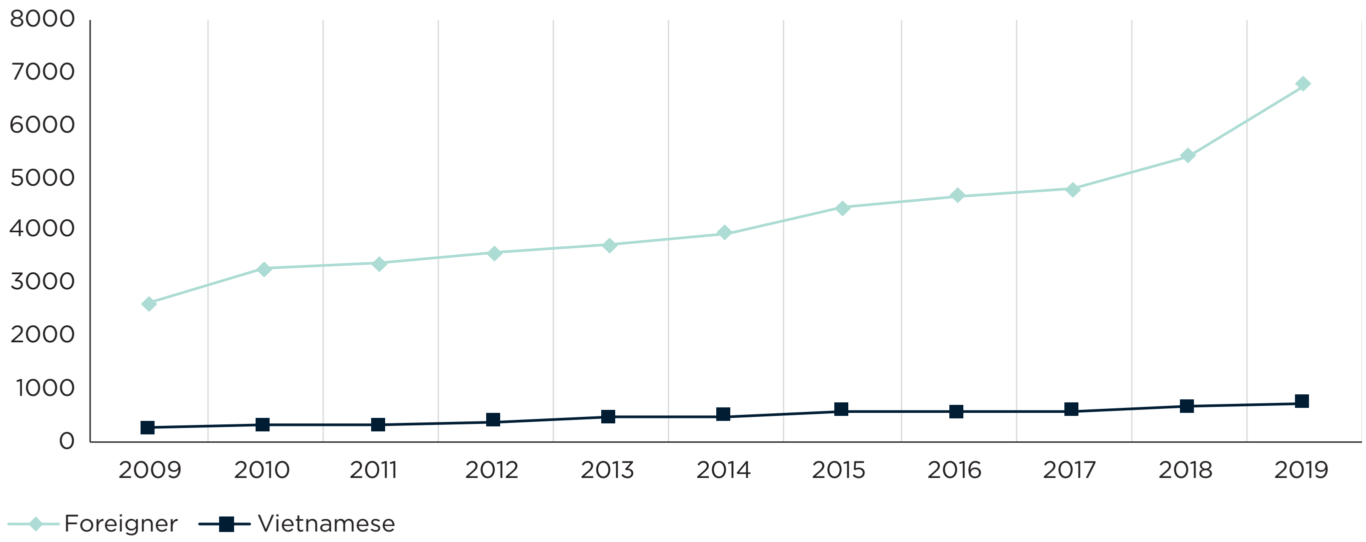


Figure 7. Invention applications filed between 2009–2019 by Vietnamese and foreigners

Source: Intellectual Property Office of Vietnam[20]

As can be seen from Figure 8, though limited, there has also been an improvement in industrial property rights transfer in terms of the number of assignment contracts in Vietnam in the last decade. Technology transfer activities in universities of Vietnam, for example, have recently achieved encouraging results. Many technology-transfer contracts have been signed with leading enterprises in Vietnam and globally, such as Vingroup, FPT group, SUN MicroSystems Group, and Rang Dong Light Source and Vacuum Flask Joint Stock Company.

However, in general, commercialisation from research institutes is still sparse. Furthermore, the management of IP in these institutes has not been given adequate attention. This results in technology transfer activities not attracting participation from human resources, and there are only a few organisations with sufficient professional capacity to manage and put the transfer into production and business.

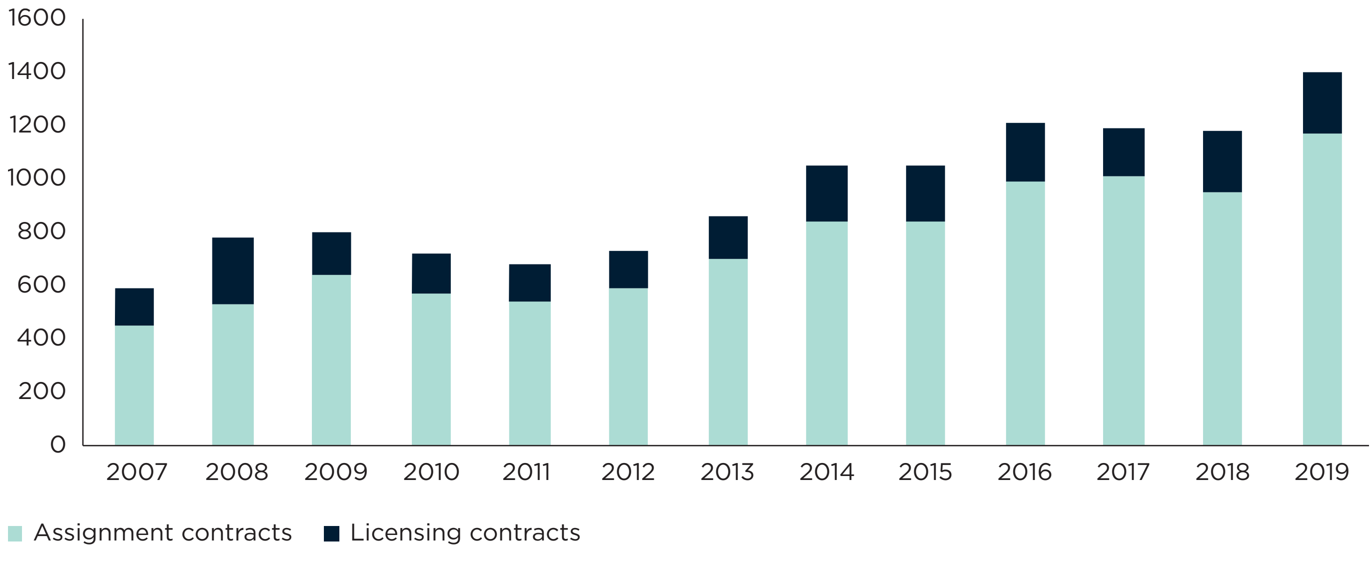


Figure 8. Transfer of industrial property rights in Vietnam between 2007 and 2019

Source: Intellectual Property Office of Vietnam[20]

2.2 TECHNOLOGY ADOPTION – THE ENGINE TO GROWTH IN VIETNAM

In this report, technology adoption is the micro process that firms or organisations go through to adopt an existing technology innovation.

At the firm level, technology adoption efforts include technology-related activities such as: attempts to buy new machine/equipment; train employees with new technologies/processes; software developments and database activities; activities related to the acquisition of lease of tangible assets; and innovation management activities.

In today's globalised world, technology is increasingly essential for firms to compete and prosper. In Vietnam, firms are increasingly turning to technology adoption as a means of efficiency and competitiveness improvement (see Figure 9).

Over the 2001–2019 period, real investment in technology adoption per worker in Vietnam increased by nearly 250%.

However, technology adoption efforts differ considerably across regions and industries

At the provincial level, investment in technology adoption tends to be higher in the Southeast and Red River Delta provinces (see Figure 10). In the period from 2015 to 2019, Ho Chi Minh had the highest level of technology investment per worker (nearly triple the average level of the nation), followed by Binh Duong and Binh Phuoc. Surprisingly, investment in technology adoption was also high in Central Highlands provinces such as Daklak and Kontum.

Figure 9. Real investment in technology adoption per worker between 2001 and 2019

Source: Authors' calculation based on the GSO business survey[22]

The variation in technology adoption is also pronounced when it comes to industries. According to the General Statistics Office (GSO) business survey, in 2019 manufacturing was the sector with the largest investment in technology-related activities for more than 36% of total businesses in the economy, followed by retail/wholesale and construction.[22] The large contributions from the latter two sectors, however, come from the fact that they are the two biggest sectors in terms of employment and number of firms in the economy. The per worker technology investment was relatively low in these two sectors in 2019. The GSO business survey data also suggest that, among more narrowly defined sectors, high-tech industries have significantly higher than average technology investment – including sectors such as computer and related activities, machinery and equipment, electronics and chemicals.

Average real investment in technology adoption per worker between 2015 and 2019 were highest in the Southeast and Red River Delta provinces.

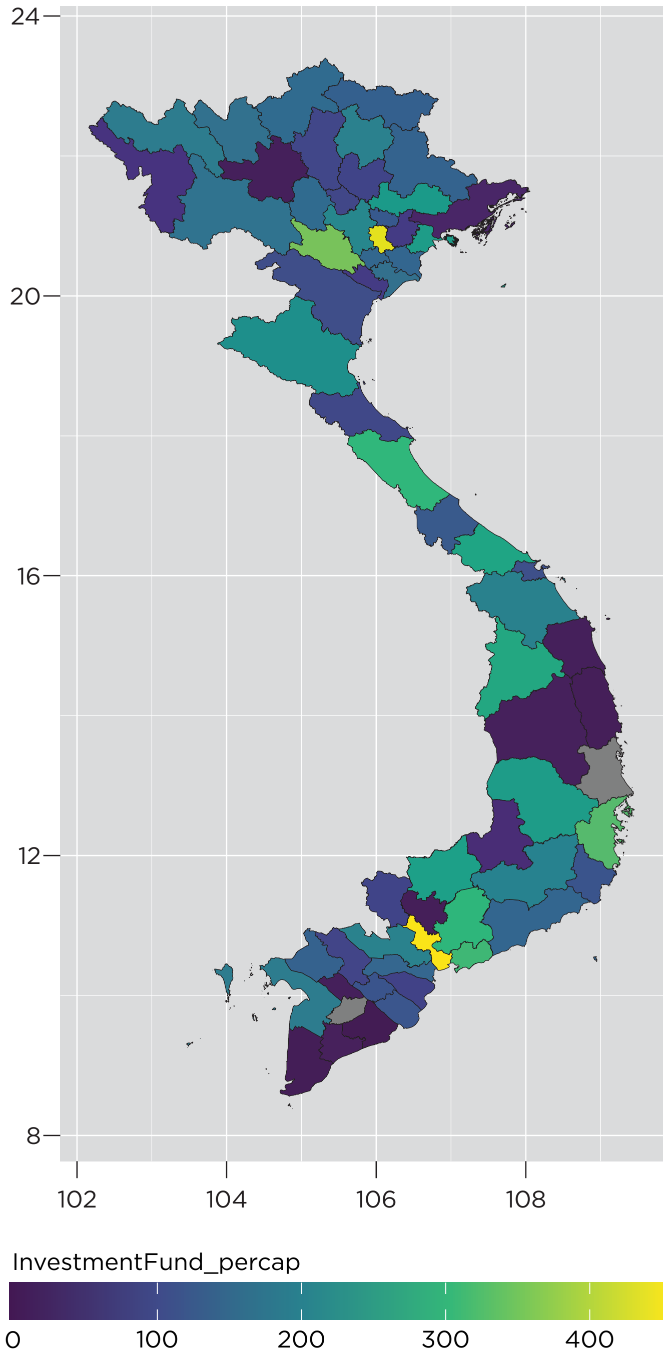


Figure 10. Average technology adoption investment per worker (mil VND) by province in 2015–2019 period

Source: Authors' calculation based on the GSO business survey[22]

The variation in technology adoption can also be seen among firms within industries

Over the last two decades in Vietnam, frontier firms (firms with the highest labour productivity) have greatly outperformed laggard firms (firms with average labour productivity) in productivity and technology adoption efforts – see Figure 11 and Figure 12.** As can be seen, the technology investment gap between frontier and laggard firms is more apparent and increasing in the service sector and agriculture and mining sector. However, since 2010 laggard firms in the manufacturing and construction sector appear to be catching up to frontier firms in terms of technology adoption efforts.

At the same time, we can also see that though the output gap between frontier and laggard firms in the manufacturing and construction sector still existed in 2019, it began to decrease in the past decade. The service and agriculture and mining sectors, in contrast, see fast-growing output gaps between the frontier and laggard groups.

The productivity and technological investment gap between the leading and laggard firms in Vietnam is likely the consequence of a slow diffusion of technology within the country. The rising gaps between frontier firms and others may signal stalling technology adoption and firm dynamics among laggard firms. The stalling may reflect increasing costs for firms to move from a low, production-based model to one based on innovation and technology.

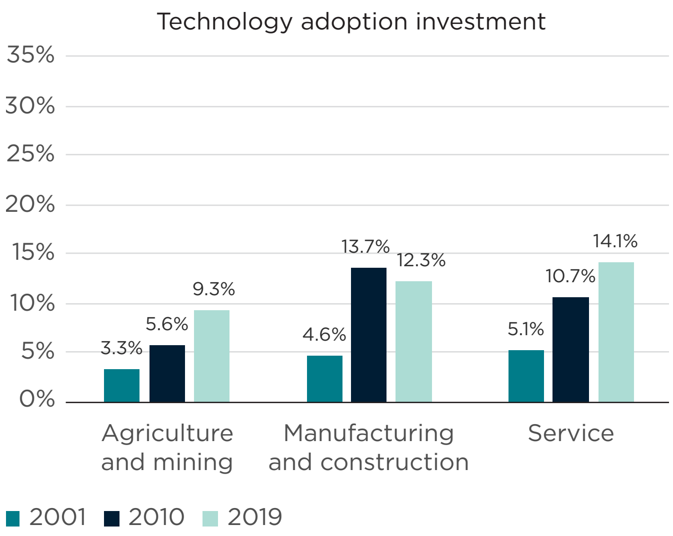


Figure 11. Technology adoption investment ratio between frontier firms and laggard firms in 2001, 2010 and 2019

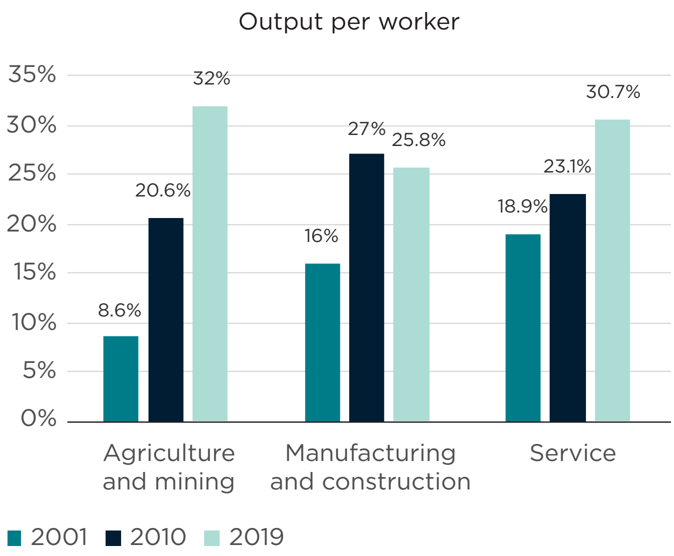


Figure 12. Real output per worker ratio between frontier firms and laggard firms in 2001, 2010 and 2019

Note: The value for frontier firms is measured as the average value for the top 3% of firms with highest output per worker within each 2-digit industry. The value for laggard firms is measured as the average value of the rest of the firms. The unweighted averages across all 2-digit sectors are used to calculate the values of three broad sectors (agriculture and mining, manufacturing and construction, and service). The vertical axes represent the ratio between the value of frontier firms and laggard firms. For example, the output per worker value of the service sector in 2019 in Figure 12 is 30.7, meaning that on average, the output per worker of service firms at the frontier is 30.7 times higher than that of laggard service firms in 2019.

Source: Authors' calculation based on the GSO business survey[22]

** The analysis utilises the Business survey conducted by the General Statistics Office of Vietnam, which includes both domestic and foreign firms.

Technology adoption in shrimp hatcheries

Post-larvae shrimp (PL) produced by hatcheries are critically important for shrimp farmers. High-quality PL production can improve grow-out farm survival rates, as well as the quality and health of shrimp, ultimately benefitting the entire industry. There are about 2,500 hatcheries in Vietnam. The hatchery industry in Vietnam is widely fragmented with many small-scale backyard hatcheries, which normally provide lower survival rates compared to imported brood stock. As a frontier firm, Viet-Uc is the first company to supply local high-quality brood stock, significantly decreasing Vietnam's dependence on brood stock imports.

Viet-Uc set up the world's largest shrimp hatchery, with the ability to produce 15 billion PL annually. The company also controls about 30% of shrimp hatcheries in Vietnam. Applying game-changing technologies has been the key strategy that brought about the company's success. Viet-Uc has collaborated with many research institutes such as: CSIRO, Australia; Benchmark Holding JSC, United Kingdom; as well as Can Tho University and Ho Chi Minh University of Agriculture and Forestry. At the moment, Viet-Uc is the only company in Vietnam that uses high-tech programs to monitor and analyse shrimp, with the goal to breed shrimp with selected genetic material. Digital technology allows Viet-Uc to control production from start to finish and can provide full traceability and sustainability over the entire supply chain.

Vietnam's firms are lagging behind in technology adoption; however, there are signs of improvement in recent years

Despite the dominant impact to growth, a survey conducted by the World Economic Forum in 2012–2016 showed that Vietnam is relatively low in technology adoption, even compared to countries at a similar development stage (see Figure 13).[23] Vietnam's poor record on investment in machinery, equipment and new technologies is directly affecting the competitiveness of businesses. Capital investment allows businesses to make more with less through more efficient use of inputs, fewer hours of labour and by generating less waste. But because Vietnamese firms underinvest in new technologies, they innovate less and fail to realise these gains. The underinvestment in new equipment and technologies consequently results in Vietnam's productivity growth lagging compared to global competitors.

Data show that different levels of technology adoption co-exist within the country. While the majority of firms are operating at a low-technological level, there is a niche of firms who are actively adopting a generation of frontier technologies in Vietnam.

A survey by the United Nations Industrial Development Organization (UNIDO) in 2019 shows that an increasing number of Vietnamese firms (33% of surveyed businesses) are expecting to adopt the highest generation of production technologies (integrated/smart production) in the next five to ten years (see Figure 14).[24] And among those, nearly 80% already have plans or are implementing them. The number is much higher than those of other countries (51% for Brazil or 20% for Thailand). Overall, around 42% of surveyed Vietnamese businesses are ready for third and fourth generation technology in the next five to ten years.

Vietnam also shows the highest level of preparedness in terms of strategy to adopt leading technologies among surveyed countries (see Figure 15).[27]

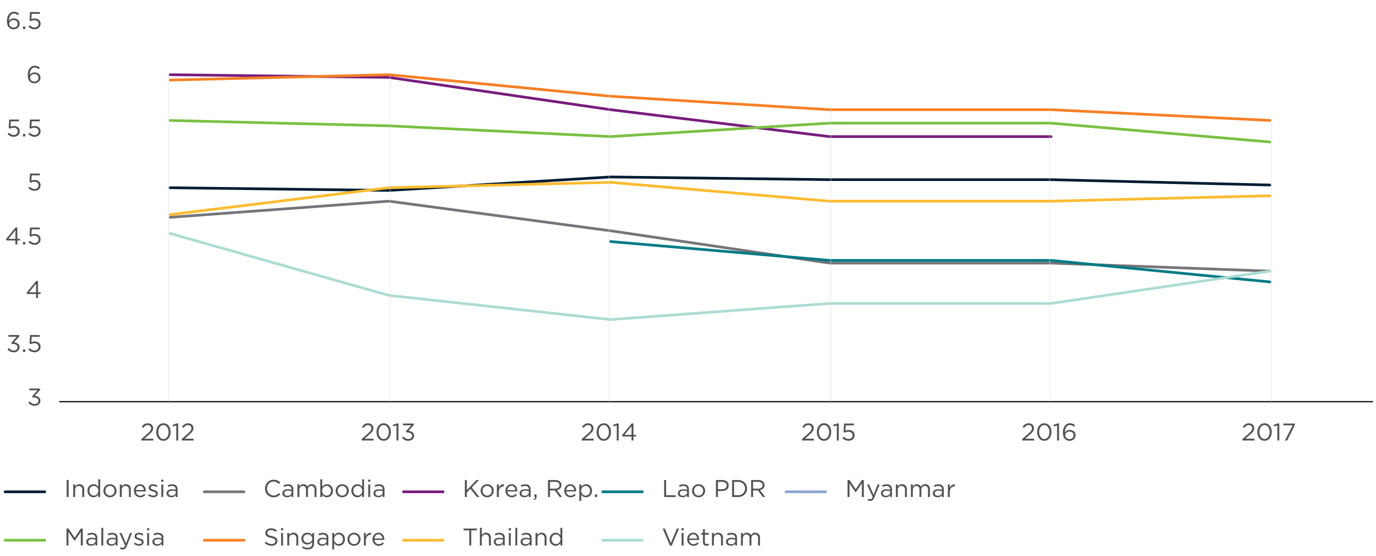


Figure 13. Response to the survey question: In your country, to what extent do businesses adopt new technology? [1 = not at all; 7 = adopt extensively]

Source: World Economic Forum[23]

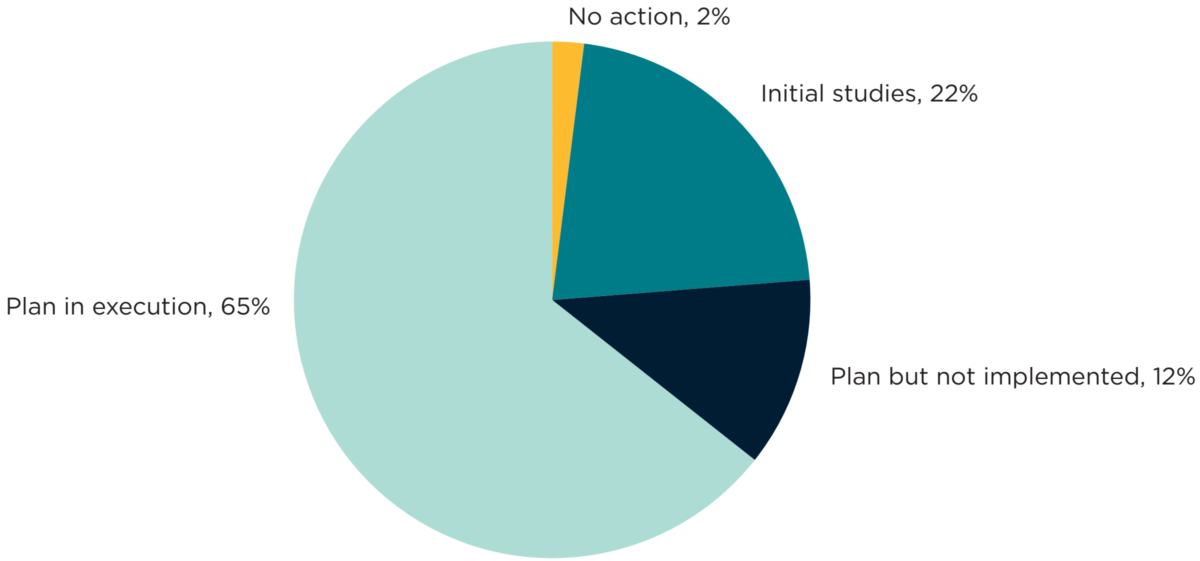


Figure 14. Plans to implement leading technology in Vietnamese firms in the future

Source: UNIDO[24]

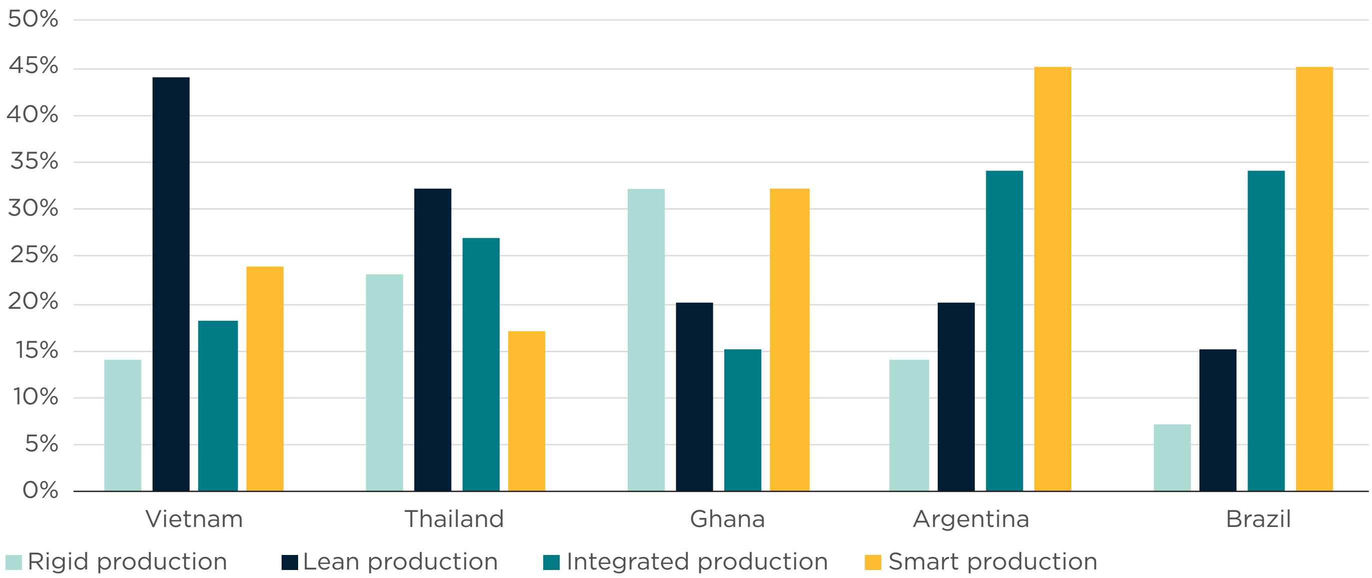


Figure 15. International comparison of plans to implement next generation production technologies within the next five to ten years

Source: UNIDO[24]

Digital transformation and adoption of emerging technologies is accelerating in Vietnam

Emerging technologies hold the potential to change the cost-benefit equation or create an entirely new product portfolio that will shift production activities in Vietnam. Technologies such as biotechnology, nanotechnology, advanced materials, energy and especially digital technologies have the potential to drive fundamental changes in global industries. The quick adoption of digital technologies in a number of leading Vietnamese firms indicates the capacity for the country to lift up productivity and growth.

Vietnam also shows encouraging signals in adopting digital technologies. A survey on Industry 4.0 readiness of 2,659 manufacturing businesses in Vietnam showed that in 2018, around 15.1% of firms were applying cloud computing, 12.4% were connecting machinery to equipment/products and 9.8% had installed sensors in their factories (see Figure 16).[28] These levels, though small, are not very far from those in developed countries. According to the World Bank, in 2016 only 24% of firms in developed countries used cloud computing.[25] Although an overwhelming number of manufacturing firms in Vietnam are still strangers to digitalisation, a selection of firms are deploying digital disruptive technologies and operating at the regional and global technology frontier.

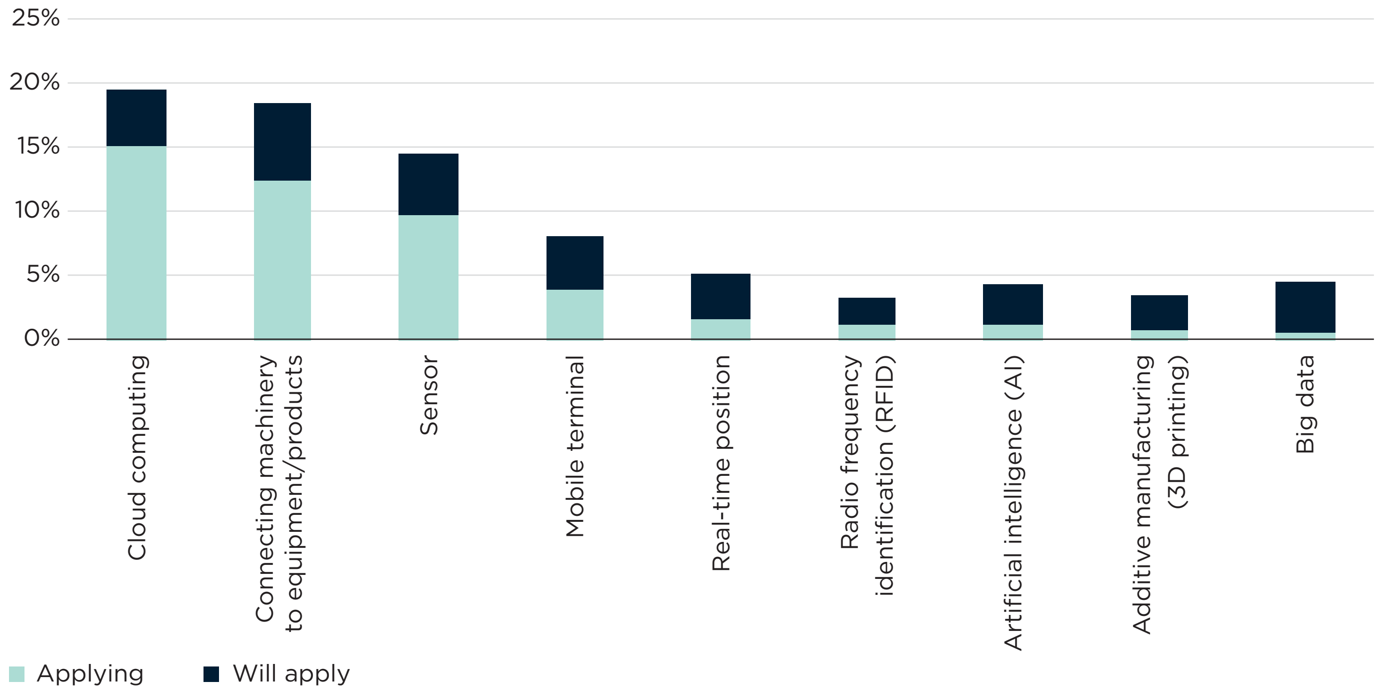
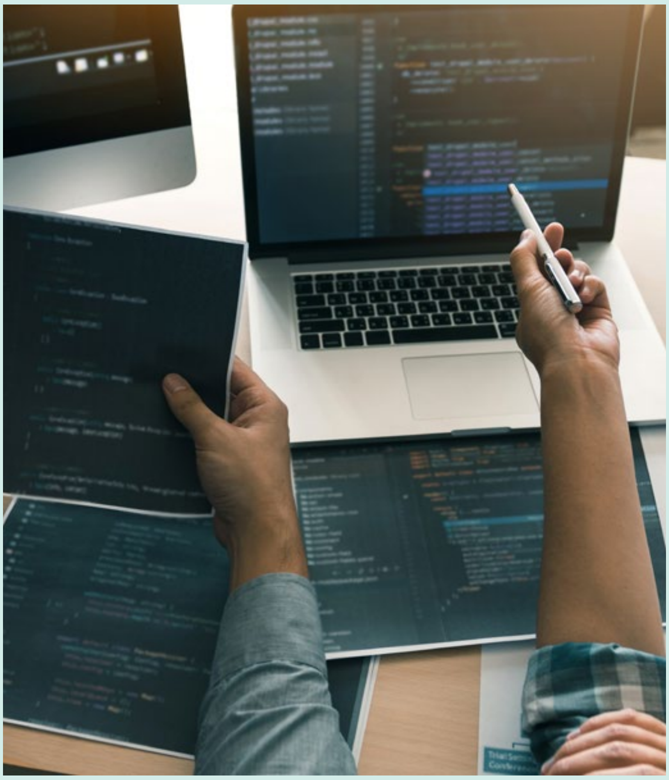
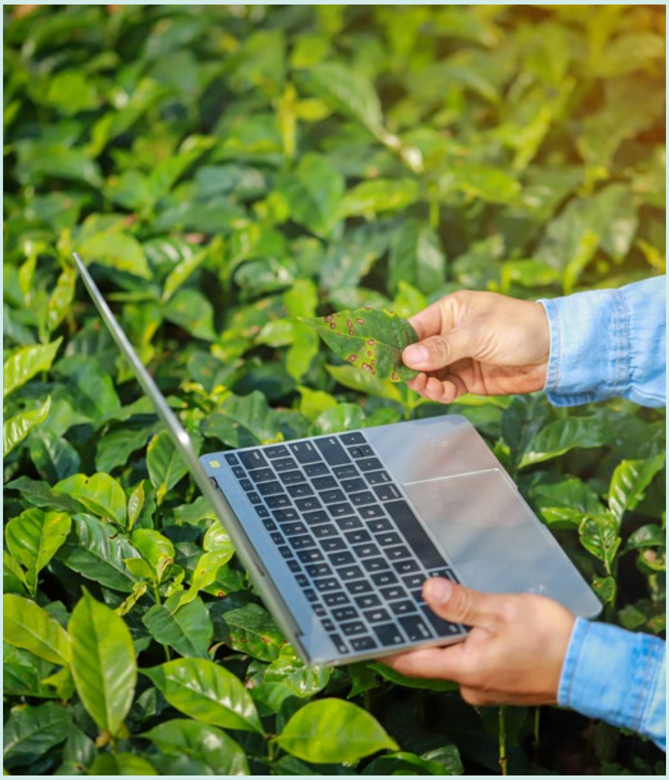


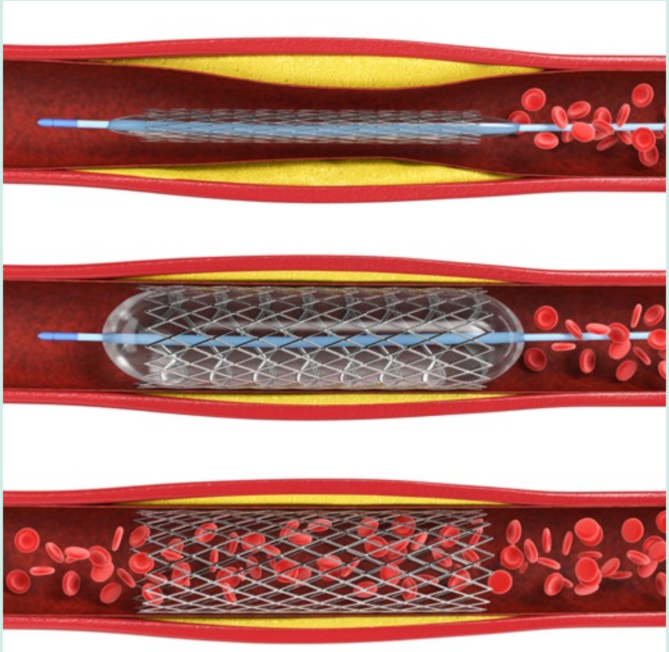
Figure 16. Proportion of Vietnamese firms applying or planning to apply various digital technologies in 2018

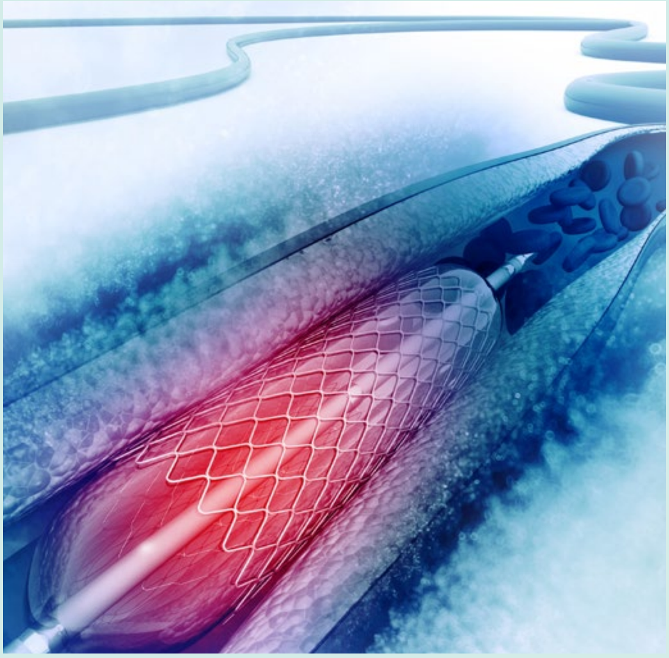
Source: Ministry of Industry and Trade[28]



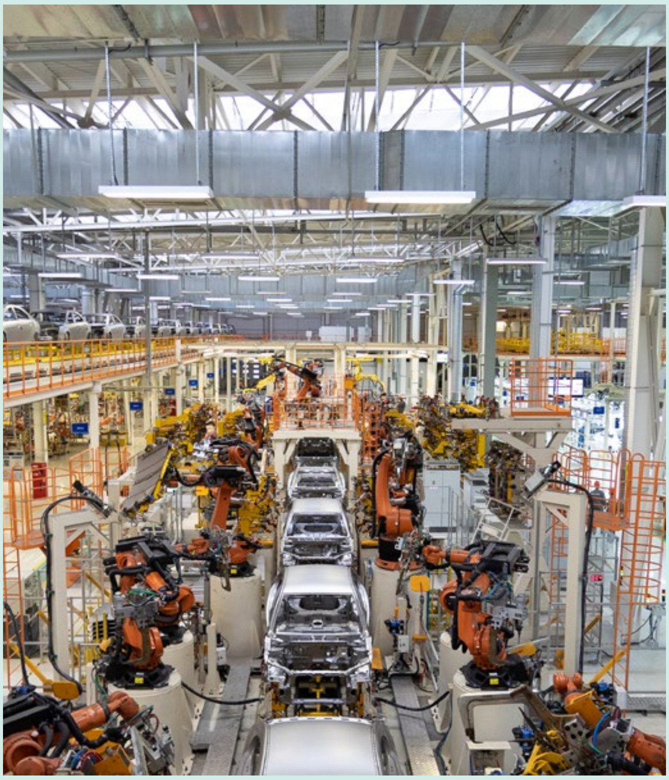


Cloud computing has become increasingly popular in the business sector. This indicates an increasing demand to utilise third-party digital resources to cut costs and stay competitive in the market. According to the Ministry of Information and Communications, Vietnam's cloud computing market is worth about US$133 million and is predicted to increase to US$500 million by 2025.[26] According to market analyst firm Research and Markets, the market for cloud services in Vietnam will grow from US$181 million in 2019 to US$427 million in 2025.[30] In 2020, the country was the home to 27 cloud computing data centres, invested by 11 domestic firms with more than 270,000 servers.[26]

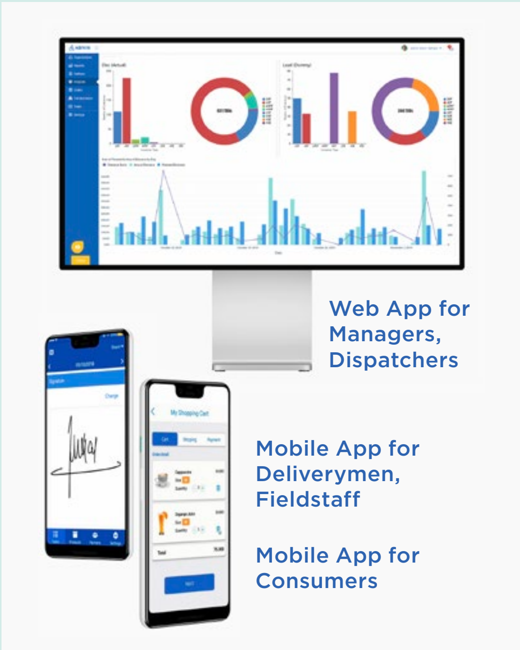




The application of technology innovation helped **USM Healthcare** become the second factory in Southeast Asia to produce coronary stents and coronary angioplasty balloons. Their products meet European standards, ISO 13485, GMP-WHO at about 50% the price (US$1,000 per stent), helping patients with cardiovascular disease receive stent implants at a reasonable cost.



Production of automobile tweezers with 70%–80% factory automation – Truong Hai company.
The automation improves the production capacity of the factory from 6,000 tonnes/year to 10,000 tonnes/year and reduces annual production costs by 5%.



ABIVIN is a start-up that provides software for dynamic route optimisation and transportation management.

The COVID-19 pandemic provides a unique opportunity to accelerate economic growth through technology adoption, creation and digitalisation in Vietnam

The COVID-19 pandemic reduced Vietnam's economic growth rate to the lowest level in decades. Despite this, Vietnam is one of the very few countries to avoid a recession in 2020, with an economic growth rate of 2.9%. Recovery in the manufacturing sector has been key to sustaining growth through the pandemic. Vietnam's exports increased by 6.5% in 2020, contributing to a record trade surplus of US$19.1 billion. Despite the pandemic, Vietnam has also proven to be an attractive destination for FDI. These successes provide a solid foundation for recovery and may even help speed up technology adoption and digital transformation across businesses in Vietnam, as they rush to adopt or develop technologies to address the health and economic effects of the outbreak.

Vietnam's GDP growth in 2020	2.91%
World GDP growth in 2020	3.5%
Vietnam's FDI growth in 2020	-20%
World FDI growth in 2020	-42%
Vietnam's trade balance surplus in 2020	2.91%

Recent product launches demonstrate how the pandemic has accelerated digital transformation in Vietnam. For example, three made-in-Vietnam digital products were rolled out by the Vietnam Government in 2020 to combat the spread of COVID-19 and accommodate changes in consumer behaviour across the nation. In April 2020, Vietnam launched its contact tracing app, *Bluezone*, as well as a virtual health check-up platform called *Telehealth*. The *Telehealth* platform enables remote medical and surgery consultations, remote training and remote technology transfer to augment the examination and treatment capacity of remote hospitals and reduce patient overload at central hospitals. Riding on this momentum, the Ministry of Information and Communications launched *Zavi*, Vietnam's first video-conferencing platform, in May 2020.[29]

A recent survey by the World Bank also reveals a rapid shift toward digitalisation among firms in Vietnam and other Asian countries during the COVID-19 pandemic (see Figure 17).[33] On average, nearly 50% of firms reported an increase in the use of digital platforms in 2020 while 28% saw improvement in digital sales. However, there has not been much improvement in digital investment in Vietnam, compared to other surveyed countries.

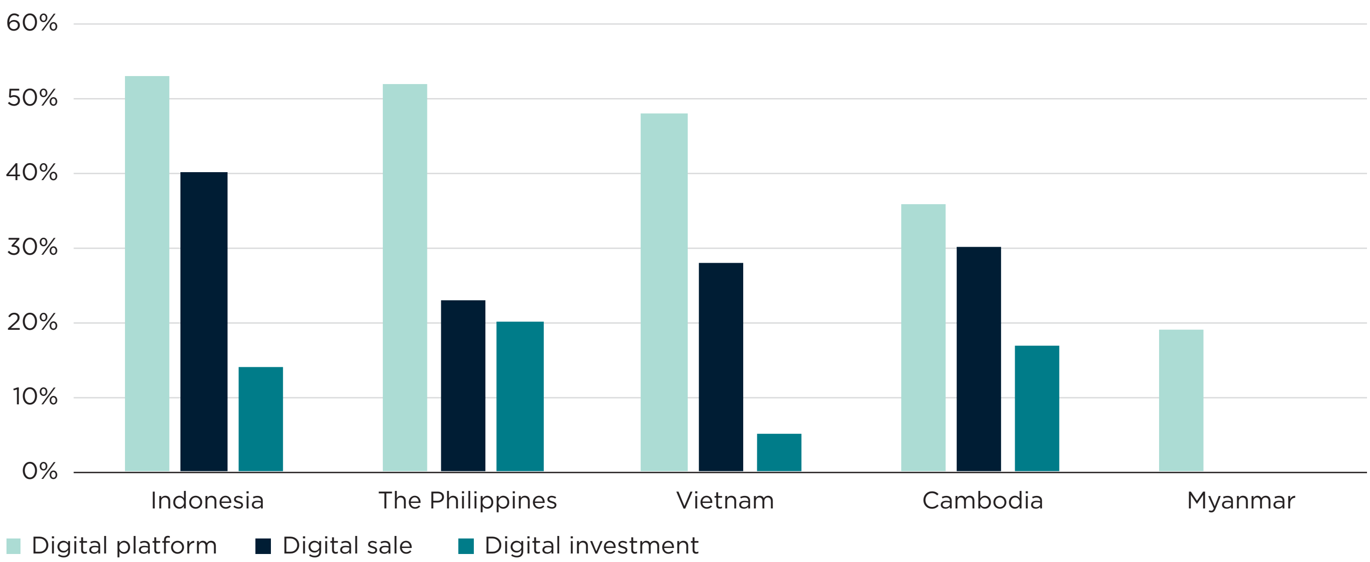


Figure 17. Increase in digital adoption across selected countries during the COVID-19 pandemic in 2020

Source: World Bank[30]

2.3 CHANNELS FOR TECHNOLOGY DEVELOPMENT IN VIETNAM

Over the last three decades of development, the economy of Vietnam has expanded rapidly on the increased availability of labour inputs and capital intensity; however, increases in labour productivity through the implementation of technology have been limited. In this section, we will examine the channels of technology creation and adoption in Vietnam.

HIGH-TECH IMPORTS

Similar to other developing countries, the purchase of any form of embodied technologies, whether they are products, machinery or equipment, is the most relevant technology development channel in Vietnam. Vietnamese firms acquire and adapt technologies mainly through capital goods imports. In 2017, capital goods imports reached US$186.74 billion and equalled six times the value of FDI to the country.[31]

Though caution should be taken when considering high-tech imports as an indicator for technology development, since imports of capital goods for Vietnam include many intermediate inputs (especially for foreign firms), there is a strong correlation between high-tech imports and the varieties of capital goods available on the domestic market for final goods production.

Over time, high-tech product imports have accounted for a rising share of Vietnam's import value. The annual growth rate of total imports of high-tech products was 18% during 2000–2005 then jumped to 27% in the 2006–2010 period and 32% in the next five years before going down to 17% in the 2015–2019 period. Vietnam also had the highest growth rate of high-tech imports among regional peers in the last 10 years since 2010 (see Figure 18).[31]

Though the high-tech share in total imports and exports remains modest in relation to that of low- and medium-tech products, the improvement partly reflects Vietnam's efforts to promote technology adoption through the capital goods import channel, which in turn has resulted in a positive change in the trade structure of the country.

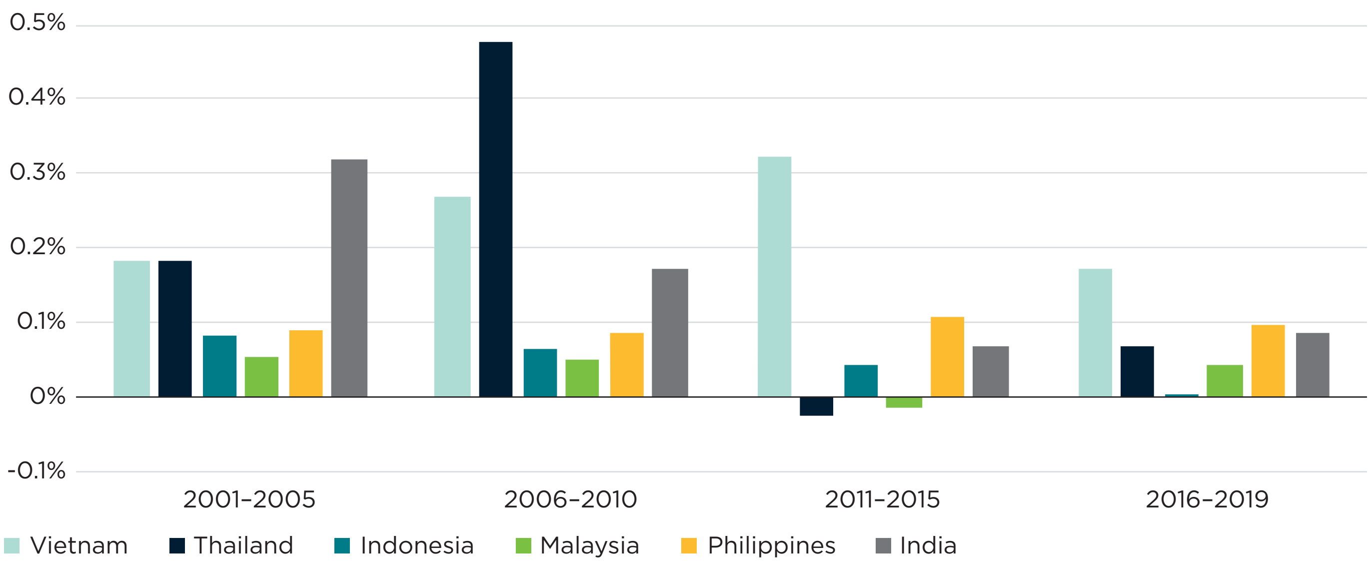


Figure 18. High-tech import growth rate across selected countries

Source: World Bank[31]

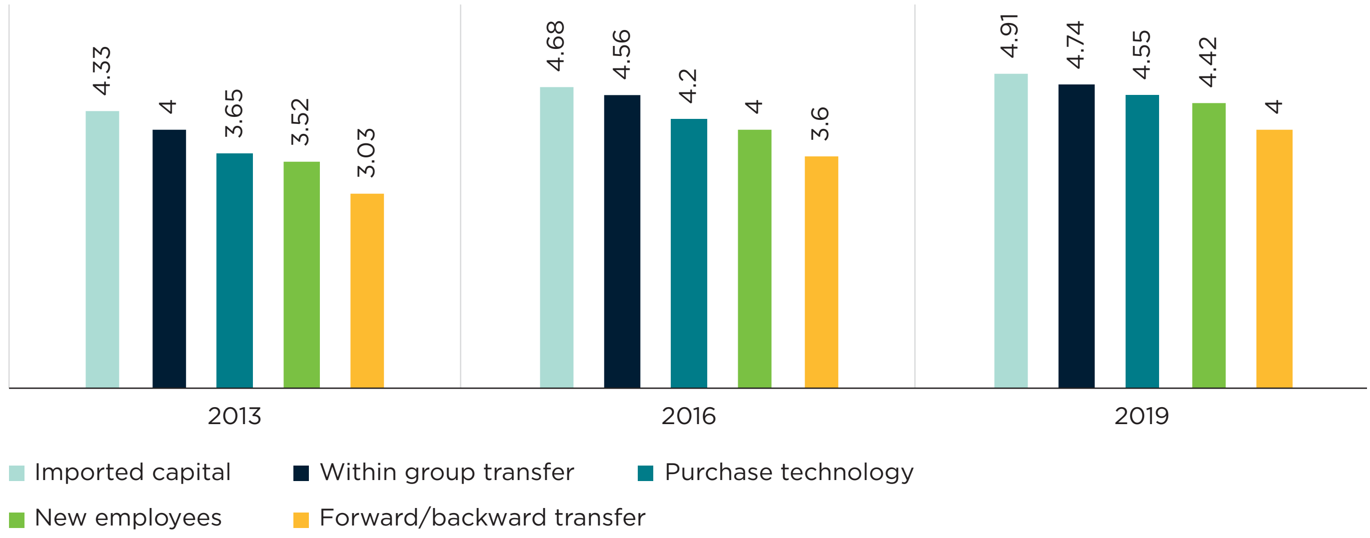


Figure 19. Average ranking scores of the most important technology channels by manufacturing firms in Vietnam

Source: Authors' calculation based on the GSO business survey[22]

LABOUR MOBILITY

Another channel of technology transfer in Vietnam is labour mobility. Technology in the forms of know-how and experiences acquired from previous occupations are transferred to the new firms that employees join. GSO conducted surveys with manufacturing firms and found that besides the purchase of new equipment or machinery, technology transfer from new employees is the second most important channel in Vietnam, at least for the manufacturing sector (see Figure 19).[22]

BACKWARD/FORWARD TRANSFER

The GSO survey results shown in Figure 19 also reveal that Vietnamese firms do not consider backward/forward transfer as an important channel to adopt technologies. This finding casts doubt on the spillover impacts from FDI to local firms in Vietnam. In the literature, the presence of foreign firms is usually associated with the increase in know-how transfer to domestic firms both within the sector and among firms in the same value chain.[36] However, this does not seem to be the case in Vietnam.

In Vietnam, despite the increasing importance of FDI firms to GDP, exports and job creation, the linkage between FDI and local businesses remains modest. According to the GSO survey with manufacturing firms, the linkage is particularly weak in high-tech sector manufacturing such as electronics or motor vehicles, compared to resource-based manufacturing such as basic metals or textiles. In high-tech sector areas, FDI firms focus mainly on assembling and packaging, which results in limited absorptive capacity among domestic firms. These findings signal the drawbacks in the FDI attraction policies of Vietnam which, for a long time, have focused more on the quantity rather than quality of FDI.

The lack of evidence for a spillover effect from FDI to local firms in Vietnam, however, is also in line with the prediction of the technology development model discussed later in this report (Chapter 5). At the initial stage of development, limited technology absorptive capabilities prevent local firms from benefitting from more formal technology transfer channels such as FDI or licensing, which can only be effective once businesses in Vietnam acquire adequate technology absorptive capabilities.

IN-HOUSE R&D

Recently, in-house R&D has emerged as another important channel of technology development in Vietnam. Businesses conduct R&D activities to generate new technologies or adapt existing ones to their local context. Given the nation's distance from the technology frontier, the majority of R&D activities among firms in Vietnam involve the adaptation of existing technologies to the local context.

In Vietnam, the number of patent registrations has been low with stagnant growth rates. In 2019, the number of patents per million population was 63 in Vietnam, which is higher than the number in Indonesia (36) or the Philippines (40), but still lower than in Thailand (117) or Malaysia (228).[34] Moreover, the overwhelming majority of patent applications (92%) was filed by foreigners.[34] It will be important to improve foreign technology transfer into Vietnam, since foreign firms are attempting to protect their IP in the Vietnamese market.

Different from patent registrations, the majority of applications for trademark and utility solutions were filed by Vietnamese people. As trademark applications do not require an innovative step or non-obviousness, trademarks capture inventions being commercialised such as marketing solutions or process innovations.[35] The increasing number of trademark applications in Vietnam provides evidence for the increasing efforts of Vietnamese firms to localise and optimise technology available in the market.

IMPROVING TECHNOLOGY ABSORPTIVE CAPABILITIES

Related to IPRs, fixed investment – especially in high-tech machinery and equipment imported from more advanced countries – contributes to productivity via process innovation or combined process/product innovation in latecomers. The contribution of fixed investment increases with learning and as labour force skills improve. A high level of investment in productive capacity and complementary infrastructure can, up to a point, reinforce the push imparted by structural change. There comes a point, however, when further capital accumulation – unless offset by accompanying innovations – leads to diminishing returns and is reflected in rising incremental capital-output ratios (ICOR). This has occurred in China where investment spending rose steeply over the past decade and now amounts to almost 50% of GDP. However, the efficiency of this investment appears to have declined, as China's ICOR rose from 3.8 in the 1990s to 4.9 in 2008–2009.[36]

Given the diminishing returns from capital accumulation, Vietnam is approaching an important crossroad and has to mobilise new drivers of productivity growth in order to sustain future growth. R&D activities, combined with upskilling human capital and greater linkages with external knowledge sources, can both improve productivity and increase the efficiency of technology transfer through upgrading the absorptive capabilities of firms.

In-house R&D and sustainable development

PHENIKAA GROUP is a Vietnamese multi-sectoral co-operation with more than 20 subsidiaries. Founded in 2002, Phenikaa (originally Vicostone Joint Stock Company) is now one of the four largest manufacturers of high-quality quartz-based engineered stones in the world. The compound annual growth rate has been nearly 20% for the last three years.

Phenikaa has been a pioneer in developing and applying new technologies, materials and smart devices to establish a long-term comparative advantage.

At the moment, Phenikaa has four R&D centers, three research institutes and Phenikaa University.

The growth ecosystem of Phenikaa is represented by the close linkage between business, scientific research, and education and training.

2.4 TECHNOLOGY ADOPTION IN VIETNAM IS NOT WITHOUT ITS CHALLENGES

Firms with different capacities may be involved in different technology development activities and thus face different kinds of barriers to technology adoption. For example, a lack of cumulative know-how is not a serious barrier for firms in the infancy stage. However, a lack of know-how can be a key barrier for firms in the later stages of technology adoption or creation.

A number of impediments for technology adoption among businesses in Vietnam are discussed here.

FINANCIAL RESOURCES

As is conventional among developing countries, firms in Vietnam experience financial constraints on technology adoption. In a 2020 survey with SMEs located in ten provinces of Vietnam, finances were found to be the greatest constraint among several examined.[22] Most commercial banks are reluctant to invest in SMEs due to various constraints that SMEs are facing in the market such as the limited domestic demand, inability to compete in the international market, as well as severe competition from FDI firms and trading companies selling imported products. It is clear that the proportion of firms with access to credit is low in Vietnam. Meanwhile, other channels of funding such as bonds or the stock market are underdeveloped in Vietnam, which significantly reduces the ability of firms to access formal financial channels. The constraints on financial resources are particularly salient for SMEs, especially when they are seeking financial support for innovation.

SKILLS SHORTAGES

Vietnam is experiencing skills shortages in many areas, from managerial to operational or technical skills. Management capacities are a particular weakness of Vietnamese firms compared to firms in other economies.[38] A separate study analysing the construction sector found that the lack of value management experts and knowledge about value chain management are the two most important challenges preventing construction firms in Vietnam from realising value management in practice.[39]

INSUFFICIENT CUMULATIVE KNOW-HOW

Know-how or practical knowledge is very important for firms in higher stages of technology upgrading, adoption or creation. In Vietnam, SMEs are mainly young firms with limited resources and thus limited access to technology know-how.

ECONOMIC UNCERTAINTY

Firms report uncertainty and lack of demand as another top constraint preventing technology adoption, according to a World Bank survey.[40] Market and competitive drivers are the main motivations for upgrading technologies. If firms are confident in the market's prospects, they are more likely to upgrade their technology, or increase their investment to enhance technological capacity for future upgrades. However, uncertainties in the market discourage firms from investing in technology upgrades.

FIERCE COMPETITION FROM FDI FIRMS

In Vietnam, the overwhelming number of FDI firms may have a countereffect to private firms' development due to fierce competition in the domestic market. Overly high levels of competition would discourage Vietnamese firms from upgrading their technologies for a couple of reasons: (i) the ability to compete with FDI firms is uncertain given the fast technological advancement of FDI firms on average; and (ii) disadvantages in accessing appropriate technologies, as FDI firms would have clearer advantages in terms of information, technology capacities and financial resources. Given this situation, domestic firms may not be motivated to adopt technologies to compete in the main market segments. Domestic firms are only able to compete in specific or minor segments, which may not be large or profitable enough to invest in upgrading technologies.

LIMITED LINKAGES BETWEEN FIRMS

In addition, the linkage between Vietnam SME firms via the supply chain or manager experience in MNCs is quite small at 10–17% of firms.[41] Information asymmetry is another factor causing barriers to linkages between Vietnam SMEs and FDI firms. There are no official channels for procumbent strategies of FDI firms, so it is difficult for domestic firms to find opportunities to form linkages with them. In addition, the low capabilities of Vietnam's SMEs limit their ability to connect to international-standard orders from FDI firms.

LACK OF TECHNOLOGY SUPPLIERS

Vietnamese firms lack information about official channels for technology transfer. More information is needed not only about suppliers of technologies but also procedures to acquire the technologies, particularly procedures for cross-border transactions. Another obstacle with the supply of technologies is that their market is not always competitive. There may only be a few suppliers, and their monopoly powers can cause difficulties in accessing the technologies. In an extreme case, suppliers of technologies or their associated establishments may also compete in the output markets, creating even more constraints for Vietnamese firms in accessing the technologies.

3 Methodology

3.1 CONDITIONAL FRONTIER MODEL TO ASSESS THE IMPACT OF TECHNOLOGY ADOPTION

In this report we utilise a conditional frontier model to estimate the impact of technology adoption on economic growth. In particular, the conditional frontier model examines how an industry in Vietnam is operating in relation to the country's best and most efficient firms.

There are two 'frontiers' developed: one that takes into consideration all the barriers to technology adoption (the conditional frontier); and one that looks at how the industry would operate if all barriers to technology adoption were removed (the unconditional frontier).

Figure 20 shows a *static* version of the conditional frontier model, which does not capture the movement of the two frontiers over time. The static model demonstrates the potential gains in output per worker for an industry, if firms across the industry operate at a fully efficient scale. Full efficiency can be achieved by: (i) removing technology adoption barriers (through greater investment in technology adoption activities); and (ii) improving operational efficiency (through applying quality management tools like international standards or lean management, or restructuring the organisation, strategies and linkages with external stakeholders). Beyond industry operation at full efficiency, additional gains in output per worker are possible through an increase in capital intensity (i.e. an increase in the capital to labour ratio).

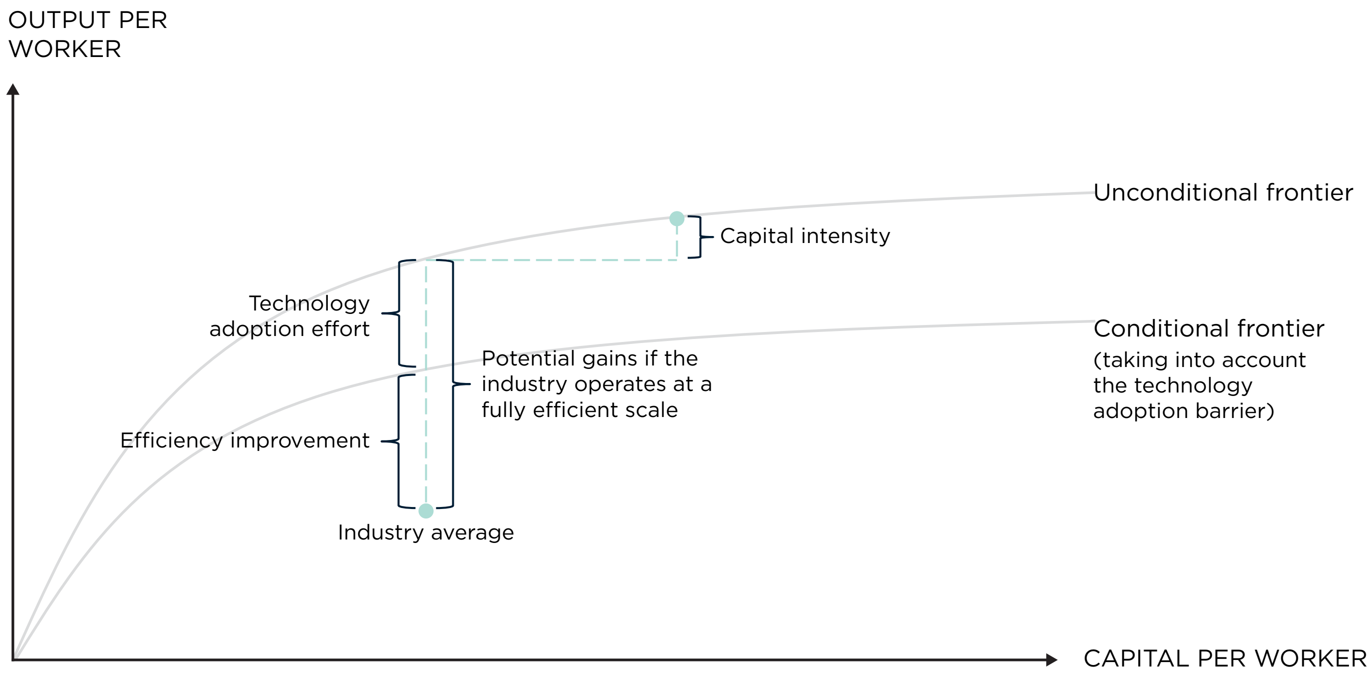


Figure 20. Static conditional frontier model

Source: Authors' illustration

In this report, however, we focus the analysis on the *dynamic* version of the conditional frontier model (Figure 21), which considers changes over time. In this dynamic model, the movement of the two frontiers, together with the movement of the industry average, help to decompose output per worker growth into different components. In particular, the growth in output per worker can be decomposed into: (i) capital intensity; (ii) the increase in technology adoption investment, allowing firms to adopt technologies that are available in the industry; (iii) the efforts of frontier firms to adopt leading technologies to lift up the potential technology frontier (conditional frontier) of the industry; and (iv) the effort of firms at the average level to increase efficiency through learning-by-doing, organisational innovation or implementing quality management tools. The various actions firms can take to increase innovation, as well as the impact these efforts have on the components of output per worker growth, are summarised in Figure 22.

The model utilises the micro-level data from the business survey conducted by GSO.[22] A detailed description of the model can be found in Appendix B; also refer to previous model in Appendix A.

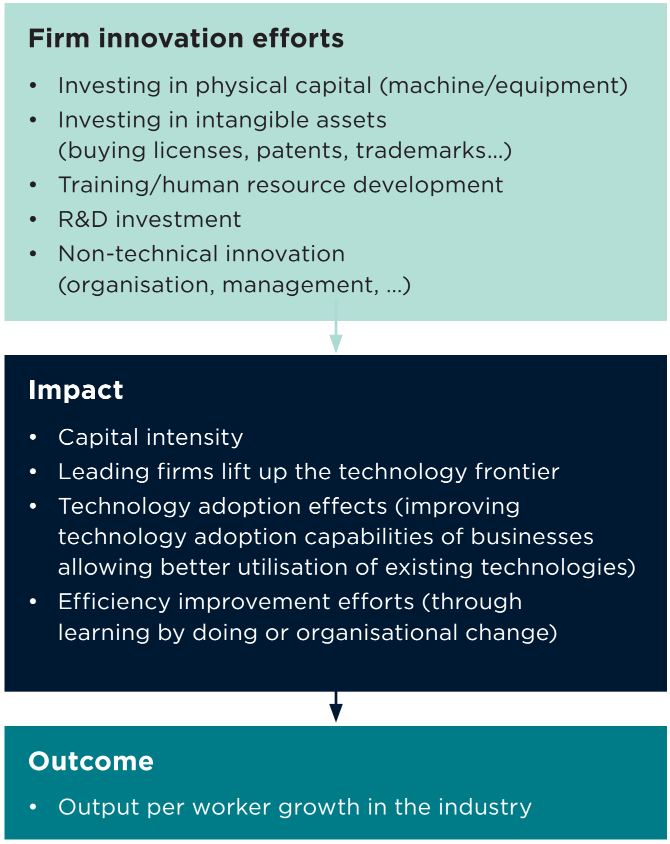
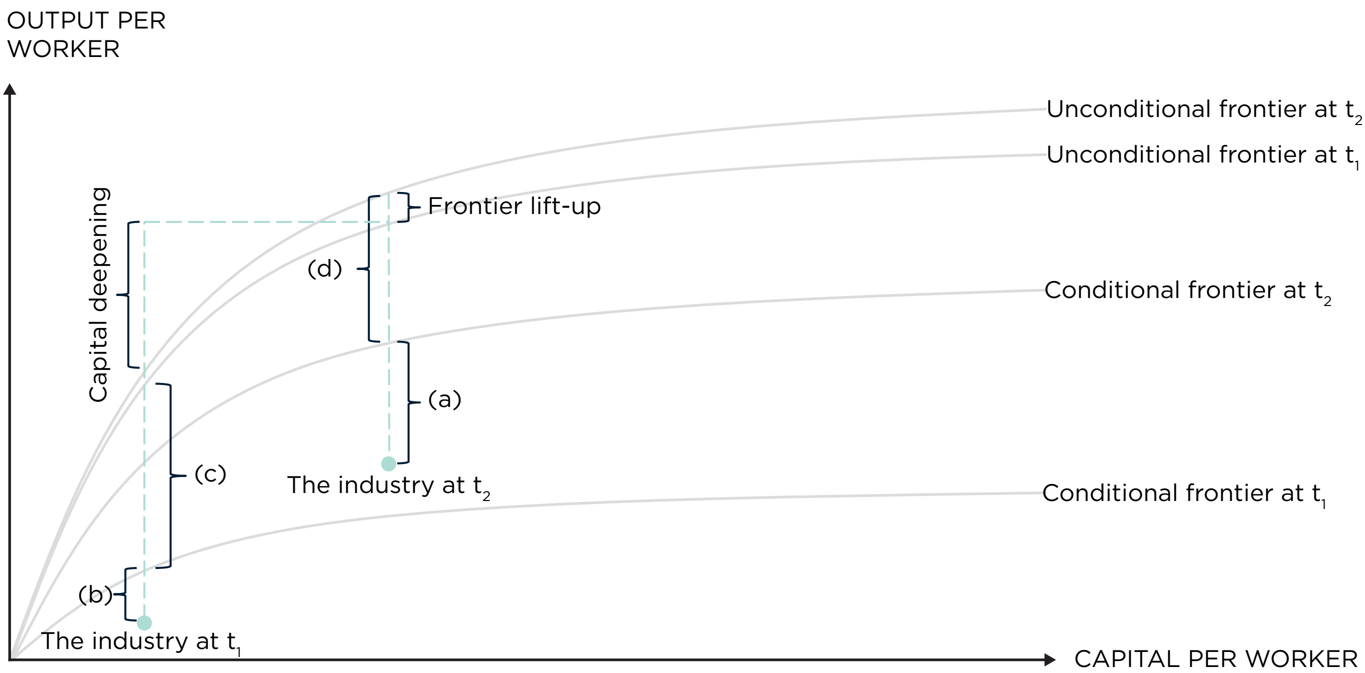


Figure 22. Firms' innovation effort diagram at the industry level



Efficiency improvement = (a) – (b)

Technology adoption effort = (c) – (d)

Figure 21. Dynamic conditional frontier model

Source: Authors' illustration

3.2 DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM MODEL TO ASSESS THE IMPACT OF R&D INVESTMENT

This report also utilises the dynamic stochastic general equilibrium (DSGE) framework to investigate the impact of R&D investment on the economic growth of Vietnam. DSGE models have been a common tool for governmental agencies across developed and developing countries due to their ability to: (i) incorporate dynamics (i.e. a time dimension); (ii) deal with stochastic uncertainty; (iii) incorporate forward-looking expectations of agencies; and (iv) study general equilibrium effects.[††]

Our starting point is a New Keynesian DSGE model, which incorporates the micro-foundation, rational expectation and general equilibrium with market imperfection and wage and price stickiness (i.e. the model allows for wages and prices to have a lagged response to changes). In the model, the market is monopolistic competitive and labour is assumed to be able to move across sectors/firms. This starting point provides a theoretically consistent micro-founded approach for modelling the innovative activities of firms as well as the impact of R&D policy options.

The non-standard feature of the model is that total factor productivity (TFP) is not assumed to grow exogenously and is instead dependent on two factors: (i) the creation of new technologies via R&D; and (ii) the speed at which businesses adopt technologies. The model is used to forecast Vietnam's long-term growth, which is driven by the adoption of new technologies developed by R&D investment. The modifications introduced into the DSGE model enable us to more properly assess the impact of R&D investments on the Vietnamese economy.

In our model, we specify a separate channel for R&D activities and also allow for new technologies to be developed by the R&D sector. The model also allows for the passage of time as R&D products commercialise and go through the technology adoption process. The focus of our model is on specifying shocks to R&D and investigating what relationships exist between the shock and growth or business cycles.

We utilise the framework in Anzoategui et al. (2019) and extend previous works in the economic literature by including technological adoption. We use this framework because we need to have a realistic period to allow for new technology diffusion.[42]

Our model is summarised in Figure 23.

†† One important feature of the general equilibrium model is that every transaction in the model triggers a proportional reallocation of resources, meaning that no resources can disappear from the economy without benefit to some agents. This feature is particularly important for comparing alternative R&D policy options. For example, in order to increase R&D through R&D subsidies, additional tax income must be collected through higher tax rates. Higher tax rates in turn affect production, and the consumption and saving behaviour of economic agents, which in turn affects the innovative activity itself.

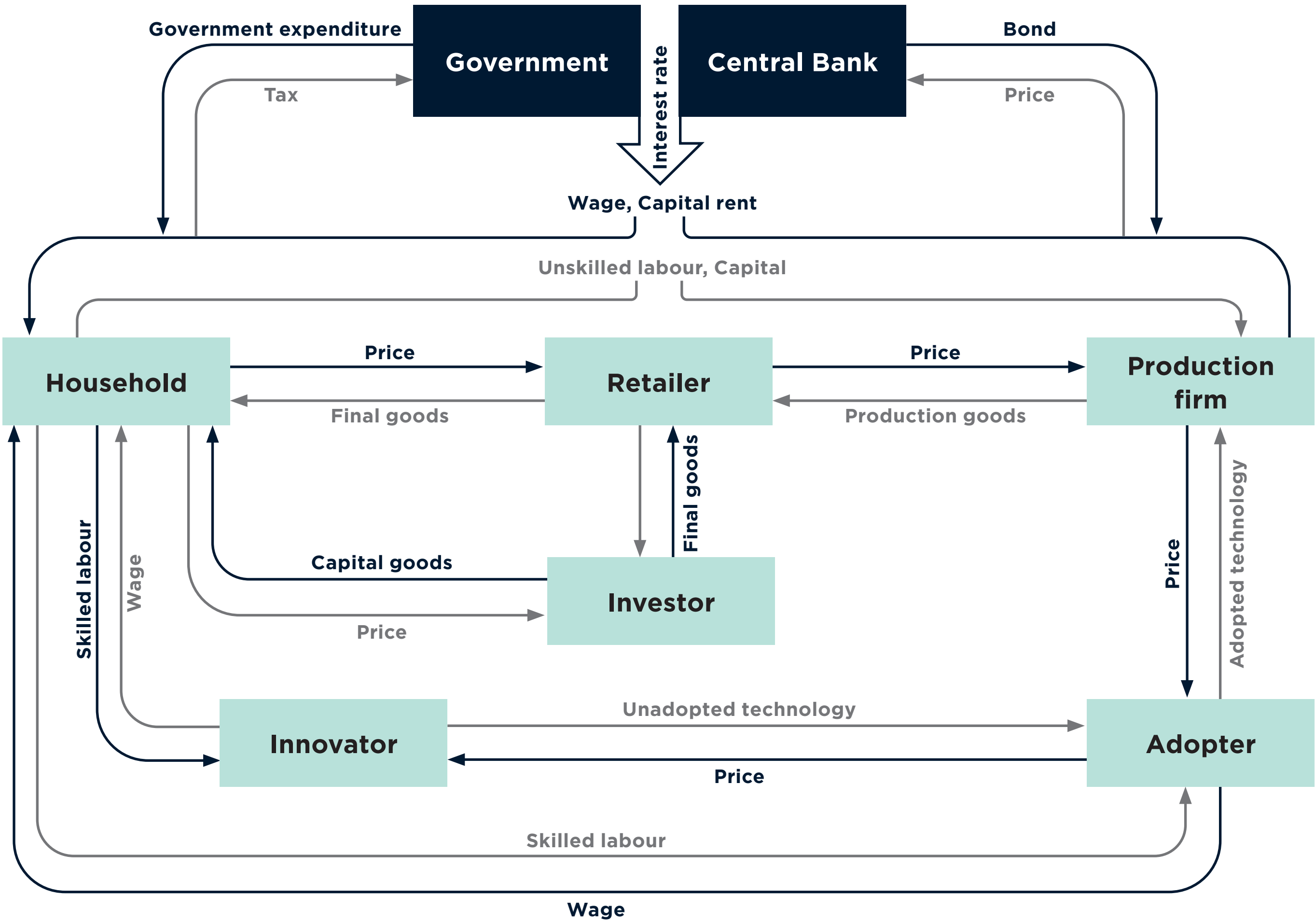


Figure 23. Dynamic stochastic general equilibrium framework

Source: Authors' illustration

There are five key agents in the model, including households, production firms, final-good firms, innovators and adopters.

The representative household consumes and saves in the form of capital and riskless bonds, and rents capital to production firms. The household provides two types of labour: unskilled labour, which is used in the production of goods; and skilled labour. Both types of labour are used for R&D activities and technology adoption.

Firms are monopolistically competitive and produce differentiated outputs. There are two types of firms: (i) retailers and (ii) producers. The retailers buy products from production firms and distribute the products to households. Production firms use capital services and unskilled labour as inputs to produce their differentiated outputs using adopted technologies bought from adopters.

Adopters are firms that buy rights to the new technologies developed by innovators and use skilled labour to convert unadopted technologies into adopted technologies that are ready to use. The adoption process implies that technology diffusion takes time on average. Once in a usable form, the adopter sells the rights to the technology to a monopolistically competitive goods producer that makes the new product.

There is a continuum of innovators that use skilled labour to create new technologies. We also allow for learning-by-doing in R&D processes and allow for decreasing returns to R&D investment in the sense that too much investment in R&D can reduce the efficiency of innovators. We also allow for technology obsolescence, where a new technology supersedes the old one.

The government collects taxes from households and spends the government revenues. The government also sets the central bank interest rate and sells government bonds to households.

What is different about our model from the standard DSGE framework is the presence of the endogenous productivity mechanism through the R&D/inventor channel. To establish this mechanism, we use data on R&D expenditure and model restrictions. Our model decomposes the utilisation-adjusted Solow residual into an exogenous, stationary component (the pure TFP shock) and an endogenous component that changes with R&D activities. Variations in R&D expenditure do not automatically translate into TFP for two reasons.

The first reason is that technologies need to be adopted, and this occurs with an uncertain lag.

The second reason is that not all R&D activities will result in new technologies, depending on the R&D productivity shock. A detailed description of the model can be found in Appendix B.

In this report, the model is used to investigate the following questions:

1. What is the impact of R&D investment on predicted economic growth in Vietnam?
2. How would macroeconomic behaviour in Vietnam be impacted by potential increases in R&D investment under different governmental policy scenarios?
3. What is the efficiency of R&D investment (R&D productivity) on economic growth in Vietnam?

In order to respond to these questions, we utilise the counter factual analysis and use two different methods:

- The conditional forecast is a counter factual method. In particular, we investigate impact of the future evolution of certain changes in some economic variables (e.g. R&D expenditure) on the outlook of other variables (e.g. GDP, consumption, investment). In this report, we use the conditional forecast to simulate various scenarios of R&D investment growth rates and examine their impacts on macro indicators.
- The impulse response function (IRF) is a standard tool to explore how a DSGE model reacts to small stochastic disturbances on its steady state. The IRF describes the evolution of a model's variables in reaction to a shock in one variable and allows one to trace the transmission of a single shock within the system of equations. Thus, the IRF is a very useful tool in the assessment of economic policies. In this report, the IRF is used to investigate the impact of an improvement in R&D productivity on the increase in R&D investment efficiency.

3.3 DATA

To enable the analyses of this report, we have compiled a database on the characteristics of Vietnamese firms, as well as their efforts in technology adoption and creation. The database includes both micro and macro datasets and is a compilation from multiple sources.

The purpose of the database is to:

- provide inputs for economic modelling to assess Vietnam's technological progress across industries, and the impact of technology adoption on Vietnam's productivity and GDP growth
- provide MoST with an ongoing source of data to assist the Ministry to develop evidence-based policies.

All data collected in this project are secondary data. The reasons for choosing secondary data as the prime source of analysis in this project include:

- Secondary data collected in census and government population and business registries allow for large sample sizes, population-level data at a low cost and a lower risk of self-reporting bias.
- Secondary data analysis provides the opportunity for longitudinal analysis, which is rare in social sciences and many economic studies.

The database includes two different datasets:

The **micro dataset**: This first dataset contains micro data on enterprises in Vietnam. The main data in this dataset come from the Business Survey conducted by the GSO and its sub-institutions.[22] This survey has collected information on enterprises operating in Vietnam since 2000 and is conducted at the end of each year.

There are also additional micro data collected from:

- the Innovation Survey conducted by the World Bank in their project to foster innovation through research, science and technology in manufacturing enterprises in Vietnam (FIRST project)[40]
- the public companies list on Vietnam's stock market. These data will be used as the validation data to re-run all the models to check the robustness of the models and add more indicators for innovation efforts among Vietnam's businesses.

The **macro dataset**: This second dataset contains sectoral-level data. The data include information relating to the main characteristics of the sector as well as the technology adoption and creation efforts of the sector. We collected data from the following sources:

- data aggregated from the Business Survey and other micro surveys by GSO[22]
- data collected by the Intellectual Property Office of Vietnam
- data collected by the National Custom Office of Vietnam.

The data are collected as a 5-digit Vietnam Standard Industrial Classification (VSIC) code, which includes around 850 subsectors in the economy.

Figure 24 summarises the main characteristics of the two datasets, outlines the data sources, identifies the main steps of data collection and cleaning, and provides an overview on main indicators of technology adoption and creation and their properties.

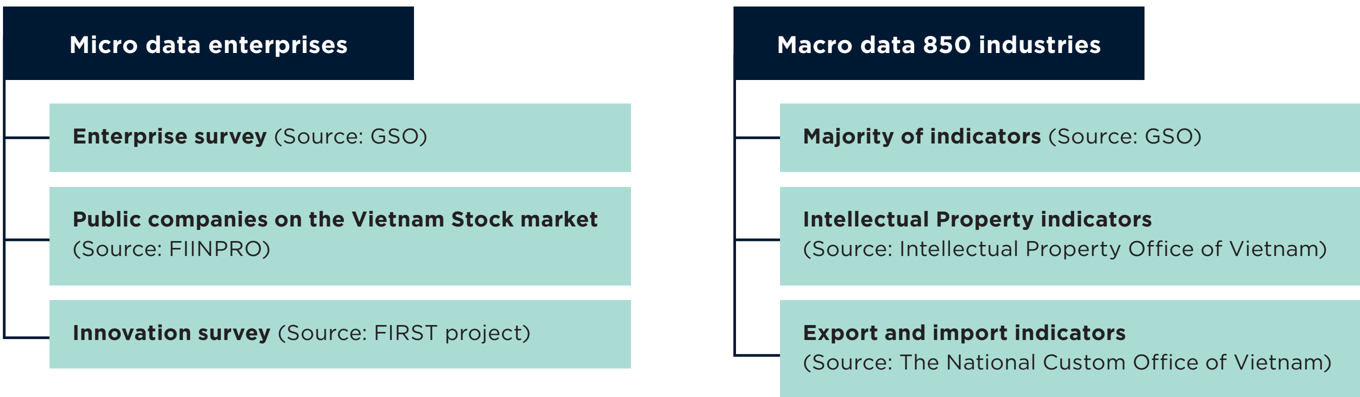


Figure 24. Database summary

Source: Authors' illustration

4 Model results

4.1 THE IMPACT OF TECHNOLOGY ADOPTION ON ECONOMIC GROWTH

Our model shows that technology adoption has been the main engine of growth in Vietnam in recent years.

As seen in Figure 25, the average annual growth in output per worker was 5.64% between 2015 and 2019. Also, 55% of the overall growth can be attributed to capital deepening (3.06% of the 5.64% per annum). The remaining 45% (2.58%) came from growth in TFP.

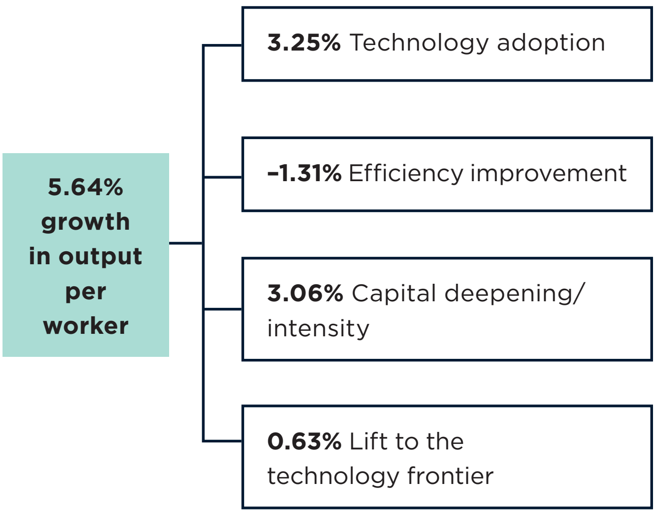


Figure 25. Components of output per worker growth per annum – average between 2015 and 2019

Source: Authors' calculation based on the GSO business survey[22]

The contribution of TFP to growth in output per worker can be attributed to:

1. The effort of frontier firms in the economy to lift up the potential output (the unconditional technology frontier) that can be produced in the sector
2. The improvement in the efficiency of firms at the average level (laggard firms) in production
3. The impact of technology-adoption-related investment among leading firms to lift up the barriers in technical efficiency change and technology adoption change.

The biggest contributor to TFP on average between 2015–2019 was the improvement in the technology adoption capacities of firms in the economy. The modelling results suggest that technology adoption efforts contributed 3.25% to the average growth in annual output per worker (more than 50% of total growth over the analysed period, more contribution to output per worker growth than the capital deepening component).

The efforts of leading firms to lift the potential technology frontier contributed more than 10% to total growth in output per worker over the analysed period (0.63% of the 5.64% annual growth in output per worker). These efforts by leading firms to lift the technology frontier is the second-largest contributor to TFP growth, and the third-largest contributor overall to output per worker improvement.

TFP would have contributed more to the overall growth in output per worker if there was no decline in the technical efficiency among laggard firms. Technical efficiency change represents the proportion of growth in output per worker resulting from the improvement in efficiency among businesses (i.e. improvement though learning-by-doing, organisational change or implementing quality management tools). If laggard firms in the economy managed to improve their efficiency at the same rate as that of improvement in technology adoption investment, then the average annual output per worker growth would be 1.31% higher and reach 6.95% instead of 5.64%.

THE COMPONENTS OF OUTPUT PER WORKER GROWTH HAVE CHANGED OVER TIME

Over the past two decades technology adoption has overtaken capital deepening as the main driver of growth in output per worker (see Figure 26).

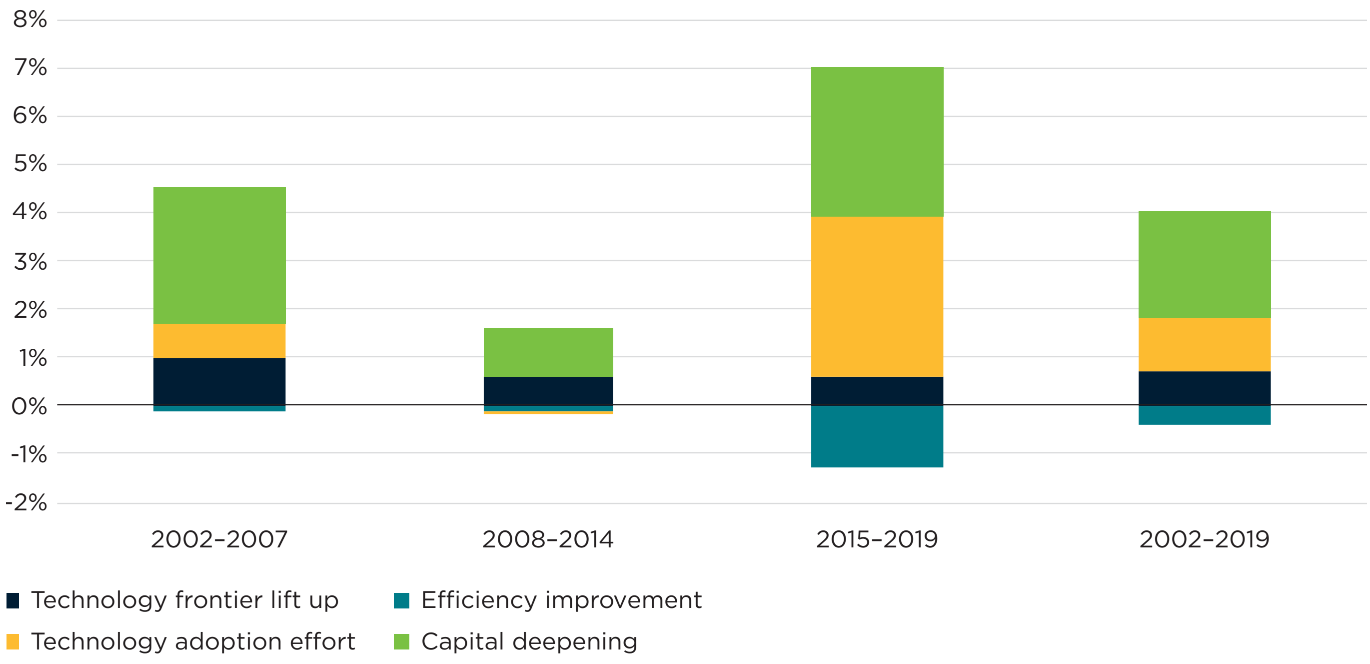


Figure 26. Output per worker growth decomposition across time periods between 2002 and 2019 in Vietnam

Source: Authors' calculation based on the GSO business survey[22]

2002–2007: Capital deepening drives output per worker growth

In the 2001–2007 period, output per worker growth in Vietnam was approximately 4.47% per year (see Figure 27). In this period, capital deepening played an important role in economic growth. Integration into the international market, together with various measures to stimulate the participation of the private sector and invite FDI, resulted in the increase in both the number and volume of investment projects and thus contributed to the strong rise in the capital to labour ratio in Vietnam's economy. As workers were equipped with more capital, output per worker increased.

In this period, TFP contributed a small portion to output per worker growth. Among TFP's components, the biggest contribution came from frontier to lift up of firms in the economy. Their efforts to reduce technology adoption barriers contributed 1.03% of the 4.47% average output per worker growth per annum, or nearly 22% of total output per worker growth between 2002 and 2007. The efforts of firms to adopt technologies was the second largest contributor of TFP to output per worker growth. This contributed 0.7% of the 4.47% growth per annum, or 15% of total increase in output per worker growth over the analysed period. In this period, the laggard firms were not able to keep up with technology adoption efforts from frontier businesses, as represented by the negative growth rate for the impact of efficiency improvement.

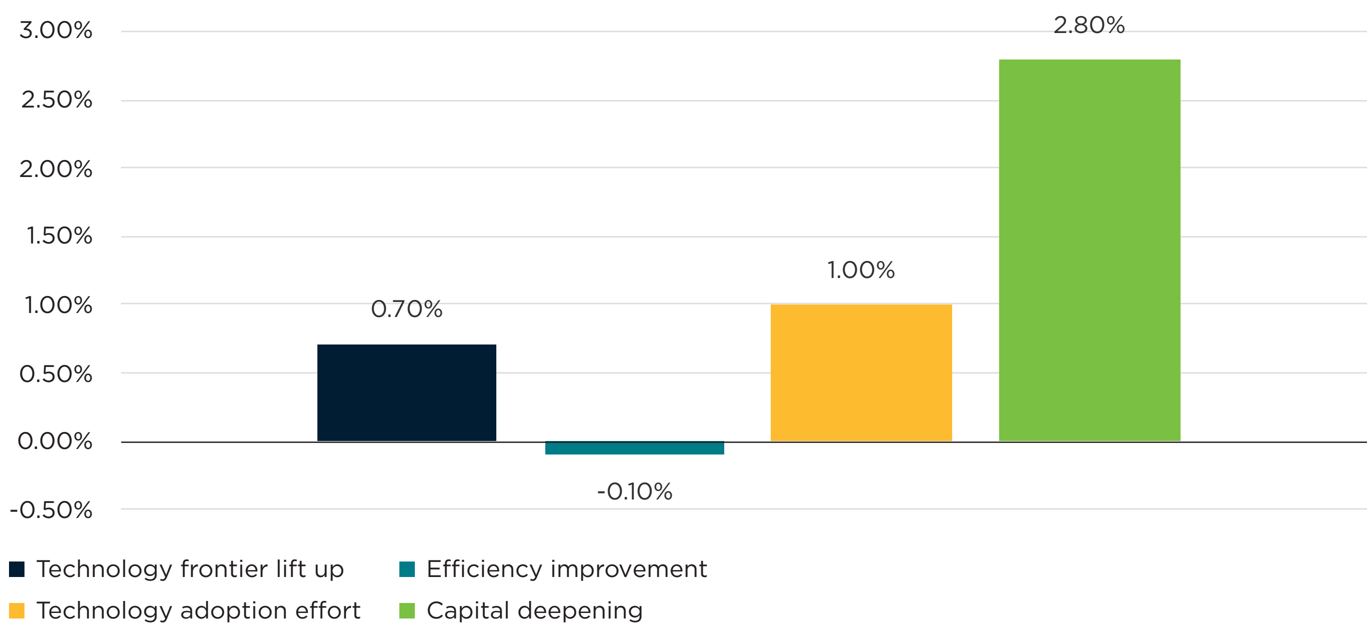


Figure 27. Average output per worker growth decomposition between 2002 and 2007 in Vietnam

Source: Authors' calculation based on the GSO business survey[22]

2008–2014: Impacts from the 2008 global recession

Following the 2008 global financial crisis, the next period 2008–2014 marked a slow-down in output per worker growth in Vietnam. In this period, a dip in capital investment resulted in a sharp decrease in the role of technology adoption investment in economic growth. The decrease in investment reflects the lagged negative impacts of the global financial crisis on development investment among businesses. Also, a government stimulus package that was counted as an increase in capital stock in 2009–2010 concluded in 2011. This caused a sharp decline in capital stock statistics.

The contribution of capital investment to average annual growth in output per worker fell sharply from 2.79% in 2002–2007 to just 1.0% in 2008–2014. Meanwhile, there was an improvement in the contribution of leading firms lifting the potential technical frontier. Firms at the frontier increased their contribution to total output per worker growth from 22% in 2002–2007 to 43% in 2008–2014 (see Figure 28).

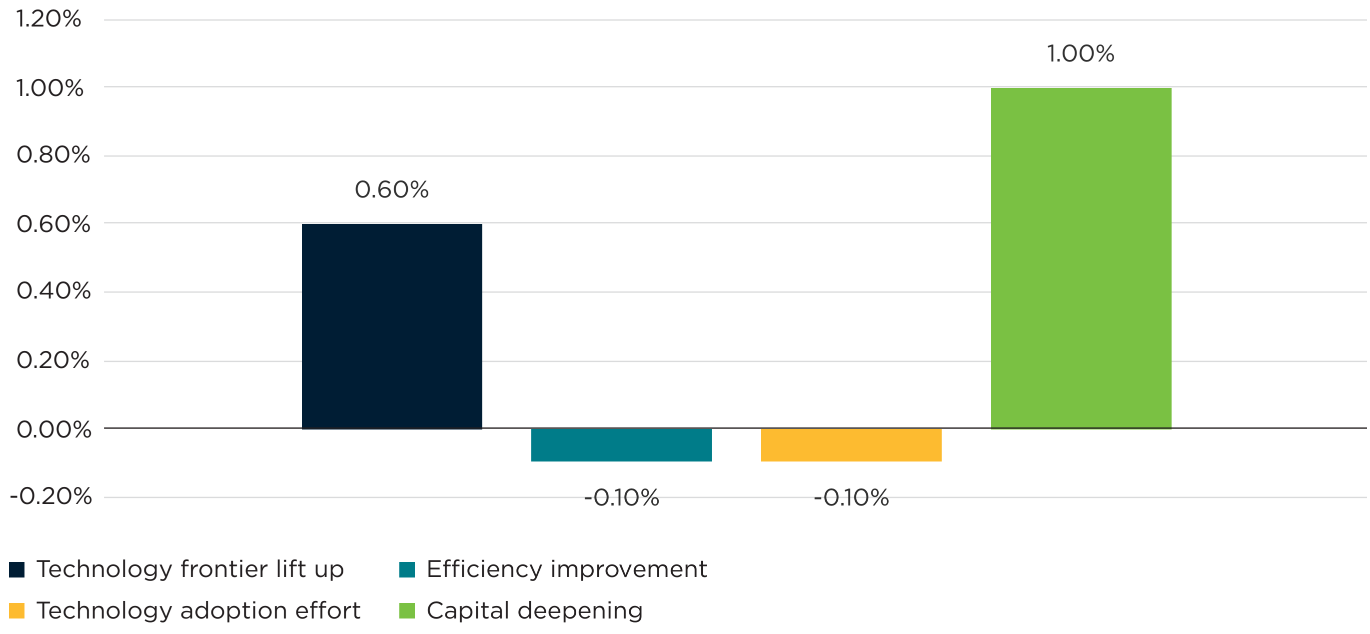


Figure 28. Average output per worker growth decomposition between 2008 and 2014 in Vietnam

Source: Authors' calculation based on the GSO business survey[22]

2015–2019: Technology adoption becomes the important driver of output per worker growth

In the most recent period of 2015–2019 the average growth in output per worker per annum accelerated to 5.64%. TFP again became a significant contributor to economic growth, contributing 2.58% of the 5.64% average annual output per worker growth in this period. Interestingly, the impact of technology adoption increased dramatically during this period, overtaking capital deepening to become the largest contributor to output per worker growth (see Figure 29).

In this period, there was a major shift in government policies toward technology adoption (e.g. Resolution 27/QD-CP, Resolution 35/NP-CP).[43,44] The amendment of the Law on Science and Technology in 2013 and in 2017 incorporated significant improvements to mobilise resources and encourage technology adoption among businesses.[45,‡‡] Since 2013, the National Technology Upgrade program, with public funding of 889 billion VND, has attracted more than 150 organisations, of which 59% were businesses, contributing more than 4,367 billion VND (about 73% of total investment[§§]). The projects were implemented in more than 30 provinces across various sectors and have contributed a significant part in the provincial socio-economic development. In these projects, businesses took the leading role and engaged closely with experts in universities and research institutes to develop commercialised products with the support from the government. These connections have facilitated innovation activities within businesses and accelerated invention commercialisation processes.

In 2015, MoST also identified five key measures to promote S&T including:

- significantly and consistently upgrading the organisational structure, management mechanisms and operations of S&T activities
- mobilising resources to implement S&T development orientations
- continuously strengthening national S&T potential
- developing the S&T market, S&T entrepreneurs and S&T-related services
- promoting international integration in S&T.

As a result, during the 2015–2019 period the number of SMEs that had technology-adoption-related activities increased by 23%. Of the top 500 businesses of Vietnam, 85% have upgraded technology, and 81% have invested in R&D. Of those, 41% have focused their R&D expenditure on developing/adapting new technologies/products for the domestic market.

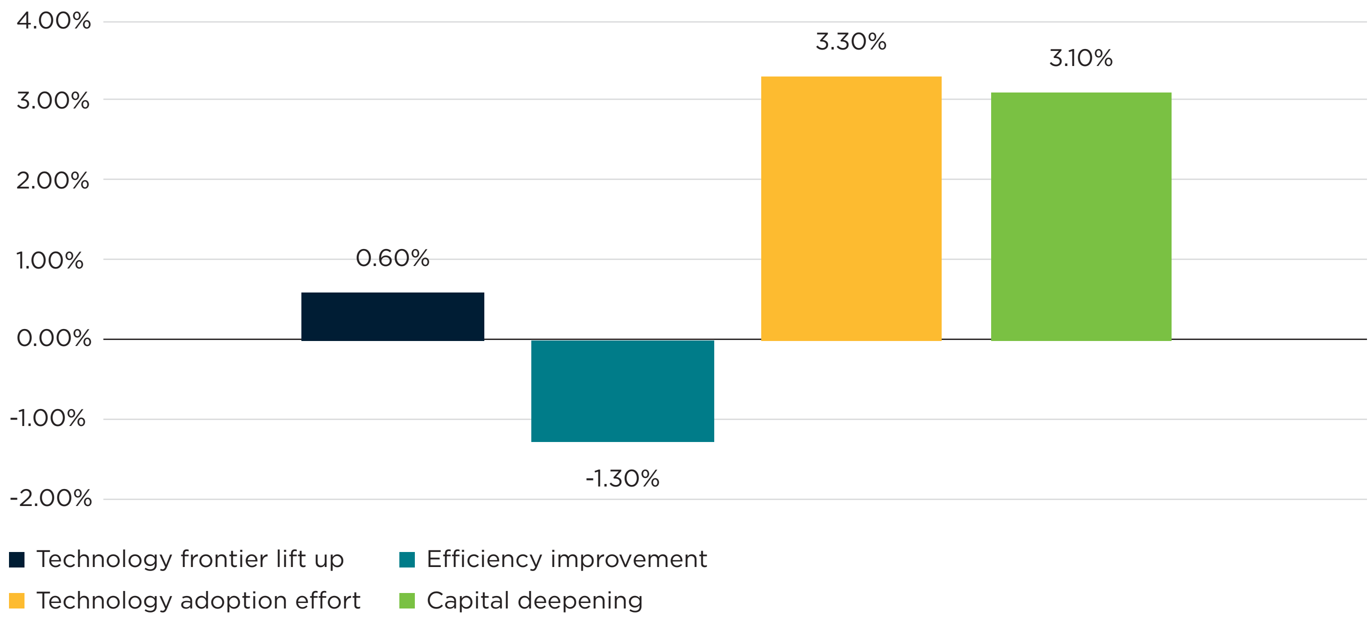


Figure 29. Average output per worker growth decomposition between 2015 and 2019 in Vietnam

Source: Authors' calculation based on the GSO business survey[22]

‡‡ Incentives include: exemption and reduction of corporate income tax for enterprises investing in high-tech zones; preferential access to land and infrastructure in industrial zones, export-processing zones, economic zones and high-tech zones; interest rate support or lending guarantees; and financial support to invest in scientific and technological projects or to cover part of the technology transfer.

§§ This did not include national security and defence projects.

With the increasingly fast rates of technology adoption investment, firms have found it hard to keep up with technological change in terms of organisational restructuring and management changes among other factors. As a result, there was a sharp decrease in firm efficiency between 2015 and 2019. In this period, if firms in the economy had managed to improve their efficiency to keep up with the rate of technology adoption, Vietnam's average annual output per worker growth would have been 6.95% (a 23% increase over the observed level).

THE COMPONENTS OF OUTPUT PER WORKER GROWTH ALSO VARY ACROSS SECTORS IN VIETNAM

Analysis at the sectoral level is important in understanding the dynamics of a nation's sources of growth. Over the period of 2015–2019, all broad sectors in Vietnam have significantly improved their performance. The development of output per worker growth, however, follows heterogenous trajectories across sectors. This section looks at the trajectories of output per worker growth and also the contribution of technology adoption to growth in Vietnam according to VSIC 1993 2-digit sector classification.

All industries are grouped into three major groups: (i) agriculture, forestry and fisheries; (ii) manufacturing, mining and construction; and (iii) services.

Table 1. Contributors to growth in output per worker between 2002 and 2019

	OUTPUT PER WORKER	OUTPUT PER WORKER GROWTH	TECHNOLOGY FRONTIER LIFT-UP	EFFICIENCY IMPROVEMENT	TECHNOLOGY ADOPTION EFFORT	CAPITAL DEEPENING	TOTAL FACTOR PRODUCTIVITY
2002–2007	46.41	4.47%	1.03%	-0.05%	0.70%	2.79%	1.68%
2008–2014	60.89	1.30%	0.56%	-0.12%	-0.13%	0.99%	0.31%
2015–2019	73.17	5.64%	0.63%	-1.31%	3.25%	3.06%	2.58%

Source: Authors' calculation based on the GSO business survey[22]

Agriculture, forestry and fisheries

Over the last two decades, agriculture, forestry and fisheries were among the industries with the lowest output per worker in absolute levels. Except for fisheries, the average level of output per worker for agriculture and forestry was around 65% of the average level of the country. These sectors, however, enjoyed relatively high rates of economic growth over the period.

Agriculture, although the greatest contributor to this broad sector both in terms of employment and total output, had a relatively low output per worker level. Over the latest period of 2015–2019, the average growth in output per worker per annum of the sector was 1.0% with capital deepening being the only contributor to that growth (see Figure 30). There were negligible impacts of TFP and efficiency improvement on output per worker growth in agriculture in the period. As such, increases in TFP growth and efficiency improvement among the laggard firms will be necessary to sustain future output per worker growth for the agriculture sector.

In comparison, fisheries not only had a higher output per worker level but also enjoyed a higher average 5-year growth rate of 7%, despite being a smaller sector (see Figure 30). More importantly, fisheries businesses were able to rely more on technology adoption to boost their output per worker growth. In the same period, the contribution of technology adoption investment overtook capital deepening to be the largest component of output per worker growth in fisheries. These developments have produced spectacular results. In 2014, Vietnam overtook Thailand to be the leading fisheries exporter in the ASEAN region.[46] In 2018, Vietnam was the 7th largest marine producer in the world, and in 2019, the country exported seafood worth US$8.6 billion.[47] Projections suggest that by 2030, fish production in Vietnam will reach 9.6 million tonnes with a growth of 28.2% compared to 2018.[46] In the future, the greatest benefits to output per worker in this broad sector are likely to come from technology adoption efforts.

Service sectors

In absolute terms, except for the transport, finance and health service sectors, most service sectors had lower than average output per worker growth in the 2015–2019 period. This section further examines output per worker growth in selected service sectors (see Figure 31).

Between 2015 and 2019 the top service sectors in terms of employment and output generation were retail and wholesale as well as accommodation and food – with retail alone employing around 10% of the labour force.

Over this time period, the output per worker growth of these sectors matched the average level of the economy and experienced relatively fast growth rates. The average growth of the retail, wholesale, accommodation and food sectors between 2015 and 2019 was 9%, 12% and 7%, respectively. Interestingly, the main contributor to the growth in these sectors was an increase in capital deepening.

In the retail sector, although traditional forms of trade such as street shops are still dominant, there has been an explosion in the number of modern trade formats such as commercial centres, convenience stores and digital platforms. Recent years have also witnessed the establishment of large domestic and international players in Vietnam such as Casino (Big C), AEON, VinGroup and Lotte. In 2019 VinGroup led the retail market with more than 100 supermarkets and around 1,900 minimarts.[48]

Another highlight has been the emergence of Vietnamese e-commerce as one of the fastest growing markets in the Southeast Asian region. In 2018 the average annual spend for an online shopper in Vietnam was US$350, nearly double the figure of US$186 in 2017.[49] Massive investment in modern trade channels has resulted in encouraging growth of output per worker; however, sustaining this growth will require an increasing contribution from TFP growth.

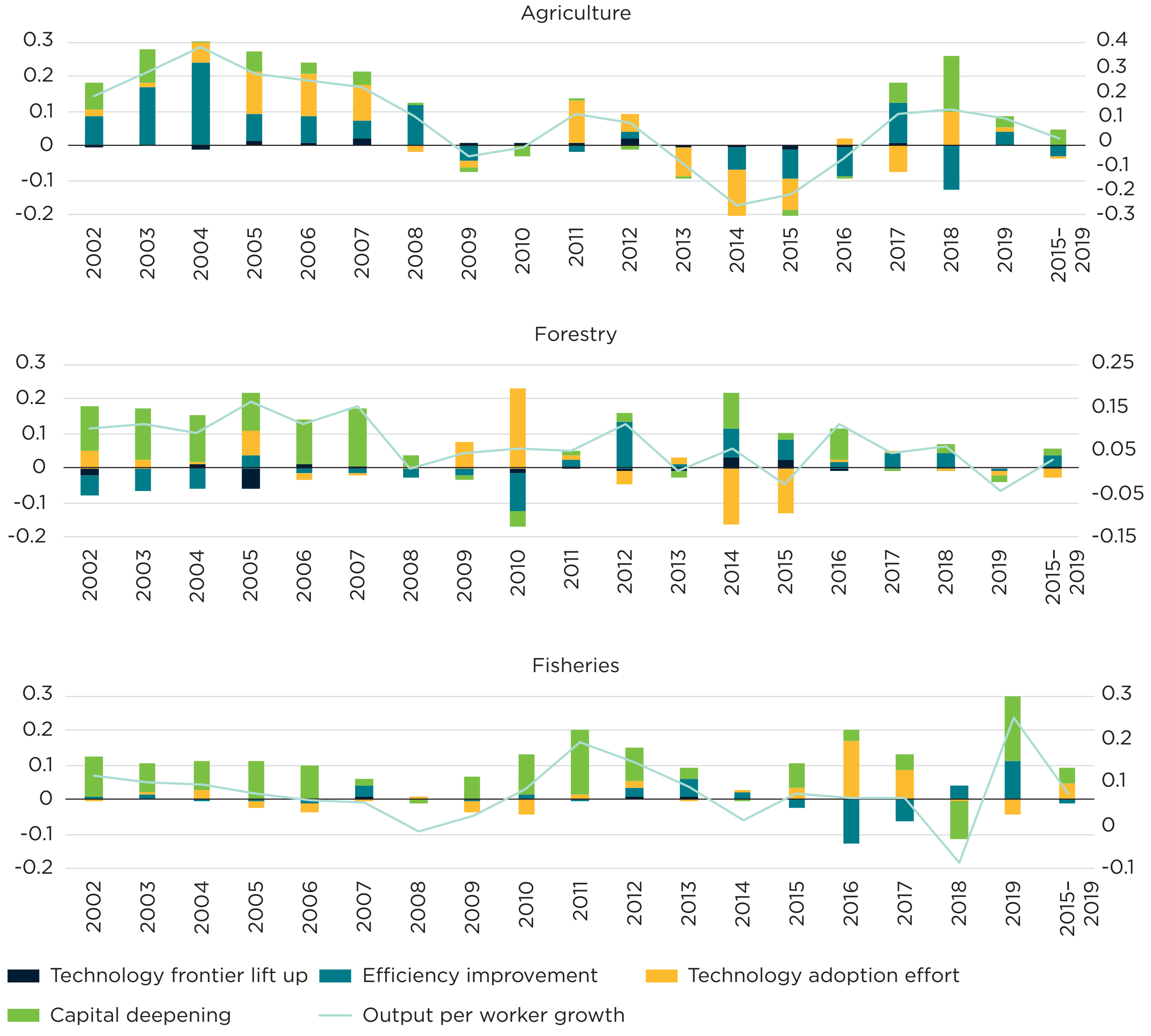


Figure 30. Output per worker growth decomposition in agriculture, forestry and fisheries between 2002 and 2019

Source: Authors' calculation based on the GSO business survey[22]

Figure 31. Output per worker growth decomposition in selected service sectors

Source: Authors' calculation based on the GSO business survey[22]

Figure 31 cont. Output per worker growth decomposition in selected service sectors

Source: Authors' calculation based on the GSO business survey[22]

The finance and real estate sectors also mainly relied on capital intensity for growth, despite being the sectors with the highest levels of output per worker. Vietnam's finance sector is relatively large compared to other lower-middle income countries (worth around 3.17% of GDP in 2017), but a range of challenges threaten the future stability of the sector.[50] For example, the ratio of bank deposits to GDP is among the lowest in the Southeast Asian region.[50] In addition, the non-bank sector is still small, accounting for only a third of the finance sector's assets in 2017.[50] Another issue is the low growth rate of these sectors in recent years, though their future growth trajectories could be high. Many financial businesses have not implemented good practices in banking supervision, which results in risky lending practices that direct credit to the stagnant real estate sector. The limited capacity to utilise technology to improve TFP could threaten future output per worker growth for both the finance and real estate sectors.

Conversely, sectors such as transport, healthcare, and computers and related services not only enjoyed relatively high output per worker growth, but also benefitted significantly from the improvement in technology adoption and efficiency. These sectors also highlight the importance of frontier firms that apply advanced technology to help lift the potential technology frontier of the industry.

Looking more closely at the healthcare sector, TFP contributed 75% to total output per worker growth in the 2015–2019 period with the bulk of growth driven by technology adoption. Technology adoption has been necessary to meet the demand for improved healthcare in Vietnam, which has expanded rapidly with the rise in income per capita, urban populations and the ageing population, as well as new opportunities provided by healthcare insurance schemes. Despite relatively low healthcare spending (6.6% of GDP in 2019), Vietnam has achieved remarkable population health outcomes.[51]

The overloading and understaffing of most of Vietnam hospitals, however, has forced the country's continued utilisation of technology and efficiency improvement in its health system. The private sector has also been quick to take advantage of the shift towards technology-enabled healthcare services. According to a YCP Solidiance report, private hospitals have relatively advanced health management systems compared to their public counterparts.[51] These factors are likely to continue to result in high output per worker growth, particularly as Vietnam moves towards a smart healthcare industry.

FPT e-hospital

In 2018 FPT officially launched the latest version of FPT.eHospital 2.0. This is a comprehensive hospital management system trusted by over 400 big hospitals and clinics. The system manages all activities from patient registration to discharges from health facilities. The system integrates various digital technologies such as artificial intelligence (AI), big data, the cloud, and the internet of things. The solution includes hospital information systems (HIS), radiology information systems (INF), picture archiving and communication systems (PACS) and supports multi-site admin and access. These solutions allow hospital leaders to manage the operations with real-time data, digital signature integration, digital medical records and other features. The solutions are expected to contribute to building paperless hospitals, optimising medical examinations and treatment processes so they are faster and more accurate, minimising the time and volume of administrative procedures, improving the capabilities of hospitals and supporting financial management systems including profit and loss management.

Manufacturing, mining and construction

Construction

The construction sector is one of the biggest employers in the economy (accounting for 8.4% of total employment). This sector, however, has a relatively low output per worker (just 80% of the economy-wide level). The average output per worker growth of the sector was 5% in the 2002–2019 period, but gradually improved to 8% in 2015–2019 (see Figure 30). The accelerated growth of output per worker was primarily driven by investment in national strategic projects, including in transport, energy and utilities, and the increasing market for residential and commercial construction. The sector, however, saw a decrease in TFP over the period. The contribution of technology and efficiency was not able to keep up with the increase in capital deepening of construction businesses. If businesses in the sector had increased their efficiency to keep pace with capital deepening, the average output per worker growth of the sector would have increased to 11% in the 2015–2019 period.

Mining

Meanwhile, most mining sectors in Vietnam enjoyed higher than average output per worker but had a lower than average output per worker growth rate (except for metal ore mining). Though these resource-based sectors, by nature, have a high capital-labour ratio, the model results show that the contribution of TFP to growth is notably high. In these sectors, the efforts of firms to lift the technology frontier was the main contributor to growth between 2015 and 2019 (see Figure 32 for data on coal mining).

In non-metallic mineral mining and quarrying, for example, the technology frontier lift added more than 50% of total growth in the sector. Clearly, the sector is still largely undeveloped but the attraction of FDI has provided the opportunity to use international, modern, efficient, sustainable and secure technologies in work practices in this sector.

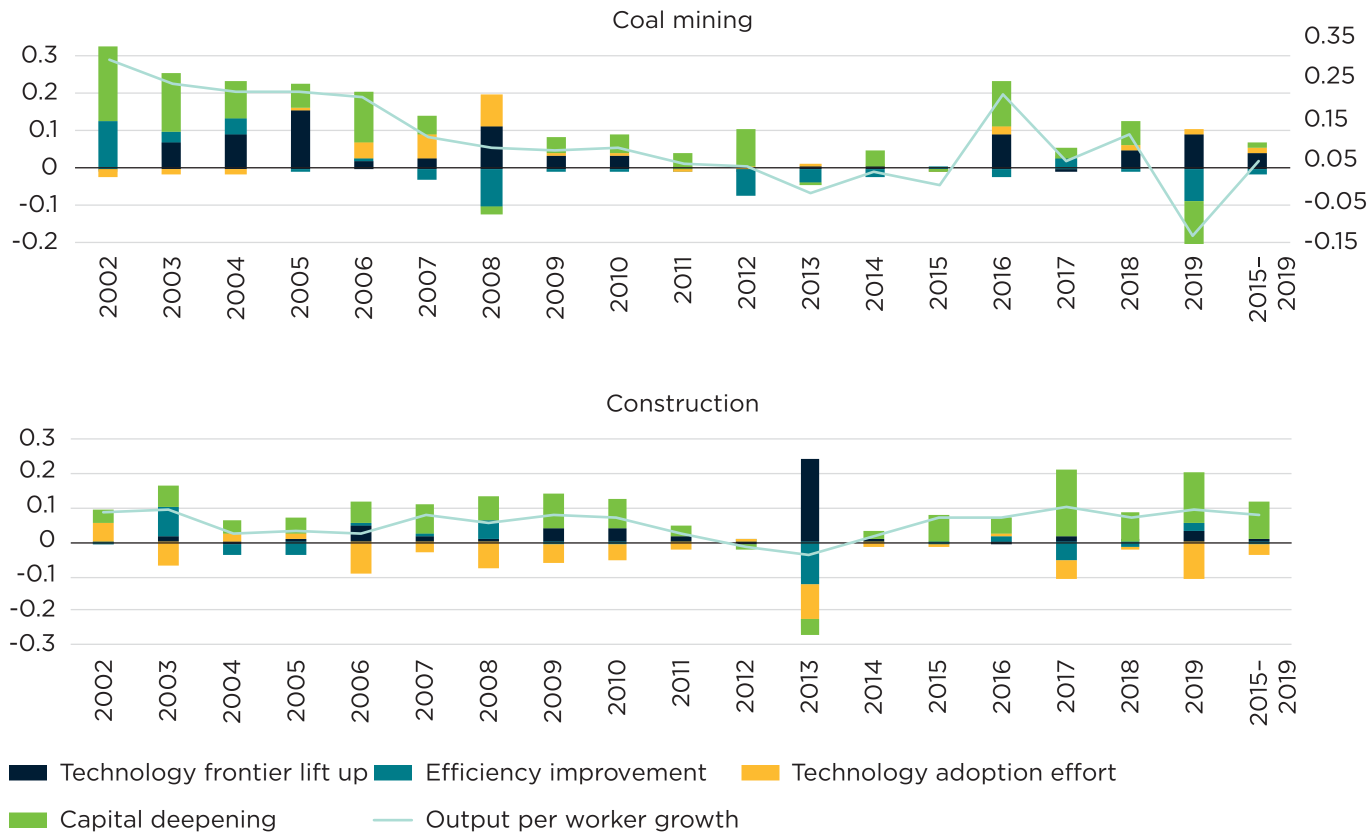


Figure 32. Output per worker growth decomposition in mining and construction

Source: Authors' calculation based on the GSO business survey[22]

The Vietnamese Government has also strongly supported the mining industry over the past decade, with the 2010 Mineral Law and other legislation. This includes the Political Bureau's Resolution No. 02/NQ-TW, Resolution No. 103/NQ-CP, Decision No. 2427/QD-TTg and Directive No. 02/CT-TTg.[55-57] These directives and regulations have provided the fundamental legal framework to manage and extract minerals effectively. MoST and other Ministries have also initiated various programs to support suppliers in Vietnam.

A hitherto highly successful mining project that applies modern technologies and international standards in Vietnam is the Nui Phao mining project. This is the largest tungsten production mine in the world to date, contributing significant value to Vietnam's economy by converting the ore into purified chemical products before they are exported.

Manufacturing

Manufacturing is by far the biggest employer in the economy, employing 20.7% of the total workforce in 2019.[22] In 2019, the sector also occupies the greatest share of total output (around 16.5%) and plays a vital role in national economic growth and transformation.[22] UNIDO's Competitive Industrial Performance (CIP) Index shows Vietnam's tremendous achievements in manufacturing: between 2006 and 2019, Vietnam overtook 31 countries and improved from 69th to 38th in global ranking, by far the biggest leap among ASEAN countries during that period.[55] Over the past decade, the annual growth rate of manufactured exports from Vietnam has rewmained at an impressive double-digit level (increasing from US$59.6 billion in 2010 to US$248.6 billion in 2019).[1]

In this report, we follow the OECD and group manufacturing sub-sectors into four groups based on their R&D intensity level (R&D expenditure to turnover).¶

Overall, low-tech industries play a very important role in employment in Vietnam, similar to that in other countries at a similar stage of development. There has been, however, a tendency for the low-tech industries' share of manufacturing to decline while the share of high-tech industries has increased over time.

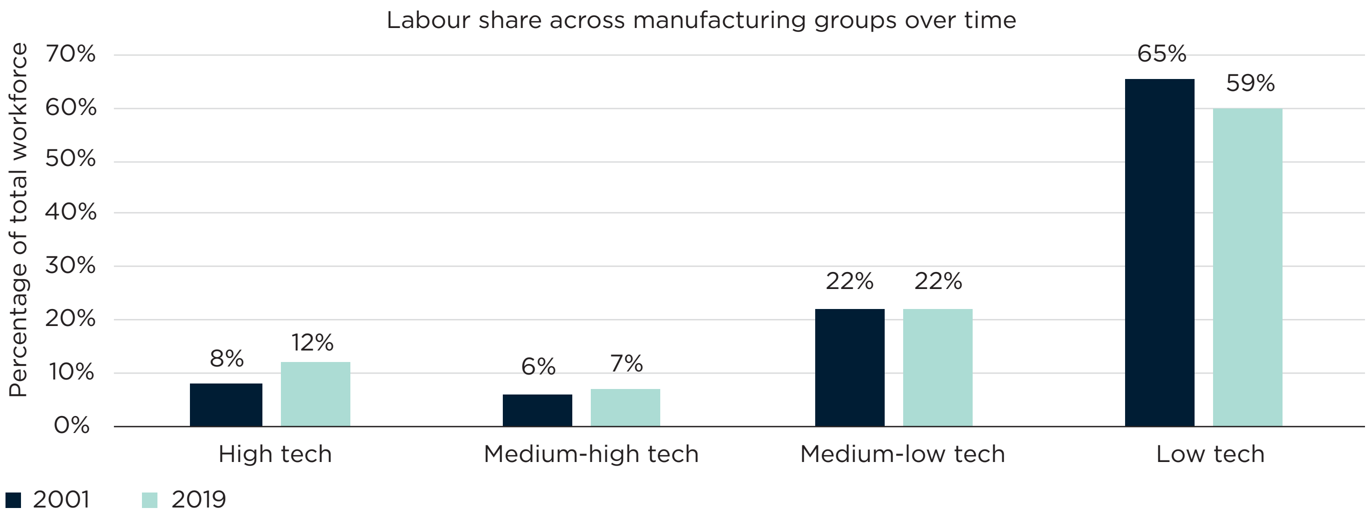


Figure 33. Labour share across manufacturing groups over time

Source: Authors' calculation based on the GSO business survey[22]

¶ High-technology sectors are those with an R&D intensity or more than 5% and are classed as 'high tech'. Sectors with complex technology with an R&D intensity between 3% and 5% are classed as 'medium-high tech'. Industries which are not research intensive and have an R&D intensity in the range 3%–0.9% and below 0.9% are classed as 'medium-low tech' and 'low tech', respectively.

Over the last two decades, Vietnam's share of high- and medium-high technology products has increased considerably. Electronics has had the most prominent expansion, followed by chemicals, non-metallic products and transport equipment. The increasing footprint of the high- and medium-high-tech sectors has been compensated by the decreasing labour share of the low-tech sector. Employment in the low-tech sector decreased from 65% in 2001 to 59% in 2019, although the sector remains the biggest employer in manufacturing (see Figure 33).[22]

A structural improvement in manufacturing is also seen in the increasing share of high- and medium-high-tech exports. In 2001, Vietnam registered a lower share of high-tech sector exports than most of the country's peers. By 2019, however, it had surpassed countries such as Indonesia and India in its proportion of high-tech sector exports and is now on track to catch up with China.

The structural improvements in the manufacturing sector are in line with the country's strategy to build horizontal and vertical links among industries (i.e. Decision No. 879/QD-TTg).[56] This strategy focused on the development of supporting industries, especially those producing mechanical, chemical, electronic and telecommunications goods, to serve industrial production and increase Vietnam's contribution to global value chains.

The four manufacturing sub-sectors also show notable diversification in both the magnitude and source of output per worker growth between 2015 and 2019 (see Figure 34).

The high-tech sector had the highest output per worker among the four groups (124.6 million VND, compared to 108.3 million VND in the medium-high tech sector, 85.8 million VND in the medium-low tech sector and 71.1 million VND in the low-tech sector). The high-tech sector also led in the average output per worker growth rate, reaching 7.50% in the 2015–2019 period. This growth rate was comprised mainly from: (i) the intense investment in capital resulting in a higher capital over labour ratio, and (ii) the ability of frontier firms to lift the potential technology frontier of the sector.

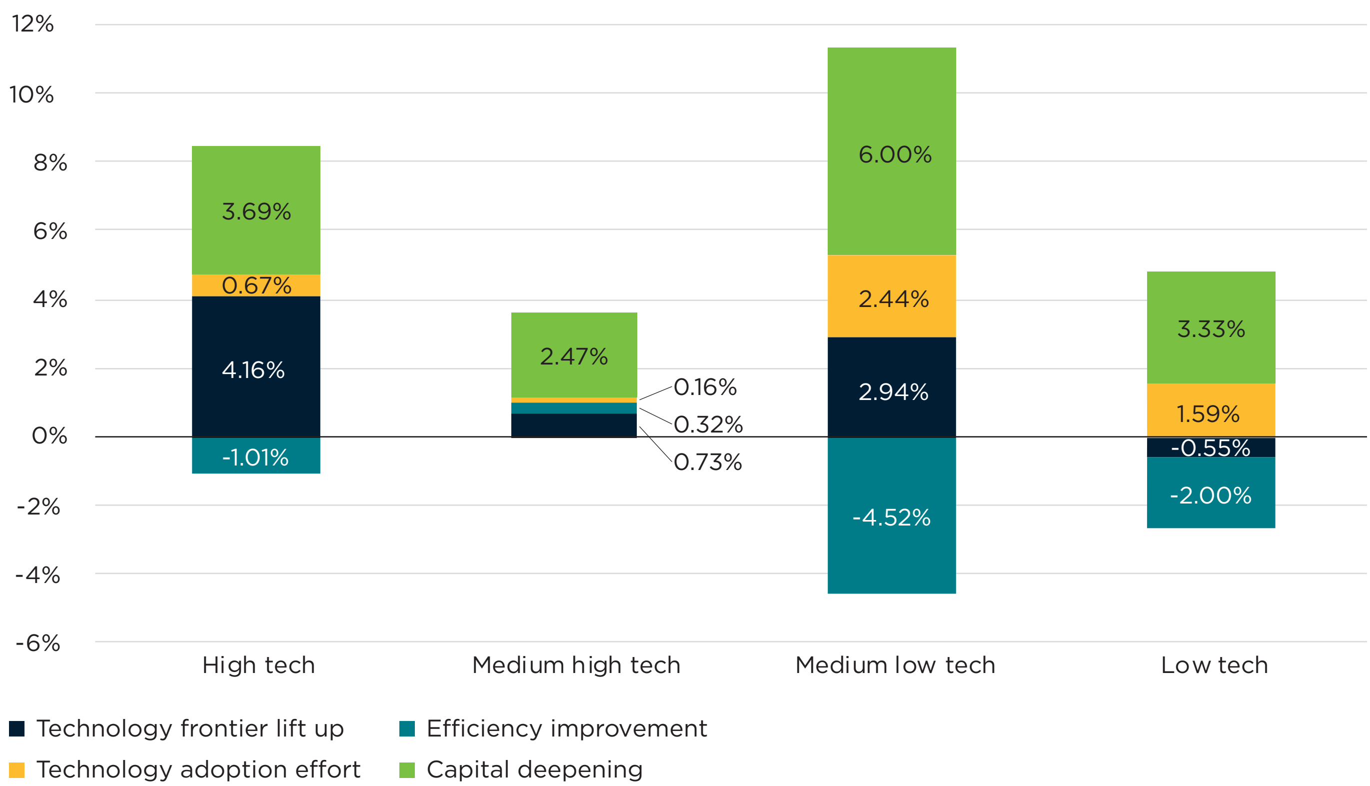


Figure 34. Average output per worker growth decomposition across manufacturing sector groups between 2015 and 2019

Source: Authors' calculation based on the GSO business survey[22]

Firms in the high-tech sector benefitted the most from investing in leading technologies to lift up the technology frontier, which contributed 4.16% out of 7.5% output per worker growth. Investment in technology adoption effort of the sector contributed 0.67% to the output per worker growth of the high-tech manufacturing sector. However, firms in the sector were not able to increase their efficiency to keep up with the change in technology, which resulted in a negative 1.01% contribution to potential output per worker growth.

The medium-high tech sector not only had the second lowest output per worker growth (3.69%) but also relied on increasing capital intensity for growth. Although efforts of leading firms in deploying technologies to lift up the technology frontier of the sector played an important role in productivity improvement, the limited technical efficiency improvement resulted in the limited contribution of TFP to total output per worker growth of the sector. The contribution of TFP or technology and efficiency improvement only comprised 20% of total output per worker growth. Medium-high tech industries mainly include machinery, equipment, chemical (excluding pharmaceutical) and motor vehicle manufacturers.

In recent years, the Vietnamese Government has actively developed domestic manufacturing, attracting many foreign businesses to invest in Vietnam and set up factories. Also, the increasing demand for domestic manufacturing has driven an increase in the general demand for machine tools. However, due to the low technical level of Vietnam's machine-tool industry, Vietnam has been relying on imports for over 70% of the machine tools used. According to the World Machine Tool survey by Gardner, in 2018 Vietnam was the 8th largest importer of machine tools in the world.[57] Increasing the local manufacturing rate of the Vietnamese machinery industry will be one of the keys to increasing Vietnam's footprint in global supply chains.

The medium-low tech sector, though having higher average output per worker growth, compared to the medium-high tech sector (6.86% in the 2015–2019 period) and also depended on capital intensity for growth. These businesses include manufacturers that produce petroleum and coal products, polymer and rubber products, non-metallic minerals, metal products and furniture, and businesses that undertake waste collection and treatment activity. The major issue with the sector was the inability of businesses to keep up with technology-related investment. One possible reason was that businesses in this sector have failed to adjust their organisational and management structures, resulting in a significant potential loss in output per worker growth.

For all three sector groups mentioned above, the main contributor to output per worker growth, besides capital deepening, was the attempt to lift up the technology from leading firms in the sector.

The last manufacturing group, and also the largest group in terms of employment, is the low-tech sector. This sector includes light manufacturing such as food processing, textiles and garments, wood products, paper and printing. These businesses are an important source of employment in Vietnam due to their ability to quickly absorb a large pool of less-skilled workers from agriculture into industry. Although there has been a tendency to shift toward high- and medium-high tech sectors in Vietnam, the low-tech sector still comprises nearly 60% of total employment in manufacturing.

Efficiency improvement with quality management tools

The application of quality management tools has been the enabler for many SMEs in Vietnam. These tools have allowed SMEs to deploy technologies and innovation to remain competitive and grow in an increasing competitive market.

One successful story is Hantex – Nam Ha textile company. To enhance efficiency, reduce costs and improve sustainability, the company implemented an operational system that integrates international standards (i.e. ISO 9001, ISO 14000 and SA8000) together with various quality management tools (i.e. 5S, TPM, KPI and Kaizen). In 9 years of continuous implementation, the company's productivity has experienced annual growth of 12% per annum. Within six months of applying the Kaizen continuous improvement system, the error rate decreased from 8.8% to 8.1%, and inventory on assembly line declined by 25%. The company's productivity also more than doubled from 415 to 899 products per day.

Hantex is now ranked one of the three leading spinning companies in Vietnam in the VNR500 ranking. The company has also received the silver award for national quality in 6 consecutive years.

The low-tech sector, however, had the lowest average output per worker (63.4 million VND) over the time period and also the lowest growth among the four technology groups. The average growth rate for this sector was 2.37% for the 2015–2019 period, much lower than the average output per worker growth rate of the whole economy.

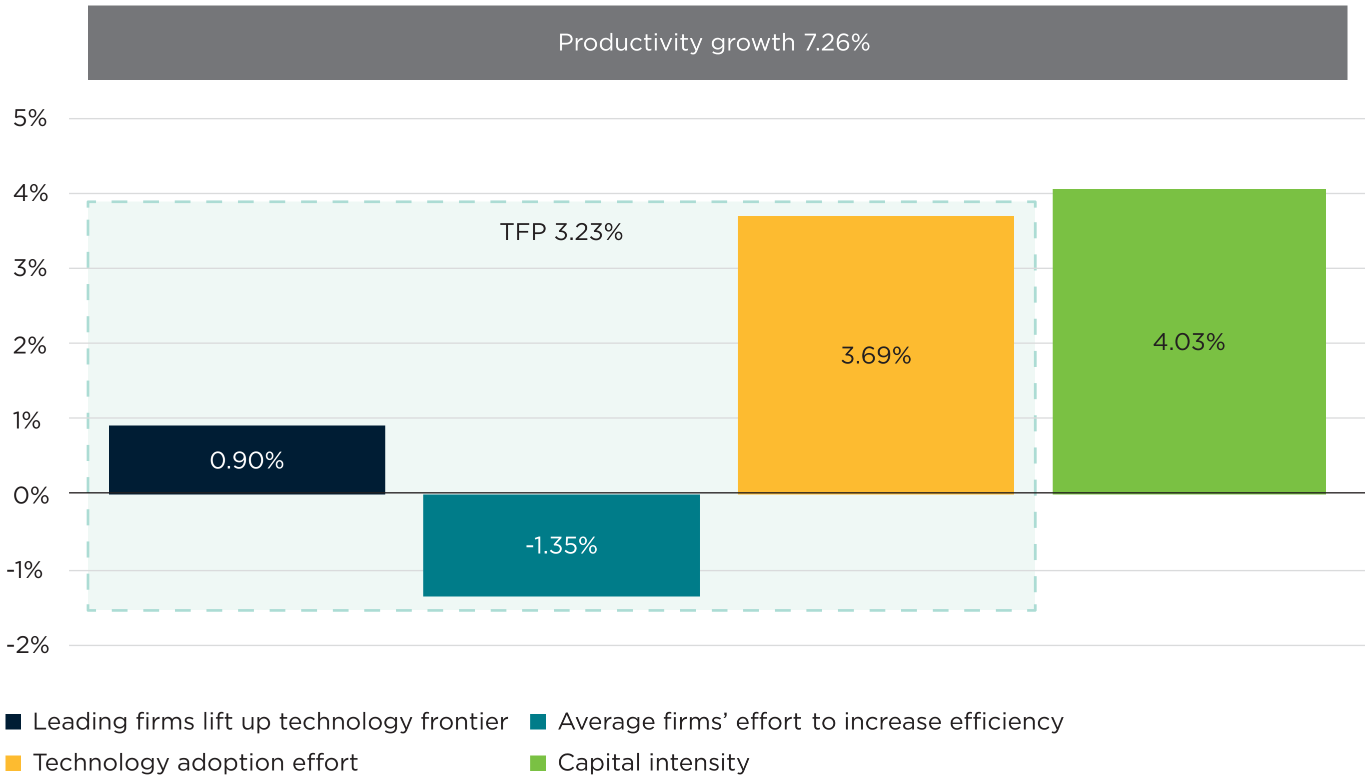
The source of growth for the sector is primarily capital deepening or the increasing capital-labour ratio within the sector. The main contributor to TFP growth in the sector is the increasing investment in technology adoption.

At the other end of the spectrum, Vietnam is home to some world-leading manufacturing businesses who are at the forefront of technology adoption. However, on the whole, advanced technology adoption is more the exception than the rule. Growth in the manufacturing sector mainly comes from sheer increases in the number of micro and small enterprises rather than from a growing number of medium and large firms. Each year, a great many enterprises disappear and as many or more enter the market. Turnover is high as few of these micro and small firms ever reach medium size, creating a 'missing middle' phenomenon that is common in developing countries. The problem with this pattern of growth is that these micro and small enterprises are engaged in low-productivity domestic production activities and have no access to modern technology and knowledge.

Another issue with the low-tech manufacturing sector is that there is a dualism in the sector in Vietnam, whereby low-productivity SMEs with low technology adoption capabilities co-exist with relatively high-productivity large-sized firms. In Vietnam, large, mainly FDI firms, rely on cheap and low-skilled labour, and imports of raw materials and intermediate goods, with few or no links to the domestic market. The domestic market remains dominated by numerous small enterprises using low productivity methods and often outdated technology to supply goods. This has limited the competition pressure and spillover benefits that can stimulate the innovation and growth of domestic producers, as well as help scale-up industrial capacity.

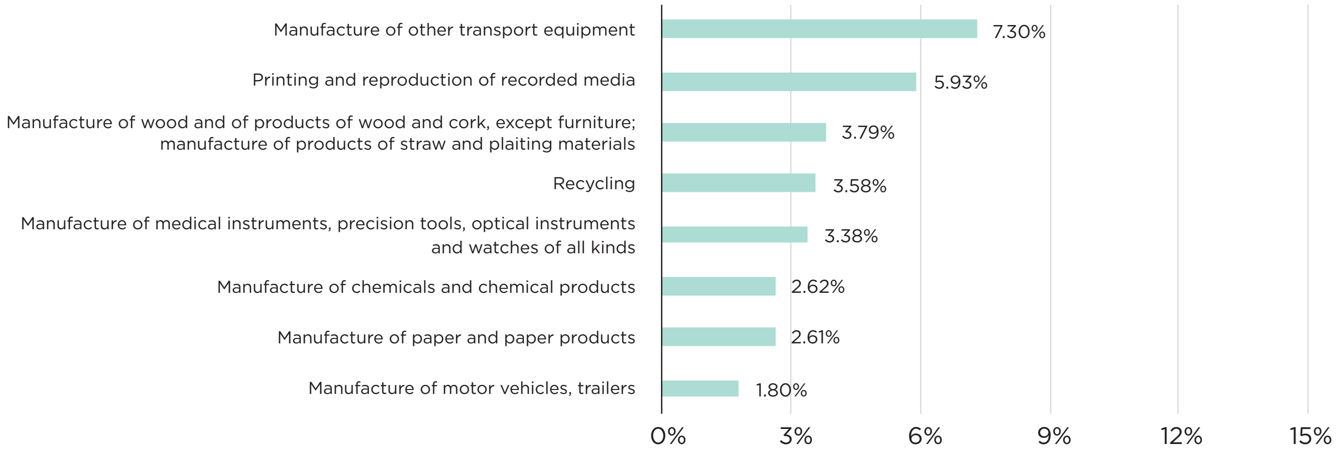
At the 2-digit level, the contribution of different components to output per worker growth also differed significantly across manufacturing sub-sectors. The figures below show the results of some key sub-sectors in manufacturing.

MANUFACTURING AT THE 2-DIGIT SECTOR LEVEL, 2015–2019

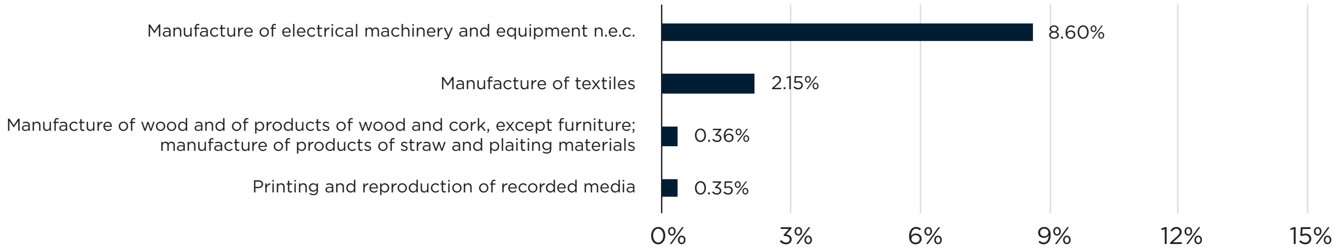


LEADING SUB-SECTORS

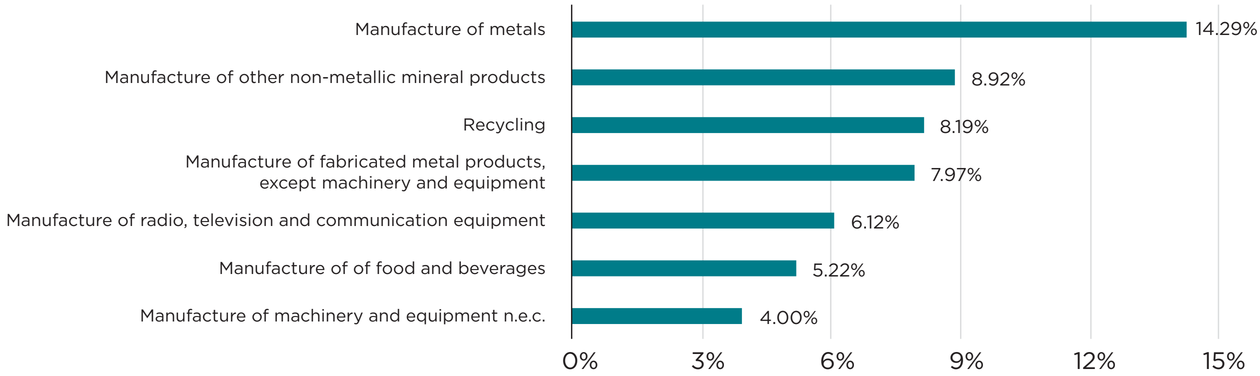
Components of leading firms lifting the technology frontier



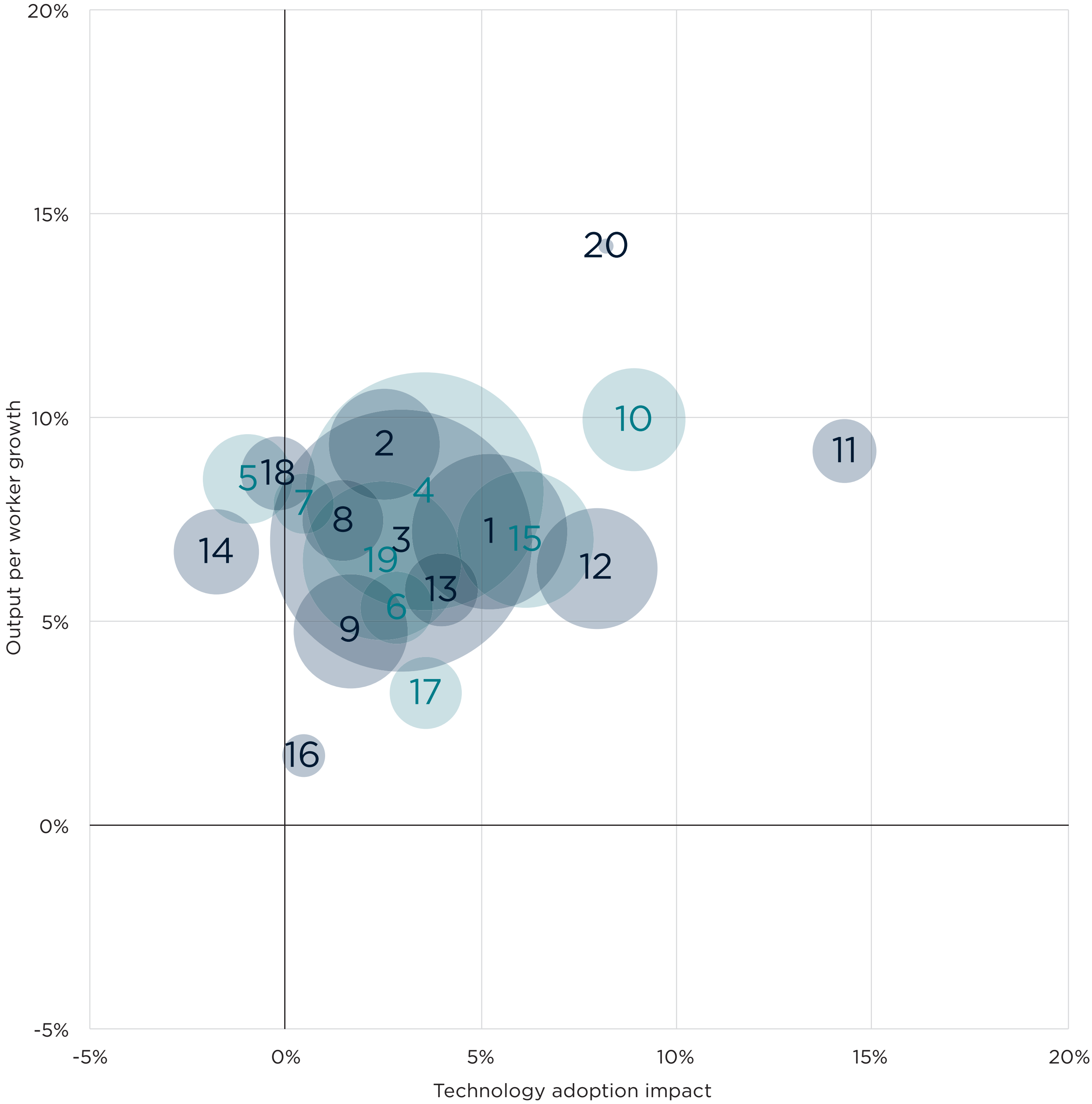
Components of average firms' effort to increase efficiency



Component of technology adoption effort

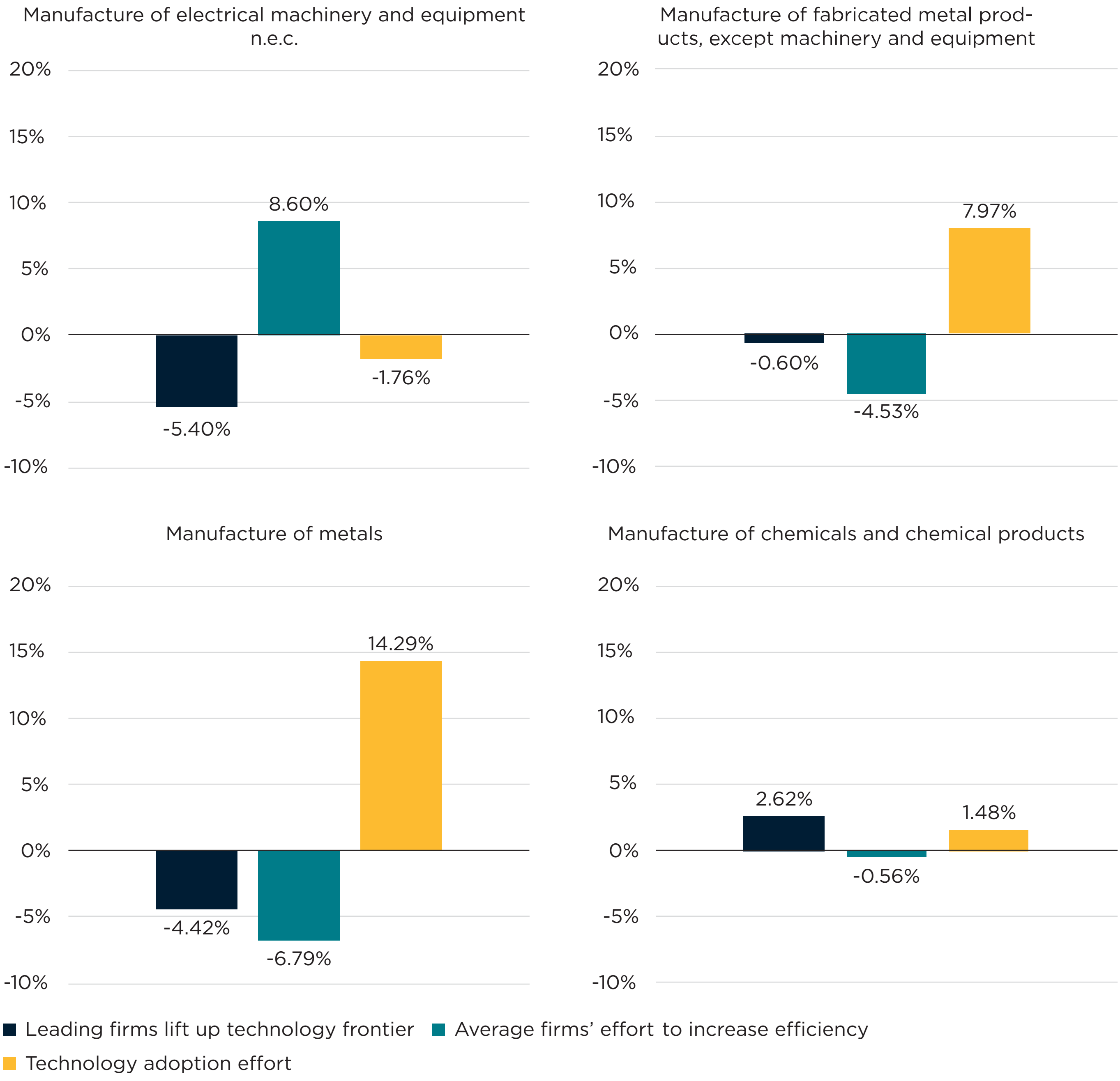


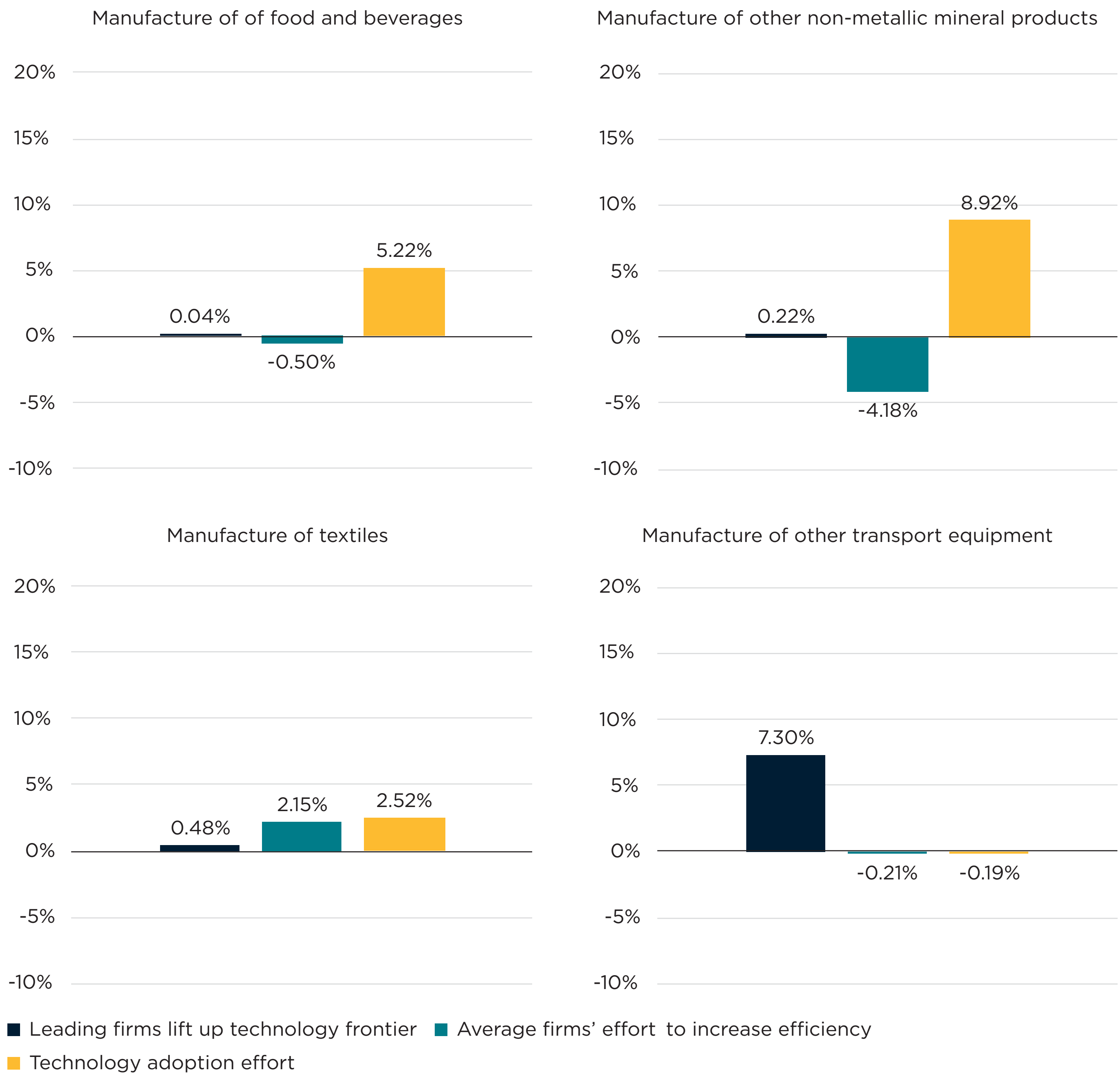
TFP GROWTH FOR SUB-SECTORS IN MANUFACTURING



1. Manufacture of of food and beverages
2. Manufacture of textiles
3. Manufacture of wearing apparel, tanning and dyeing of fur
4. Tanning and dressing of leather; manufacture of luggage, handbags, saddlery
5. Manufacture of wood and of products of wood and cork, except furniture; manufacture of products of straw and plaiting materials
6. Manufacture of paper and paper products
7. Printing and reproduction of recorded media
8. Manufacture of chemicals and chemical products
9. Manufacture of rubber and plastics products
10. Manufacture of other non-metallic mineral products
11. Manufacture of metals
12. Manufacture of fabricated metal products, except machinery and equipment
13. Manufacture of machinery and equipment n.e.c.
14. Manufacture of electrical machinery and equipment n.e.c.
15. Manufacture of radio, television and communication equipment
16. Manufacture of medical instruments, precision tools, optical instruments and watches of all kinds
17. Manufacture of motor vehicles, trailers
18. Manufacture of other transport equipment
19. Manufacture of beds, wardrobes, tables, chairs; Manufacture of other products n.e.c.
20. Recycling

SUB-SECTORS ACHIEVED HIGH TFP GROWTH THROUGH TECHNOLOGY ADOPTION AND EFFICIENCY ENHANCEMENT





In this project, we provided the analysis for all 2-digit sectors in Vietnam (using VSIC 1993 sector classification). Sample of the analysis for one sector is presented on the following pages. Detailed analysis for all 2-digit industries can be found in the online Appendix.

SECTOR 29: UNCLASSIFIED MACHINES AND DEVICES

For this sector, besides capital deepening, technology adoption effort is the main driver of TFP and a significant contributor to overall output per worker growth.

Over the period 2015–2019, the sector had an average output per worker growth of 5.8% (see Figure 2). The level of output per worker of the sector was 98.04mil. VND (constant 2010 price), which was 98.67% higher than the average level of the economy.

Figure 3 shows change in the industry-wide average production level relative to the industry's frontier (the production level groups of most efficient firms in the industry) as well as the movement of the frontier itself of the industry in the last five years.

Output per worker growth	5.8%
Technology frontier lift up	0.7%
Technology adoption effort	4.0%
Efficiency improvement	-2.9%
Capital deepening	4.0%

Over the last two decades, total labour employed in the sector has increased by 97.26%. On the other hand, the proportion of labour engaged in Unclassified machines and devices over total labour of the economy decreased from 1.15% to 0.9%.

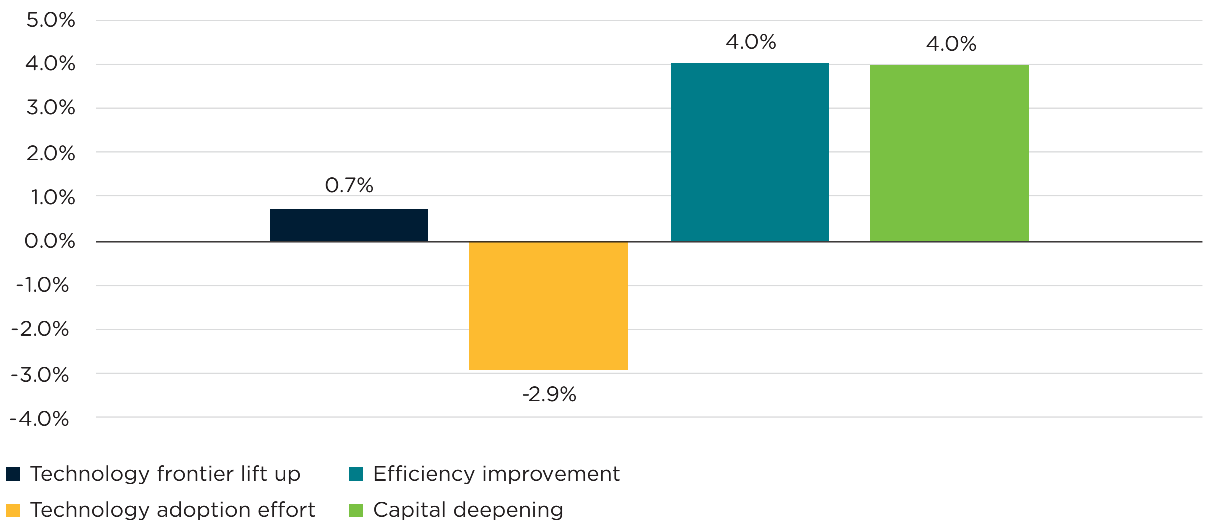


Figure 1. Output per worker decomposition 2015–2019

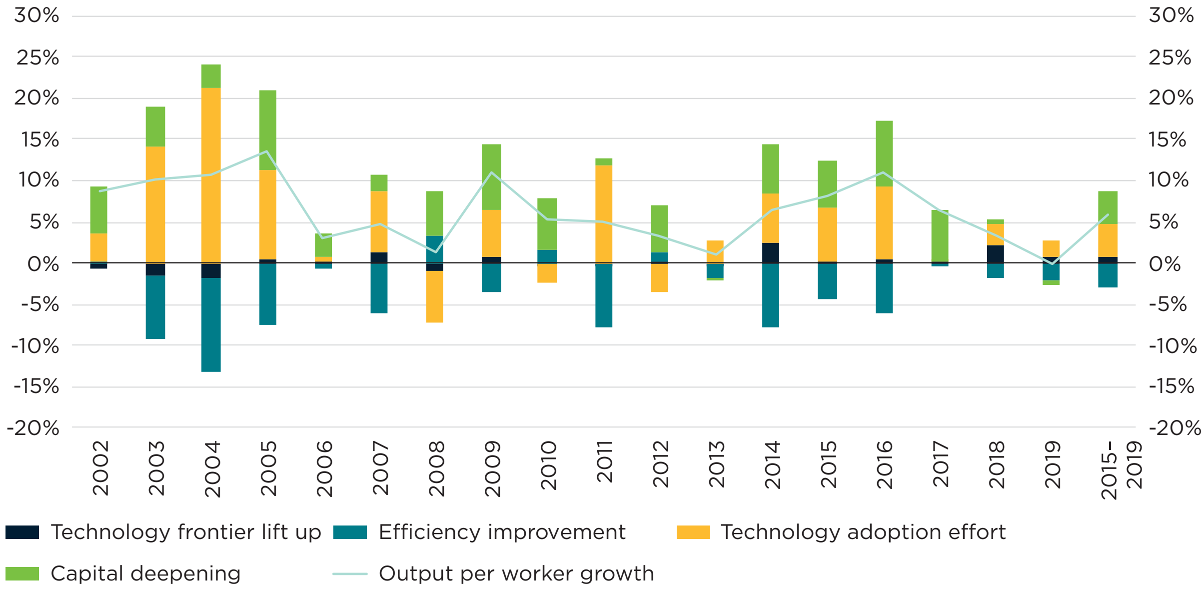


Figure 2. Output per worker decomposition 2002–2019

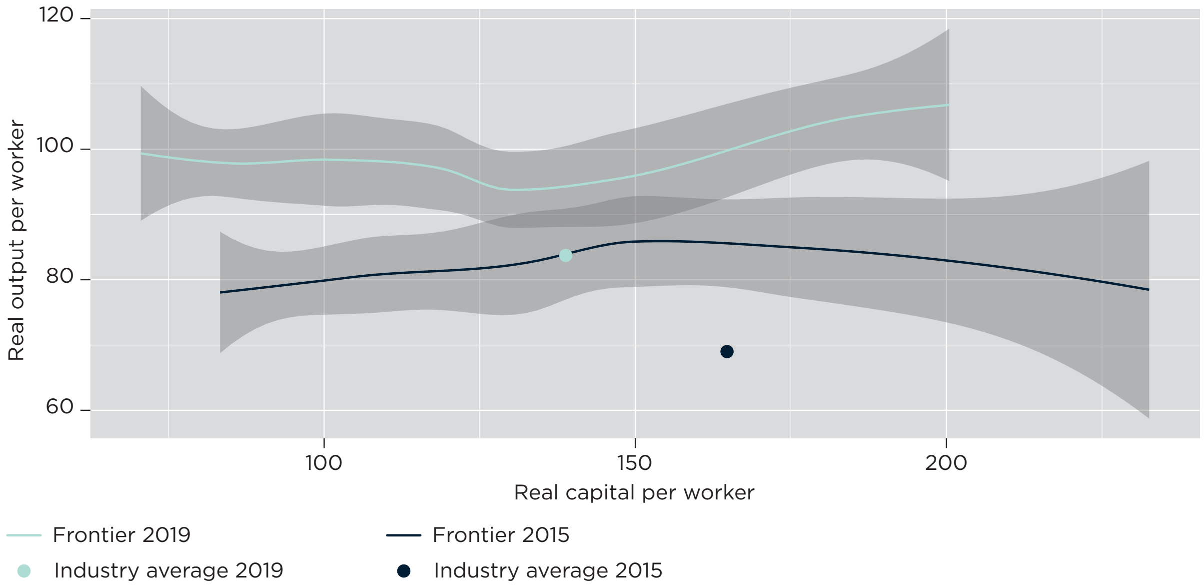


Figure 3. Conditional frontier for the sector 2015–2019

Figure 4. Labour share of unclassified machines and devices sector in the Vietnamese labour force, 2002–2019

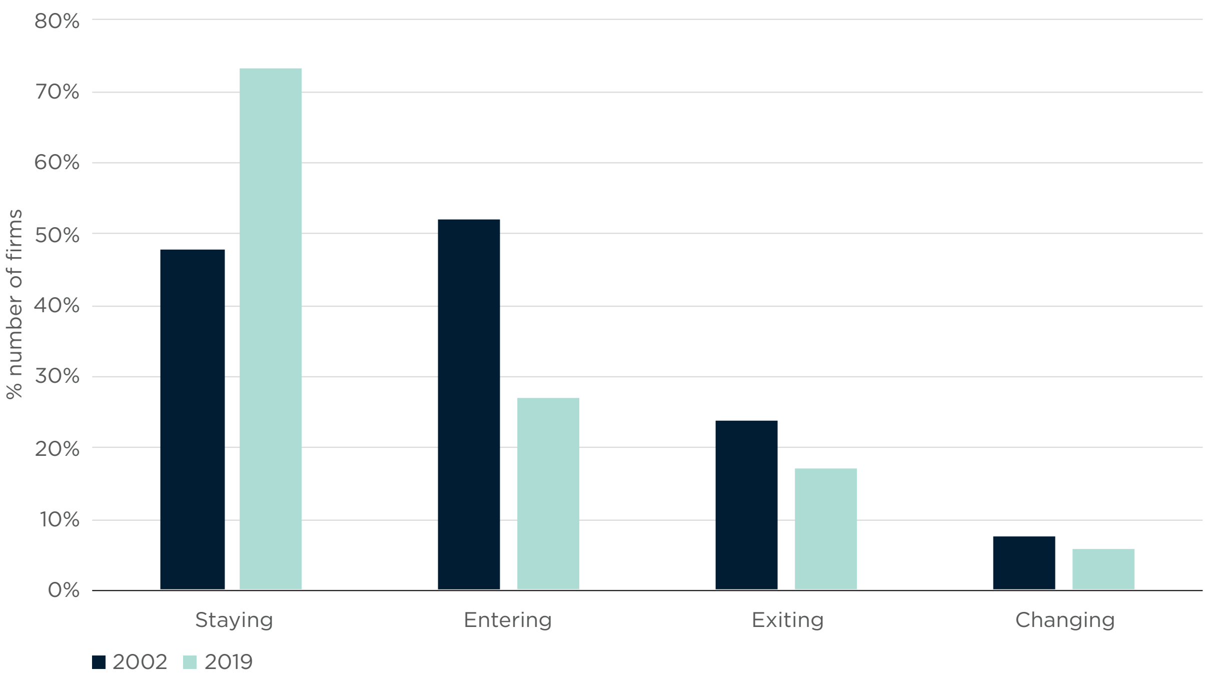


Figure 5. Firm dynamics for unclassified machines and devices in 2002 and 2019

Figure 4 shows that the number of firms in unclassified machines and devices has increased 12 times. In 2019, the net entry was 10% with the entry rate being 27% and the exit rate being 17%. The proportion of exit and changing firms is calculated over total number of firms in the previous year while the proportions of staying and entering firms are calculated over total number of firms in that year (2019).

The maps below show the distribution of technology adoption effort of businesses across different provinces of Vietnam over time. The technology adoption effort is measured by the business investment per worker in technology-related activities such as buying machine/equipment, training, buying intangible assets like patents, trademarks, etc. As can be seen from the maps, there has been significant dynamic in technology investment intensity across regions/provinces in the sector over the analysed period.

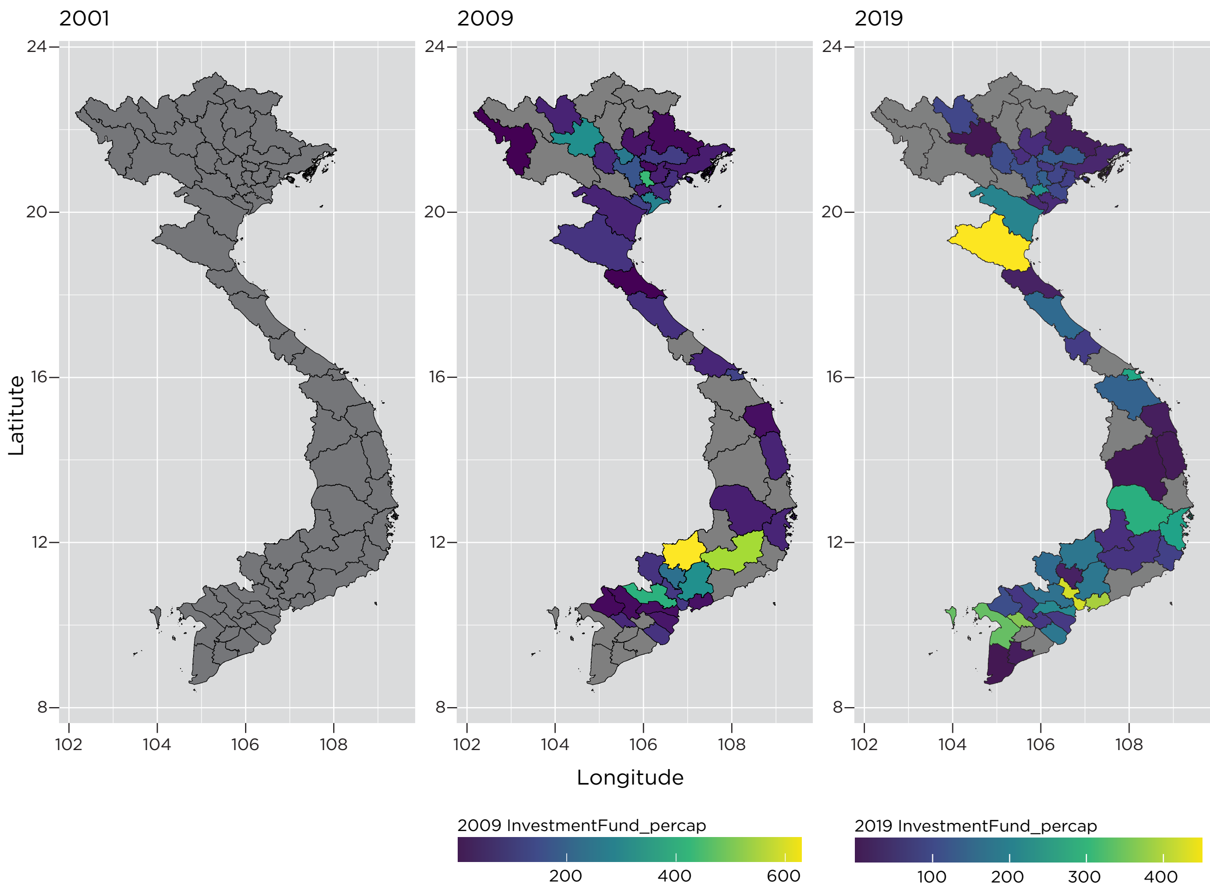


Figure 6. Per worker investment in technology adoption across regions in 2001, 2009 and 2019

CONTRIBUTIONS TO OUTPUT PER WORKER GROWTH, THE DIFFERENCE BETWEEN FDI AND PRIVATE FIRMS

FDI firms

There is no doubt that FDI is an important source of growth in Vietnam. In 2019 the FDI sector accounted for 23% of the country's social capital investment (up from 18% in 2000), 13.5% of government revenue and created 4.7 million jobs for Vietnamese workers. Exports, however, are the most significant contribution FDI businesses make in Vietnam. In 2019 FDI businesses accounted for 68% of total export turnover and 57.1% of import turnover. FDI contributed to 100% of telecommunications equipment exports, 95% of computer exports, 89% of machinery and equipment exports, 79% of footwear exports and 60% of apparel exports.[58]

Overall, FDI firms have a higher output per worker compared to private firms. There was, however, a period of stagnancy of output per worker growth among foreign firms in Vietnam in the early 2000s (see Figure 35). In 2002, the real output per worker within FDI firms was nearly double that of private firms, however, the gap decreased significantly to around just 20% in 2009.

The stagnancy in FDI output per worker growth also partly explains the low growth in manufacturing productivity, especially in the low-tech sector, in recent years given the dominance of FDI firms in the sector.[***] FDI in Vietnam is concentrated in the manufacturing sector, accounting for more than 70% of total FDI into Vietnam (as of December 2009) – the largest proportion of FDI in manufacturing in ASEAN followed by Indonesia and the Philippines.

There was, however, an improvement in the performance of FDI businesses in recent years.

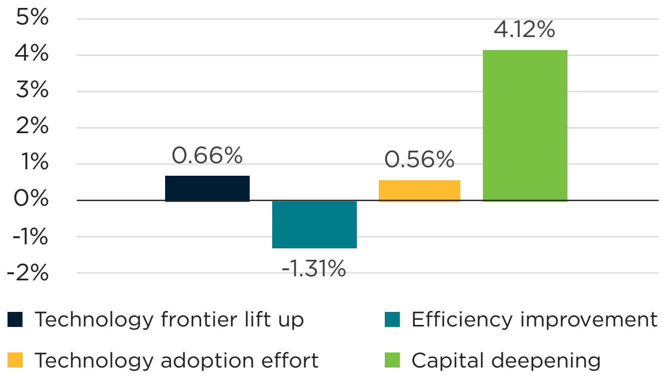


Figure 36. Output per worker growth decomposition among FDI firms in 2015-2019

Source: Authors' calculation based on the GSO business survey[22]

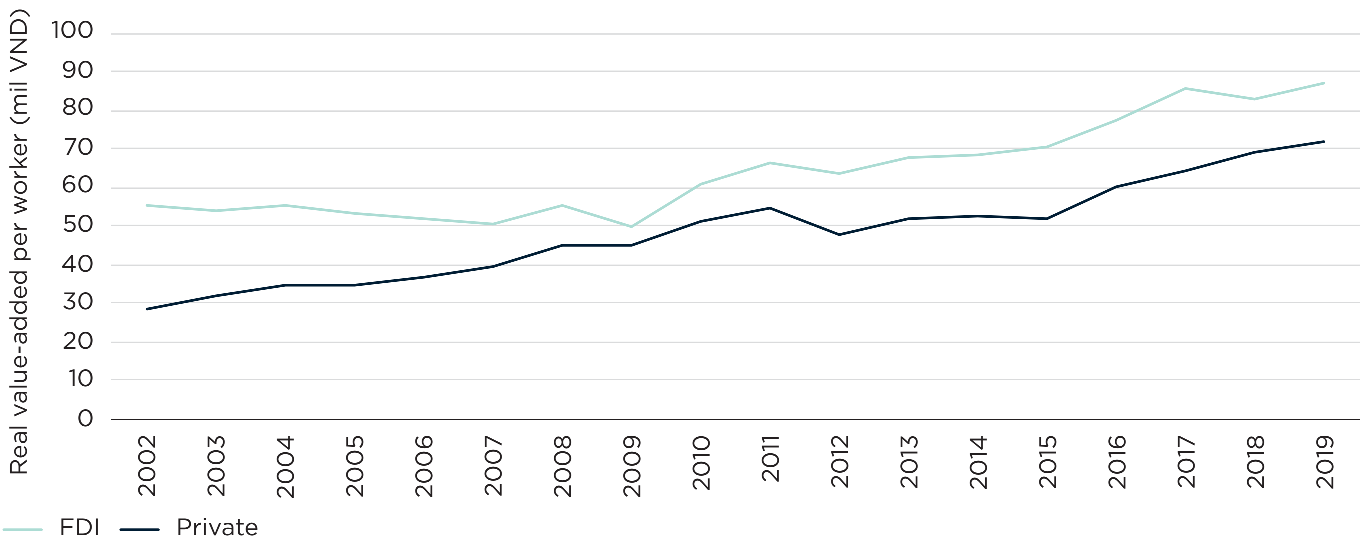


Figure 35. Output per worker of FDI and private firms between 2002 and 2019

Source: Authors' calculation based on the GSO business survey[22]

*** The output shares of FDI firms is 82.4% in footwear and 72% in textiles.

In the 2015–2019 period the average output per worker growth rate of FDI businesses was 4.03% – a growth rate close to the average level of the economy (see Figure 36). In recent years, FDI flows have also tended to diversify for different FDI sectors. Other notable FDI sectors aside from manufacturing include construction, wholesale, transport, mining, education and information technology.

The majority of FDI flows were concentrated in export-oriented, labour-intensive sectors such as garments, textiles and food processing. Moreover, many of the sectors only engaged in the low value-added activities of the supply chain in Vietnam. These include assembly or other simple production processes, rather than executing upstream or downstream processes that contribute to greater value creation.

Figure 37. Output per worker growth decomposition in FDI and private businesses between 2003 and 2019

Source: Authors' calculation based on the GSO business survey[22]

Interestingly, besides capital deepening, the efforts of leading firms to lift the technology frontier has been the main source of growth for FDI firms. Over the last decade Vietnam has attracted investment from world-leading multinational corporations like Apple, Samsung and Foxconn, among others. These companies have begun to see Vietnam as a viable destination to expand their R&D activities.

In 2017 Samsung launched a second R&D centre – the Samsung Ho Chi Minh Research & Development Centre (SHRD) and Executive Briefing Centre (EBC) – located at the Saigon Hi-tech Park (SHTP). In 2020 Samsung announced they would build the largest R&D centre in Southeast Asia in Tay Ho Tay New Town, Hanoi. LG electronics, Bosch Vietnam and Intel have also announced the establishment of various R&D centres/offices across Vietnam.

There is concern, however, about the strength of links between FDI firms and the rest of the economy. FDI links with domestic firms are particularly weak in high-tech manufacturing (such as electronics and motor vehicles). In this sector most FDI firms focus mainly on assembling (imported) components and packaging final products for export (electronics) or the local market (motor vehicles). FDI in resource-based industries tended to have higher links with domestic firms (backward links in basic metals and chemicals were 96% and 62%, respectively).[59] Weak links between FDI and domestic firms may also be signs of the limited integration of Vietnam's industry with global value chains through FDI channels.

Private firms

Together with FDI, the private sector has been a key contributor to Vietnam's economic growth in recent years. In 2019, the private sector accounted for 42.7% of total GDP, and 15.4% of the state budget. Importantly, women contributed significantly to the growth of the private sector. In 2016, around 25% of private firms in Vietnam were owned or led by women, as compared to the average of 8% in South Asia.[60]

The private sector also enjoys a considerable output per worker growth rate. In the 2015–2019 period, the average annual growth of private businesses was 6.2% (higher than their FDI peers).

Private firms are also found to operate more efficiently than public sector firms. The results of our modelling show that across all sectors, FDI firms operated significantly below the optimal level, compared to private firms (see Figure 38 for 2019 data). The Investment Capital Output Ratio (ICOR) statistics also show that private firms are more efficient at utilising capital and resources compared to FDI firms.

Though our model results show that private firms are more efficient than others, it seems resources have not been allocated to private firms to assist in technology adoption. In absolute values, while the capital stock of the private sector has increased significantly, the proportion of capital stock of private firms has remained relatively unchanged.

There is also evidence of an improvement in the performance of larger private firms. Consolidated data from the top 100 private companies on the stock market in Vietnam show that revenue per worker and profit per worker of these firms grew steadily over the last 10 years. The number of private firms in the top 500 largest Vietnamese enterprise list (VNR500) increased by 2.5 times over the last 10 years, comprising half of the total list.[61] In 2020, five out of the 10 largest listed companies were private enterprises (Vingroup, Vinhomes, Hoa Phat, Techcombank and VPBank). Of the top 1,000 enterprises with the highest payments of corporate income tax to the state budget in 2017, domestic private sector enterprises accounted for 45.8% in terms of number of enterprises (40.4% for FDI firms).[61]

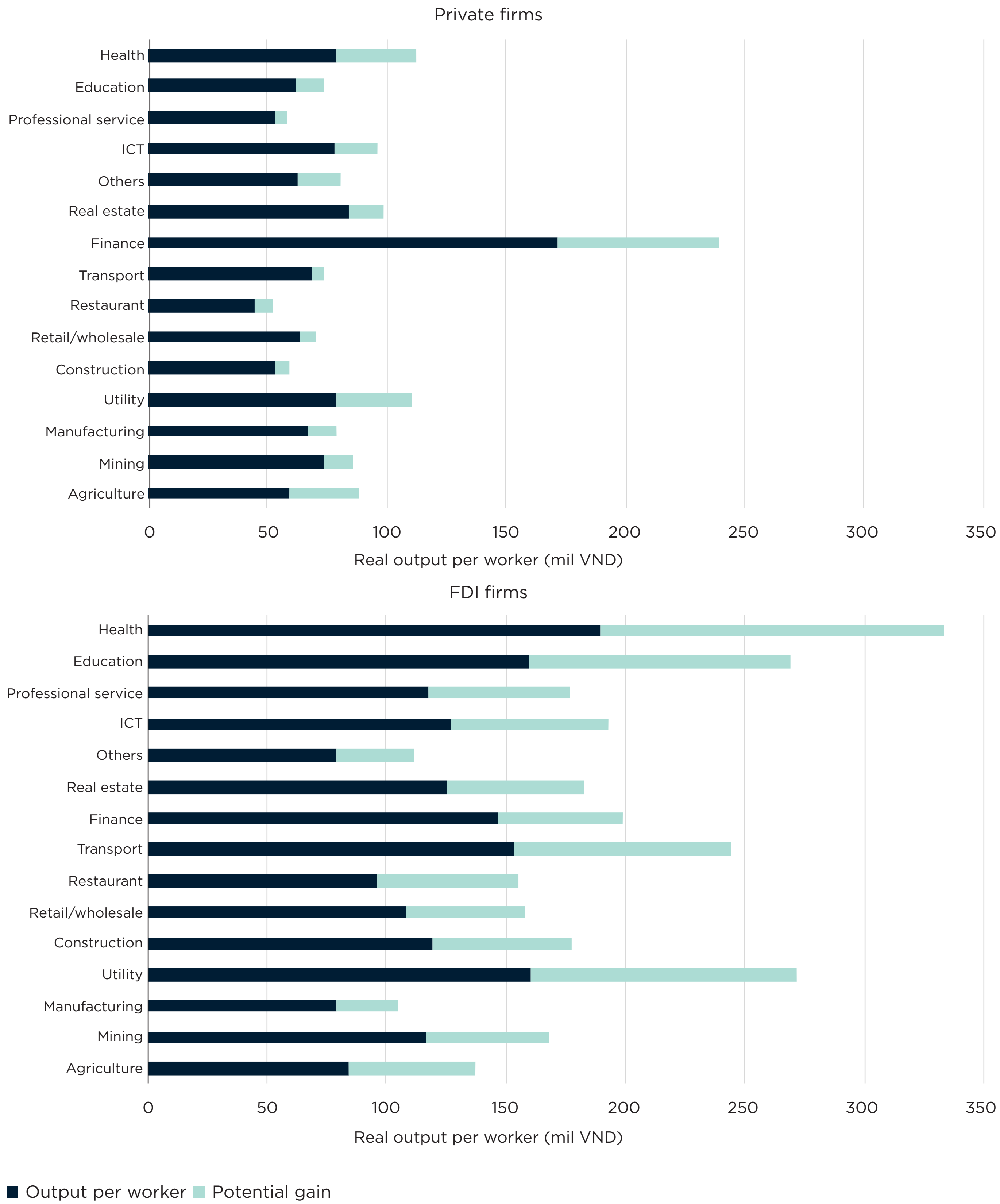


Figure 38. Potential gains if firms operated at the optimal level in 2019

Source: Authors' calculation based on the GSO business survey[22]

Not only did large firms improve their performance, private-sector giants played a leading role that helped drive the growth of a whole sector or a whole supply chain. Thousands of small businesses have benefitted from the forward and backward links with such leading private companies. These include companies such as TH, VinGroup, Hoa Phat and Vinamilk.

In the last 5 years the main source of output per worker growth for the private sector besides capital deepening was technology adoption improvement. The stagnancy in technical efficiency improvement is the main reason for the limited contribution of TFP to growth amongst private firms (see Figure 39). At the same time, the share of domestic businesses contributing to exports has plummeted in recent years (decreasing from 45.8% in 2010 to 32% in 2019), causing the economy to depend heavily on exports generated by foreign firms.[63]

The 'missing middle' (i.e. the absence of medium-sized enterprises), is another area of concern. In 2019, 98% of private firms were micro and small. Large and medium-sized enterprises accounted for only 1.2% and 0.8% of the total number of firms in Vietnam.[64] The dominance of small firms has deterred the abilities of private firms to take advantage of economies of scale, specialisations, new and emerging technologies and innovation. The underrepresentation of medium-sized firms also limits their ability to access modern technology and business know-how. Thus, medium-sized firms have had to develop their comparative advantages by increasing efficiency and driving down their costs rather than by increasing their levels of knowledge, technology and innovation.

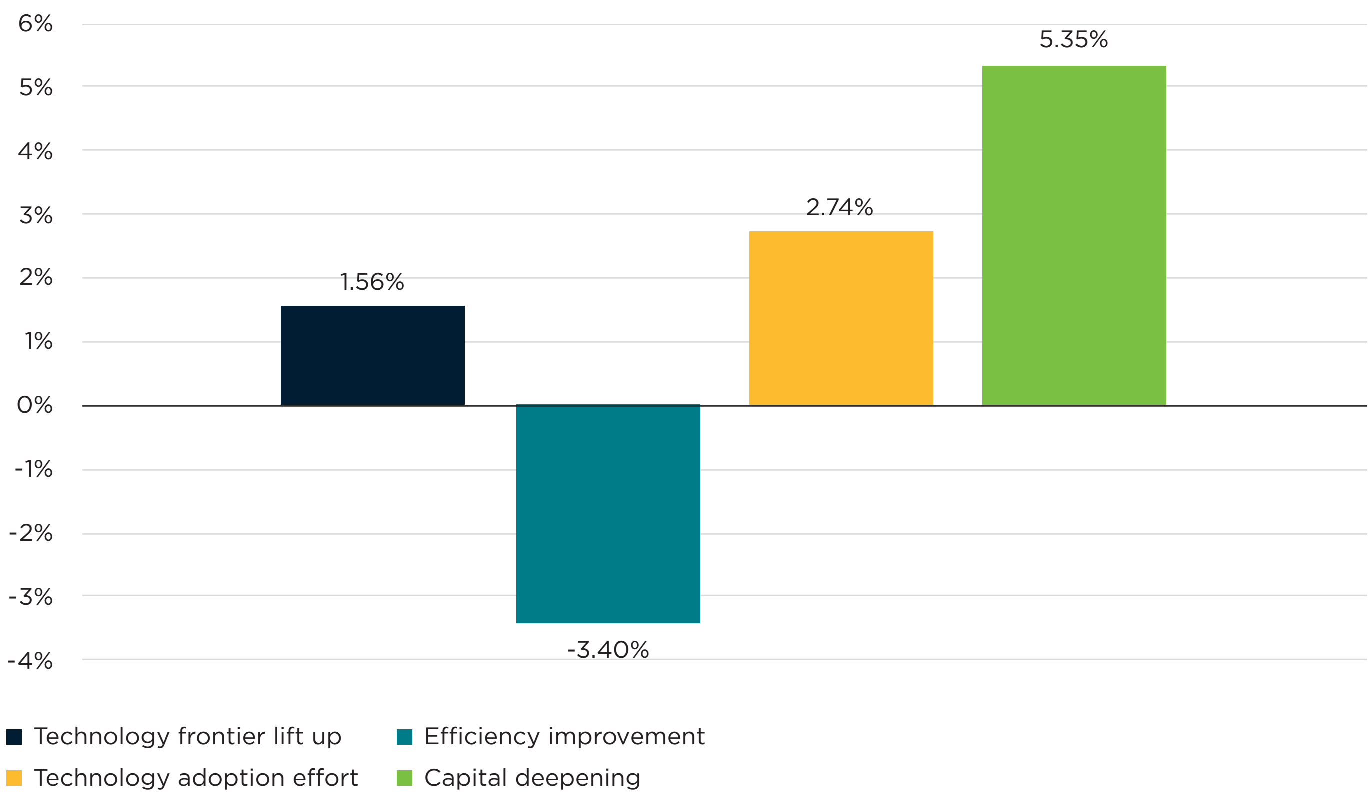


Figure 39. Output per worker growth decomposition among private firms in 2015-2019

Source: Authors' calculation based on the GSO business survey[22]

Smart manufacturing model in VinFast's high-tech vehicle manufacturing complex

VinFast's auto factory was officially opened on June 14, 2018. It only took 21 months to complete a state-of-the-art, modern car and motorbike factory on 335 hectares of vacant land.

The advantage of the VinFast car factory is its use of automation technology, with a series of robots operating all aspects of vehicle construction – from production to the transportation of spare parts. VinFast's car production lines are connected to each other via cloud computing or through an internal network connection. Information on the production process is constantly updated, stored and analysed. These data provide an important input for the R&D of new product lines with new designs, materials and production processes to suit a wide range of customer needs. The application of 4.0 technology in the factory is supported by a range of systems for data collection and management, business planning, product lifecycle management and production management. These systems were developed by two leading global technology firms: Siemens and SAP.

The body welding workshop covers an area of 100,000 square meters and is said to be the most automated and modern car body welding factory in Vietnam. The car body welding factory applies Industry 4.0 technology in many different areas, from equipment monitoring to process evaluation and optimisation. The optimisation of equipment efficiency is also used to improve productivity and product quality. Industry 4.0 technology in the factory runs preventive crisis management and predictive maintenance for the digital production line to heighten flexibility when changing product lines.

VinFast's ambitious vision, which led to this factory opening, proves that the Vietnamese automaker believes in its success, is confident that the market will welcome Vietnamese-branded models, and is able to reach European and export quality standards through technology adoption.

4.2 THE IMPACT OF R&D INVESTMENT ON ECONOMIC GROWTH

This section investigates the effect of knowledge accumulation driven by R&D investment on the dynamics of economic growth.

THE IMPACT OF R&D INVESTMENT ON PREDICTED ECONOMIC GROWTH

In this section the conditional forecast is used to investigate the impact of R&D investment change on Vietnam's economy. We examine the impact over the 25-year period from 2021 to 2045. In particular, we forecast the real GDP of Vietnam by 2045 under the new assumption that the R&D expenditure growth rate of Vietnam increases one additional percentage point for each year to the steady state R&D growth rate in the whole 25-year period till 2045. The potential gain is calculated by subtracting the conditional forecast described above to the real GDP forecast under the business-as-usual case.

A note to the simulation exercise is that we have already included the impact of the COVID-19 pandemic in the simulation. In particular, in the model Vietnam's GDP growth rates for 2020 and 2021 are 2.9% and 6.0%, respectively.

Figure 40 presents the potential gain in terms of real GDP associated with a 1.0% increase in R&D growth in a year. Clearly, in the first 5 years, there is hardly any positive impact. This can be explained by a crowding-out effect whereby resources from production in businesses and government expenditure on other activities are redirected to R&D activities.

Initially, the GDP increase in the first year is mainly due to the increase in R&D expenditure that flows into higher incomes of researchers and skilled workers. From the second to third forecast years, the increase in R&D expenditure results in further negative impacts to real GDP. This is because in the short run there will be a reallocation of high-skilled workers from technology adoption to research activities and a decrease in the resources devoted to production, resulting in a decrease in social investments in production.

In the longer term, the modelling results confirm the long-term impact of an increase in R&D investment to the Vietnamese economy. R&D investment will result in the accumulation of inventions that are ready for adoption and production application. This results in an increase in productivity, and TFP in particular. The increasing number of unadopted technologies also stimulates an increase in adoption and thus production activities.

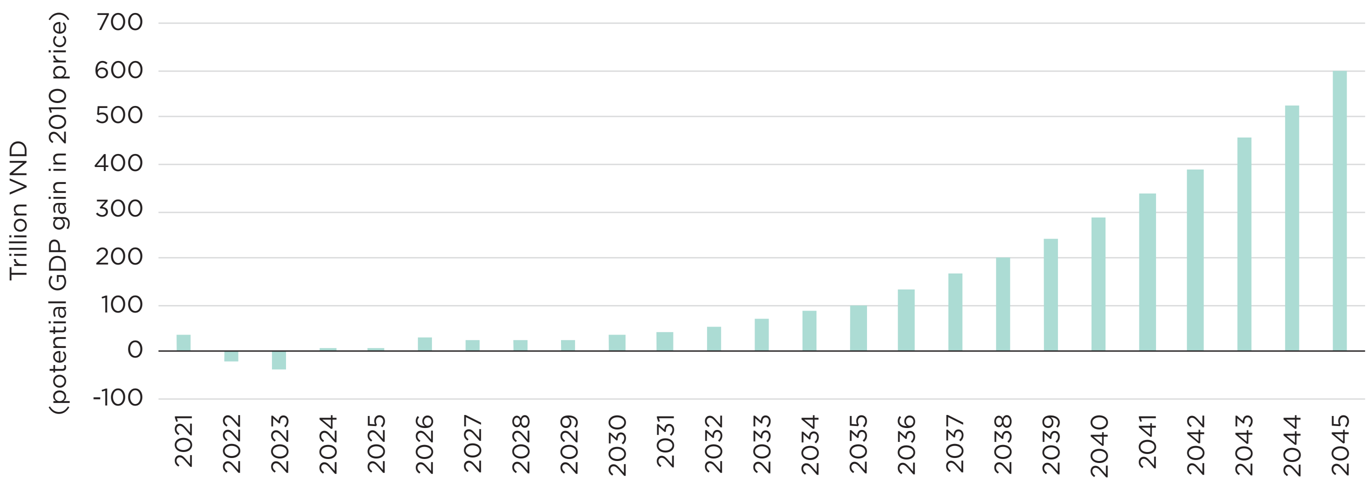


Figure 40. Potential gain in Vietnam's real GDP with 1% increase in R&D expenditure

Source: Authors' calculation based on the GSO business survey[22]

As can be seen from Figure 40, the impact of R&D investment is more apparent after 10 years of investment. By 2030, a 1.0% increase in the R&D expenditure growth rate can generate approximately 106 trillion VND to Vietnam's real GDP (at 2010 prices). This is approximately 1.0% of total GDP in 2030. However, by 2045, a 1.0% increase in R&D investment will result in around 600 trillion VND, or around 3.7% of total real GDP by 2045. That is because it takes time for R&D investments to turn into inventions. The adoption process whereby unadopted technologies need to be commercialised and applied in real production is also a lengthy process.

Beyond its putative direct value as an input into the provision of services, R&D expenditure may generate social benefits in the form of knowledge and training 'spillovers'. Several recent econometric studies, for example, document positive, statistically significant 'spillover' effects via the stimulation of technology adoption investments as well as improving the quality of human resources in the economy.[65]

THE IMPACT OF DIFFERENT GOVERNMENTAL POLICY SCENARIOS ON R&D INVESTMENT

In this section we apply the model for an analysis of two policy scenarios, which have the potential to result in different rates of R&D expenditure growth and which play a prominent role in the policy debate. We implement a number of policy simulations, by introducing exogenous shocks to the R&D growth variables. As the value of the R&D expenditure growth rate changes, we have both benefits (productivity increases leading to extra GDP per capita) and costs (extra R&D expenditure). The question is therefore whether the benefits are larger than the costs. Both depend on the size of the shock (i.e. the magnitude of the change in R&D investment growth) and the length of the period under consideration.

The two scenarios are summarised below.

- **Scenario 1**. In this scenario, we investigate the impact of R&D investment on Vietnam's economy following the growth path to meet the target set by MoST in the *Scheme on Mechanism to Attract Social Investment to Science, Technology and Innovation*, especially in the form of social enterprises. According to the decision, by 2030, social investment in R&D activities will comprise of 2% of total GDP.[†††] The increase in social investment will come both from the increase in public R&D investment (through policies such as an increase to R&D tax initiatives and the establishment of more R&D funds) and the promotion of R&D investment by the business community, with a strong emphasis on business community investment.

  Assuming Vietnam will attain a growth rate of 6% per annum in R&D investment in the next 20 years, for Vietnam to achieve the 2% target, the annual growth rate of R&D expenditure over the next 10 years (2021–2030) will need to be 22.43% per annum.

- **Scenario 2.** In this scenario we investigate the impact of R&D investment if Vietnam follows a development path similar to that of South Korea. South Korea is a typical example of 'catching-up' success through R&D investment intensity. In the 1980s and 1990s, facing increasing competition from developing countries with cheap labour production, South Korea shifted its focus to developing and adopting relatively more knowledge-intensive intermediate technologies across all industry sectors. As technologies at this stage were a lot more complex and difficult to acquire and adopt, South Korean firms increasingly intensified their own R&D activities. R&D investment rocketed from US$28.6 million in 1971 to US$4.7 billion by 1990, and to US$12.2 billion by 2000. The average annual growth rate in R&D expenditure per GDP in 1981–1991 in South Korea was 24.2% per annum.

  In this scenario, we simulate the impact of R&D expenditure to Vietnam's economy assuming that Vietnam follows a similar path to that of South Korea with an average R&D expenditure growth rate equal to 24.2% per annum over the next 10 years (to 2030).

In both scenarios, the additional benefit from the growth in R&D expenditure to the economy is calculated by the difference between the conditional forecast values of main macro indicators (real GDP, consumption and social investment in production) in the scenario and the forecast value of the business-as-usual case.

††† Currently, R&D expenditure comprises about 0.53% of total GDP.

Similar to the first simulation, the results of the two scenarios incorporate impacts of the COVID-19 pandemic. In particular, in the model, Vietnam's GDP growth rate for 2020 and 2021 are 2.9% and 6.0%, respectively.

Figure 41 and Figure 42 show the difference in the potential gains for Vietnam's economy under the two scenarios. In both scenarios the increase in R&D investment results in an increase to growth and the level of total social investment, consumption and GDP in Vietnam over the next 25 years.

If Vietnam is able to achieve the 2% target, by 2045 the GDP gain from the increased R&D investment will be 1,870.3 trillion VND, which is equal to approximately 11.7% of forecast total GDP for Vietnam (Table 2).

The increase in R&D expenditure also positively impacts consumption and investment, mainly due to the increase in incomes of skilled labourers and later to unskilled labourers as production grows in the economy. In particular, real consumption and investment gains from R&D investment comprise 20.2% and 11.0% of total real consumption and investment, respectively, by 2045 (Table 2).

As can be seen, the biggest impact will be the increase in real consumption (Figure 42), mainly through the increase of real incomes both from increases in real wage of skilled workers and increases in profits and returns to capital investment. This occurs once productivity (TFP) increases as a result of the increase in technology adoption in production processes.

The impact will be higher if Vietnam follows a similar path to that of South Korea. R&D investment is expected to contribute up to 15% of total forecast GDP by 2045. The potential gains in real consumption and investment are also higher at 25.4% and 15.0%, compared to 20.2% and 11.0% as obtained in the first scenario respectively (Table 2).

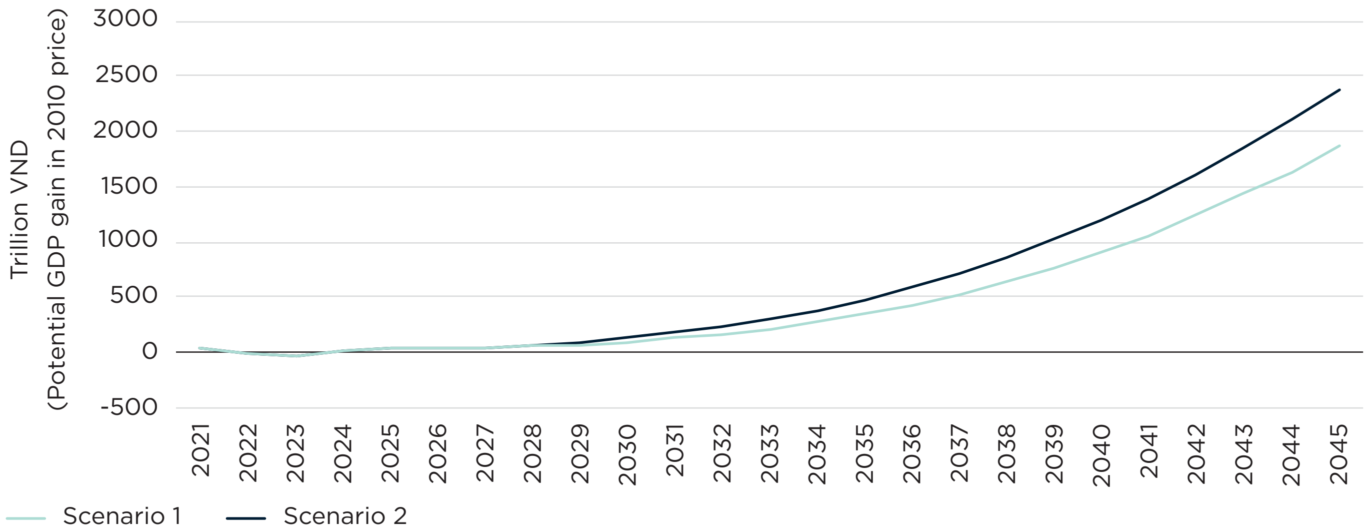


Figure 41. Potential GDP gain from R&D investment in two scenarios

Source: Authors' calculation based on DSGE model

Table 2. Conditional forecast on impacts of R&D investment on macro indicators across different scenarios

		2030			2045		
		REAL GDP	REAL CONSUMPTION	REAL INVESTMENT	REAL GDP	REAL CONSUMPTION	REAL INVESTMENT
SCENARIO 1	Real gain (tril VND)	92.58	177.56	-22.06	1,870.25	2,233.97	389.97
	%	1.4%	3.8%	-1.5%	11.7%	20.2%	11.0%
SCENARIO 2	Real gain (tril VND)	124.73	240.07	-29.57	2,381.80	2,793.98	529.40
	%	1.8%	5.1%	-2.0%	14.9%	25.4%	15.0%

Source: Authors' calculation based on DSGE model

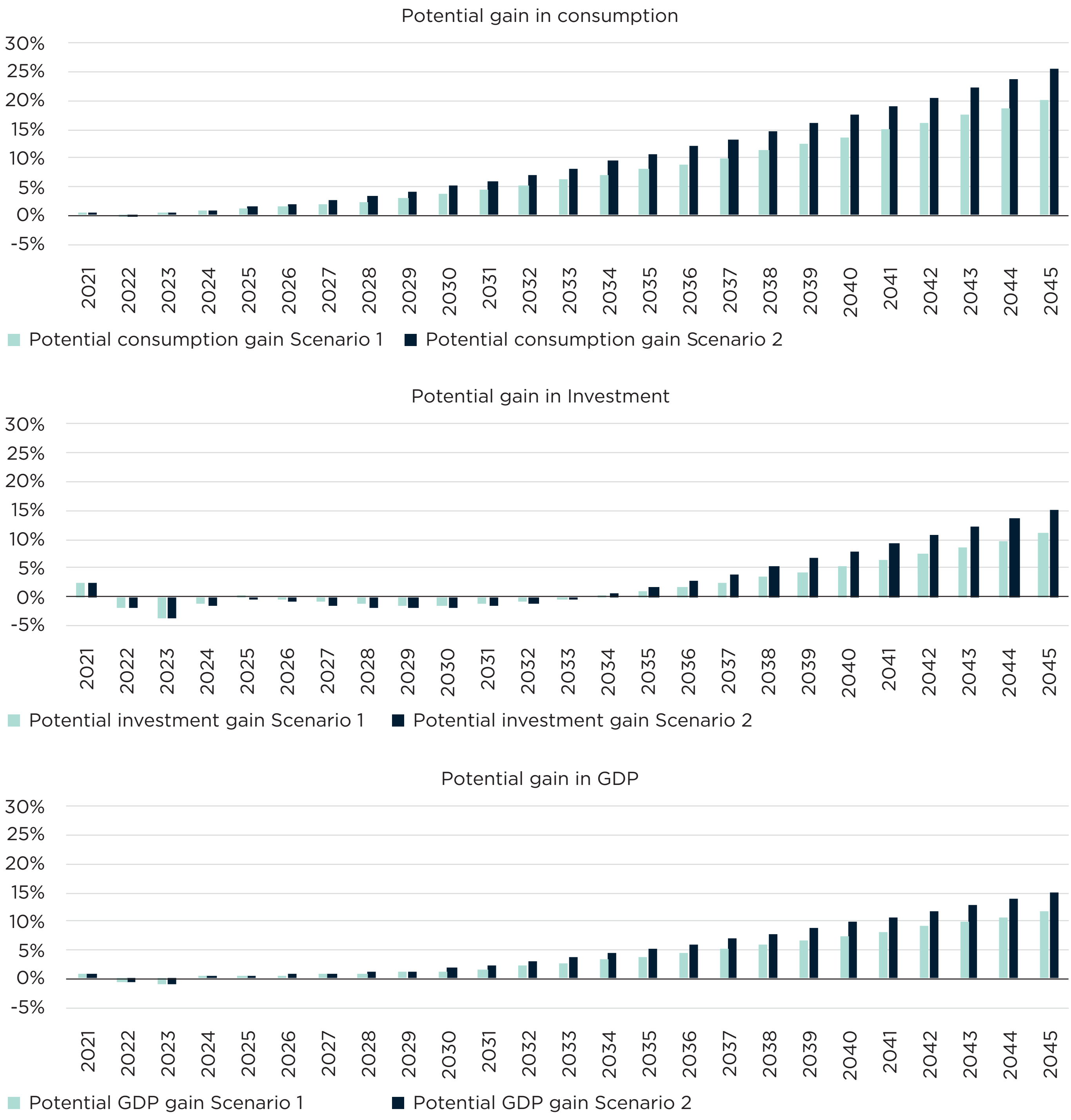


Figure 42. Gains from R&D investment as proportion of real consumption, investment and GDP in the two scenarios

Source: Authors' calculation based on DSGE model

Analysis on the channels of impact for an increase in R&D expenditure in the model

Immediate impact

An increase in R&D expenditure increases the value of, and demand for, skilled labour in the R&D sector. This results in diversion of skilled labour from the technology adoption sector towards the R&D sector, result in a simultaneous decrease in adoption expenditure. The initial reduction in adoption activities also lowers the supply and increases the costs of adopted technologies for firms in the intermediate goods sector, leading to a slow-down in investment expenditure in the economy.

National income initially grows faster than in the business-as-usual scenario (in year 1) due to increased income for skilled labourers and the increase in R&D expenditure, but dips slightly down below its steady state in year 2 due to the slow-down in both adoption and investment expenditure growth.

As the stock of unadopted technologies quickly accumulates, the rapid increase in the supply of unadopted technologies reduces the value (or equivalent price) of unadopted technologies. This has two effects: (i) as R&D activity becomes less profitable for innovators, demand for skilled labour in the R&D sector falls, bringing R&D expenditure down; and (ii) since adopters have to acquire unadopted technologies from innovators at market prices, the fall in the value of cost technologies increases the marginal return on skilled labour employed in the adoption process, thus increasing demand for skilled labour in the adoption sector. As skilled labour gradually returns to the adoption sector, adoption expenditure gradually reverts to and then overshoots steady state levels due to the persistent low prices of unadopted technologies and the large stock of unadopted technologies that remain from the initial spurt in R&D activity.

Medium to long-term impact

The subsequent increase in adoption activity eventually results in a greater supply of, and lower price for, adopted technologies available for firms to invest in. This, in turn, results in persistently higher levels of investment growth, at least until the stock of adopted technology returns to steady state values. The recovery of investment and adoption technologies, along with increased economic productivity from the greater adoption of new technologies, also results in persistently high economic growth rates relative to the steady state. This is also reflected in wage growth.

THE IMPACT OF IMPROVING R&D INVESTMENT EFFICIENCY (R&D PRODUCTIVITY) ON ECONOMIC GROWTH

The above simulation exercise examines the impact of different allocations of resources on the R&D sector. There is also another angle: improvement in R&D efficiency can result in positive economic outcomes. The increase in R&D efficiency can result in, for example, an improvement in the R&D workforce or an enhancement of links between research institutes. Many studies have identified human resources as the key constraint affecting R&D development in Vietnam. An improvement in both quality and quantity of skilled workers is expected to boost the R&D sector in Vietnam.[66]

To investigate this, we have used an impulse response. This exercise traces the response of macro indictors (i.e. consumption, investment, wages, capital accumulation) when we create a positive shock to R&D efficiency. When there is a positive shock to R&D productivity there will be a deviation to the long-run equilibrium. This deviation will lead to an adjustment to the dynamics in the short term. Given that the estimated model is stable, the economy will, over time, return to a new long-run equilibrium. These changes to the equilibrium are considered as the (causal) effects of the original shocks (i.e. as the economic effects of R&D).

As expected, as the R&D sector becomes more efficient there is a positive impact on real GDP as well as consumption and investment over the longer term. Different from the initial impact (i.e. an increase in R&D investment), the impact on real GDP due to increased efficiency seems to pick up much sooner, after approximately 20 quarters (i.e. 5 years, instead of 10 years as mentioned in the previous section) (see Figure 43).

There are still crowding-out effects on physical investment in the first 5 years as skilled workers will be attracted to a more efficient sector with higher wages: the R&D sector. This results in the reduction in both investment and capital accumulation in the short term. However, after five years the accumulation of unadopted inventions reduces the price of patents and stimulates entry to adoption activities and production. Output is gradually built up.

As can be seen, the improvement in R&D investment efficiency, in the long run, leads to an enhancement of R&D investment. This is because, for firms that do R&D efficiently, it is more profitable to invest in R&D. Increased R&D will result in a higher demand for skilled labour not only in R&D but also in the adoption sector as more unadopted technology is now available, making adoption more profitable as well. As such, there is an increase in wages for skilled labour and this affects the inflation rate.

It is interesting to note that despite the initial dip in national income and wage growth rates, the consumption growth rate increased steadily over steady-state values over the period of analysis. This is due to households correctly predicting that the initial increase in R&D efficiency will result in greater wage growth in the future. Households therefore are willing to increase consumption in the near term despite falling wages (in periods 1 to 6). They can do this, for example, by borrowing in anticipation of having larger incomes in the future.

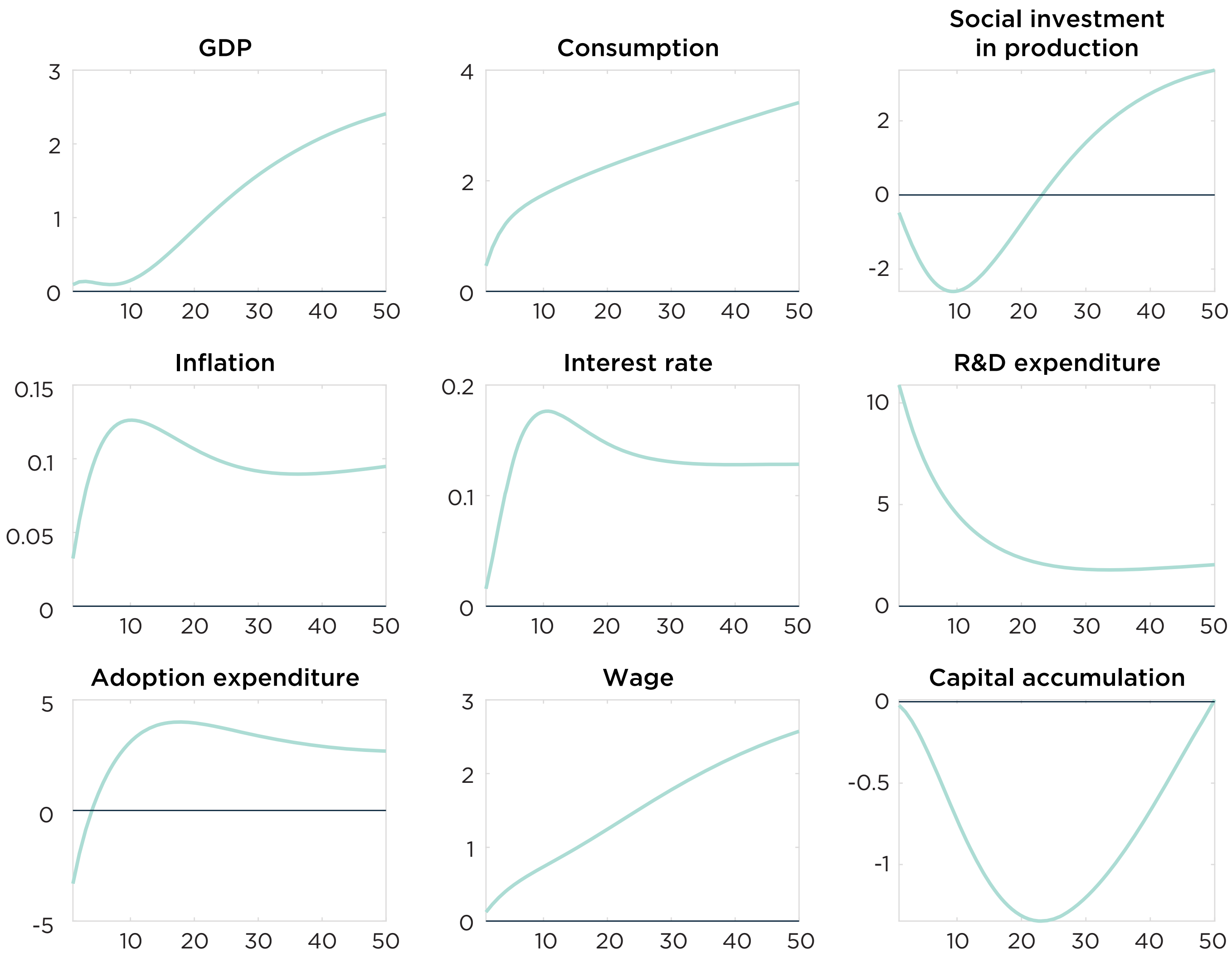


Figure 43. Impulse response function for a positive shock to R&D productivity‡‡‡

Source: Authors' calculation based on DSGE model

‡‡‡ In the graph, the horizontal axis represents the number of quarters forecast and the vertical axis represents the percentage deviations from the equilibrium.

5 The link between technology adoption and R&D investment

5.1 OBSERVATIONS AND FINDINGS FROM THE MODELLING RESULTS

The analysis demonstrates that technology creation and technology adoption are beneficial to the Vietnamese economy. However, a combination of technological capabilities and development strategies and policies will determine what innovation activities will be the most beneficial to the country.

To formulate the optimal policy response, it is important to have a realistic view of the current level of technological capabilities across industry, and the strength of institutions to support technology creation and adoption. Appropriate and effective policies are required to gradually promote the development of innovative capability in the private sector. The evidence presented in this report also suggests that policies should initially focus on targeted support for organisational and governance capabilities, then gradually shift to supporting R&D and new technology creation. The appropriate policy mix to accomplish this shift for the greatest economic benefit depends on the country's level of innovative capability, and the availability of complementary policies and supporting institutions.

To understand the country's level of innovative capacity, this report has shown the overall impact, level, capability and demand for technological creation and adoption across industries/sectors.

Observations from the modelling results include:

1. Technology adoption is the main driver of growth in Vietnam

Since 2015, the main driver to Vietnam's rapid economic growth has been technology adoption. However, the data show that Vietnam is still slow in technology adoption when compared to other countries at the same income level.

Technology adoption is not an easy process. Technology, in most cases, cannot be sold like physical products in fully embodied forms. Technology transfer usually requires training and skills development, financing and structural or organisational change. The process of technology adoption is generally slow, incremental and path dependent.

In Vietnam the majority of firms adopt simple and basic technologies to improve their businesses, though there are examples of far more complex technologies being taken up. For most firms the innovation process involves the procurement of equipment, training for human resources, learning new technological processes, and implementing production/product design. There are also firms that can conduct reverse-engineer processes, design their own processes and actively purchase technology and equipment for production. They also gradually obtain the capability to improve productivity and product quality as well as deploy new technology. These firms contribute to the technology frontier lift up or removal of technology adoption frontier through increasing investment in equipment, training or intangible assets.

A clear observation from the model result is that there is significant diversification in the intensity and impacts of technology adoption and creation across industries in Vietnam. Technology adoption is the key for output per worker growth for many sectors, especially for high-tech manufacturing sectors or high-tech services. Capital deepening, on the other hand, is critical for traditional sectors such as agriculture, forestry, low- and medium-low tech manufacturing. In a number of sectors such as forestry, the impact of technical improvement is highlighted.

2. New technology development is still a minor contributor to economic growth

Technology frontier lift-up – as a result of new technology development – has only been a minor contributor to economic growth in the most recent phase of development in Vietnam. This is to be expected from a lower-middle income stage of development.

However, there are a small number of leading firms within Vietnam that have developed advanced technological capabilities and skills. These capabilites and skills have come from improving and adapting imported technologies for the Vietnamese context. In some cases firms have improved the technologies themselves through designing and creating more complex technologies that can be sold internationally.

These new, locally developed but world-class technologies have the potential to create new emerging export industries for Vietnam. The companies developing these technologies are normally high-tech and large-scale. They operate at the technology frontier of the region and the world.

Industry 4.0 policies that recognise and support the creation of world-leading technologies can potentially help Vietnamese industry leapfrog technological phases. Vietnamese firms can thus avoid costly investment in increasingly redundant technology and stimulate the development of new technology and more knowledge-intensive industries or emerging sectors.

The most important actors in the development of world-leading technology in Vietnam have to be domestic, although foreign consultants and experts, and foreign knowledge and information are critical.

3. Technical efficiency improvement can achieve the greatest potential gains for output per worker growth

Results from the conditional frontier model show the majority of firms in Vietnam were not able to change their organisation's structure, culture and strategies to keep pace with technology investment and adoption. Therefore, implementing changes to organisations to more efficiently use adopted technology will be the key to improving productivity at firm level.

4. R&D investment creates long-term positive impacts on economic growth

An increase in R&D investment not only directly contributes to GDP growth but it also has an indirect impact by stimulating structural change through improving skills and human capital. Much of the R&D investment in Vietnam is in training and education, and incremental improvements to processes or technologies through adaptations and copying. Over time, however, R&D becomes more important. This is because it is needed for organisations and businesses to better understand, absorb and adapt complex, fast-changing technologies in high-tech industries at a higher level of development.

5. Technology adoption and R&D effort are closely linked

There is a need to harmonise and co-ordinate policies on technology adoption and R&D promotion, as there is a dependent relationship between them. Strategising and implementing Industry 4.0 is one of the ways to build bridges to connect technology adoption and R&D spending for further economic development.

To summarise, in the previous sections, we have provided evidence on different impacts of different technology development efforts on output per worker growth. Clearly, as firms improve their technology adoption capabilities with development, they gradually upgrade their activities in technology adoption and creation.

In general, technology deployment and creation activities amongst businesses can be divided into four different levels.

LEVEL 1. ACQUISITIVE AND OPERATIVE 'PACKAGED' TECHNOLOGY IMPORT

In the first level of development, with limited technological capabilities, firms acquire technologies mainly through importing technology packages, which include both machines, product specifications, know-how and technical expertise. Technologies acquired by firms at this level are quite standard and simple, and natural resource and/or labour intensive. Firms work mainly on efficiently operating the technology under foreign experts' instruction. Basic schooling and literacy may be sufficient to absorb simple industrial technologies at this level. Labourers in these businesses mainly require basic production training to develop skills in machinery operation, maintenance, and quality control.

LEVEL 2. ASSIMILATIVE TECHNOLOGY ADOPTION

Firms' capability at this level is mainly to implement duplicative imitation of standardised foreign products. Firms resort to informal technology transfer such as imitative reverse engineering or labour mobility. Backward and forward links between local firms and MNCs are another source of learning in businesses. Foreign buyers, for example, will transfer product designs and technical specifications to ensure the quality of products produced by local firms.

Other formal technology transfer channels such as FDI and licensing is much less effective in this level due to the lack of technology absorptive capability, not only at the micro but also at the macro level. This may be due to an unskilled labour force and/or infrastructure failures.

The process of technology adoption, however, also requires local firms to gradually develop local capacities to adopt imported technologies and undertake reverse engineering tasks. The focus of this level is to successfully acquire, absorb and, in a few cases, localise the imported technology. Most technology adoption efforts are usually dispersed and less systematic and more incremental due to the lack of complementary factors. These efforts, in many cases, can be strengthened when paired with public technology centres or research institutes.

Through the process of learning by doing and conducting reverse engineering, firms gradually improve their technical capability, which enables them to shift from mastering imported technologies and making minor improvements, to developing more innovative processes as well as generating differentiated products/services.

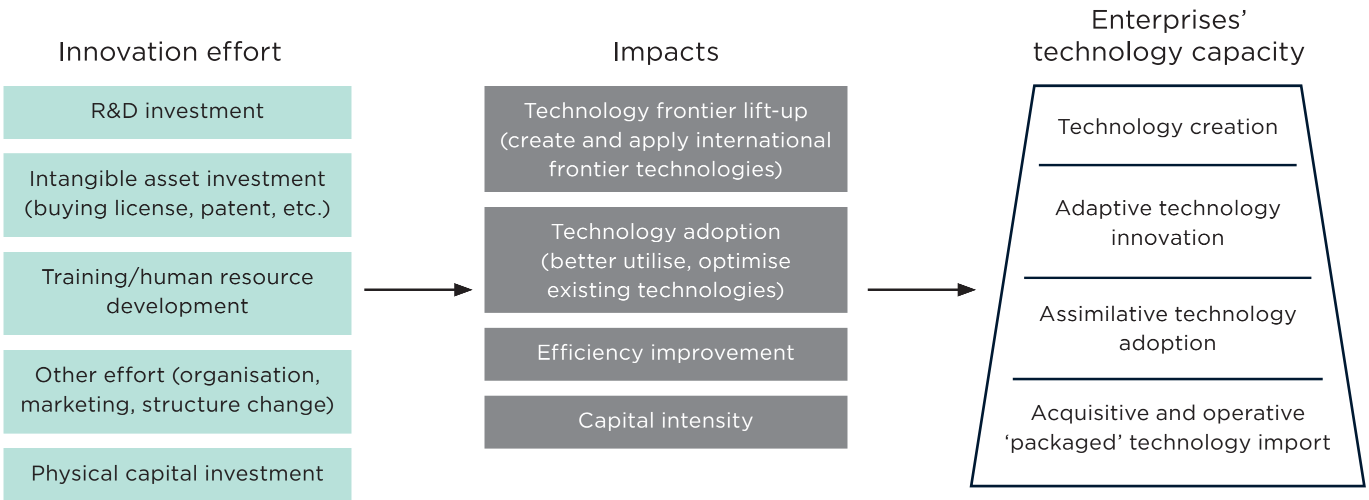


Figure 44. Technology development efforts and business capabilities

Source: Authors' illustration

DO DEVELOPING COUNTRIES INVEST ENOUGH IN R&D?

In the macroeconomic literature, estimates of the returns to R&D are generally extremely high for developed economies. The potential catch-up effect suggests that rates of return for R&D investment are generally even higher for developing countries.[67] This may be due to the potential gains achievable from R&D afforded to developing nations.

Despite vast potential returns for innovation, empirical evidence clearly shows that developing countries invest far less in innovation than developed economies. This innovation paradox is partly explained in Cirera and Maloney (2017).

Cirera and Maloney (2017) show that the returns for R&D investment vary according to the distance to the technology frontier.[68] Figure 45 measures the rate of return for R&D spending according to the distance of countries from the global technological frontier (denoted as zero at the far right along the horizontal axis). For countries that are close to or at the frontier and for countries that are farthest from the frontier (situated at the far left), the returns for R&D spending are small or negative. The largest returns for R&D spending occur in countries that are at a moderate distance from the technological frontier (around the middle of the x-axis). These countries have the capacities and complementary infrastructure required to adopt existing technologies and take advantage of the productivity gains that they yield. These high returns are consistent with the higher speed of catching up found in these countries.

One proposed explanation is that countries further from the technology frontier have an increasing scarcity of complementary factors needed for R&D. This in turn hampers the materialisation of potential returns. Adopting an emerging foreign technology, for example, not only calls for the R&D investment to modify the technology to the local context, but also requires well-trained engineers to operate the machinery or skilled managers to develop and manage the new business model.

That is, countries may increase direct investment in R&D, but if they lack the necessary complementary factors – a flexible financial market, skilled human resources, adequate energy, reliable ICT infrastructure for technology adoption, and an open, dynamic market environment – the returns will be low.

Developing countries, thus, need to remove barriers to the accumulation of all types of capital – human, physical and knowledge – through structural reforms to improve education and training and ensure access to finance and open trade, as well as develop a favorable business environment and competition framework. Undertaking these structural reforms will then allow them to realise the potential returns of R&D.

Figure 45. Rate of returns to R&D relative to the technological frontier[68]

LEVEL 3. ADAPTIVE TECHNOLOGY INNOVATION

At this level, local firms invest more in R&D activities and start to develop more sophisticated competencies, particularly around quality. Designing copies, creative adaptations, and adapting to other industries are some forms of adoption at this level. Firms now look more into design copies that mimic the style and design of the market leader. These copies carry their own brand name and unique engineering specifications. Firms are also actively involved in continuous incremental improvement and diversification in product specifications to capture higher value market niches.

Still, foreign technology transfer serves as the main source of technology development. Innovation efforts among local firms focus more on processes (i.e. to optimise production, increase efficiency, reduce costs and improve quality). Product innovation is still incremental and mainly aims to modify and improve existing products to differentiated and more value-added products/services.

At this level, firms need to resort to more formal foreign technology transfer activities such as FDI, licensing or technical consultancies. Technologies at this level tend to be more complex, though capital goods imports still play an important role. The local talent pool is again key to technology adoption.

IPRs become more relevant to these firms, with an increasing trend towards patent and trademark applications from local firms. At the macro level, private R&D also becomes more important and contributes an increasing proportion of the country's R&D efforts. The government plays a role in creating a favourable environment for private innovation as well as developing a high-quality research system and facilitating the collaboration between the two.

LEVEL 4. TECHNOLOGY CREATION AND EMERGING TECHNOLOGIES

Gradually firms that accumulate sufficient innovation capacity may be able to reach the technology frontier to innovate and create new technologies that can challenge firms in developed countries. At this level, firms are deeply involved in technological R&D and associated design and engineering for technology applications that cannot be acquired from foreign sources. Firms at this level are able to introduce new products/processes that can compete internationally.

Technology leapfrogging is possible at this level as firms may leverage late entrants' advantage in access to frontier technologies and utilise them with more understanding of the growing market. The adaptation of technologies to other industries is another example of technology innovation.

These firms may develop core competencies and technology platforms for the country's economy. And when a substantial number of firms reach this level, the country may move to the innovation level where technology creation is the primary source of economic growth and local R&D is the engine of the economy.

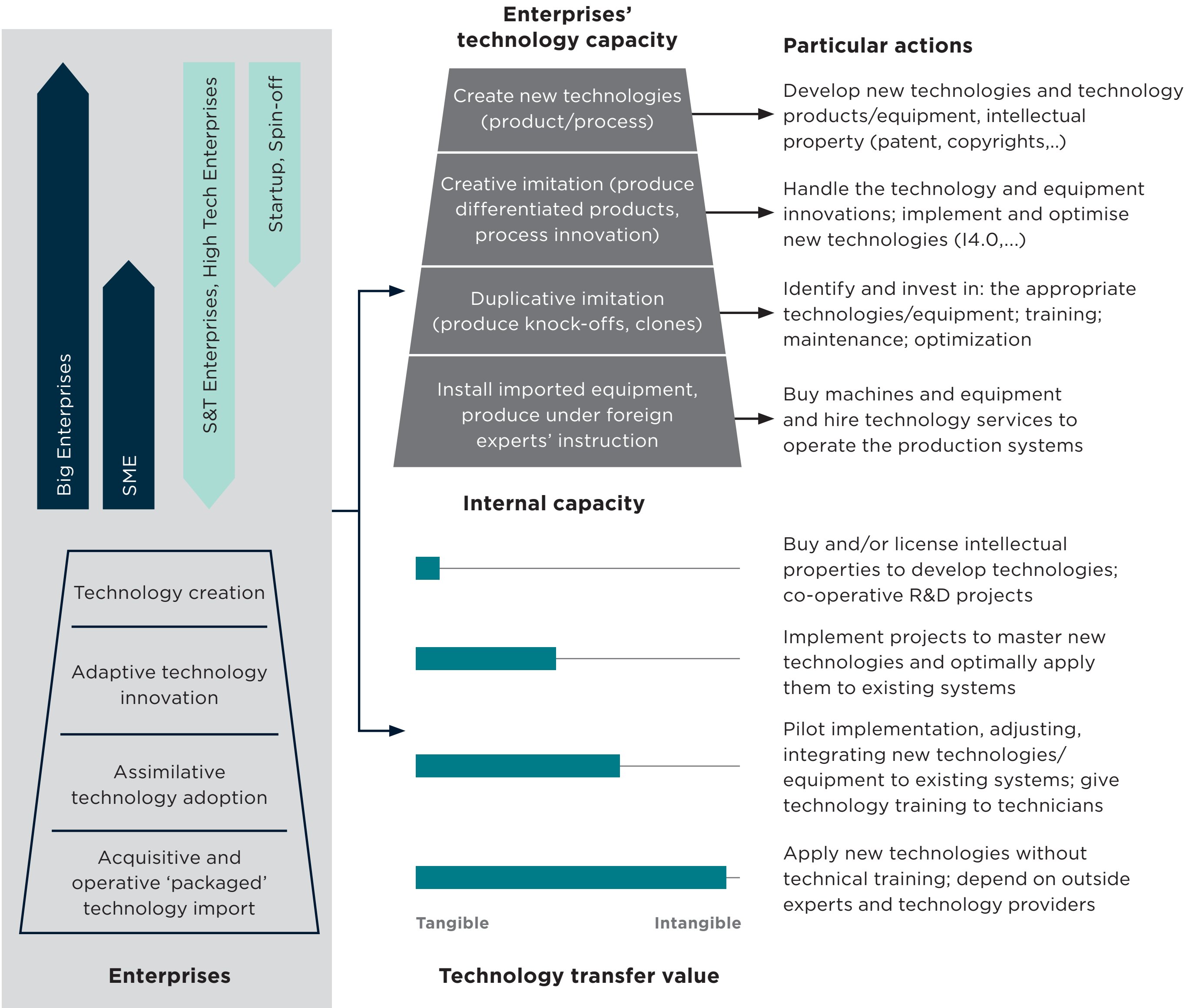


Figure 46. Technology development activities in businesses

Source: Authors' illustration

TECHNOLOGICAL DEVELOPMENT IN KOREA

Intellectual Property Rights and Sustainable Development by Linsu Kim.[69]

Foreign technology transfer has been the prime source of developing the knowledge base for Korean businesses.

In the 1960s and 1970s, Korean firms, at the early stage of economic development, obtained mature technologies from developed countries through acquiring 'packaged' foreign technologies to produce standard and undifferentiated products. Technology adoption at this stage was mainly duplicative imitation through reverse engineering, imported capital, human mobility or learning-by-doing with MNCs along the supply chain. Capital goods imports far exceeded other means in terms of value. Subcontracting arrangements created another significant channel to acquire skills to create products that adhere to international standards and technical specifications. In the process, public research institutions, rather than universities, played an important role in the technology adoption process. The Korea Institute of Science and Technology (KIST), which was established in this period, was able to help industries to enforce their bargaining power to acquire foreign innovations.

As Korean firms gradually mastered duplicative imitation, the increasing competitive threats from second-tier developing countries together with increasing domestic wage rises forced firms in Korea to shift the focus to relatively knowledge-intensive complex technologies. At this stage, Korean firms relied more on formal technology transfer such as FDI or foreign licensing. During the 1980s, FDI increased from $US218 million in 1967–1971 to $US1.76 billion in 1982–1986 and foreign licensing increased from $US16.3 million to $US1.18 billion in the same period.

In this period, firms intensified their R&D activities to increase their bargaining power in technology transfer, decrease the foreign dependency in technology and develop differentiated and more value-added products. R&D investment increased from 10.6 billion Won in 1971 to 3.4 trillion Won in 1990. R&D expenditure per GDP increased from 0.32% to 2.68% during the same period. The private sector took an increasing role in R&D efforts. The proportion of private-sector R&D activities increased from 2% in 1963 to over 80% in 1994, among the highest in the world. Korean firms also globalised their R&D activities, allowing them to monitor innovation at the frontier and form international R&D collaborations.

The Korean Government, in this period, invested heavily in developing university research. The government issued the Basic Research Promotion Law in 1998 to upgrade research capabilities in targeted universities. The number of researchers doubled from around 21,300 to 51,600 during the period. The government also issued policies to repatriate Korean scientists from abroad. These scientists became important sources of technical networks and knowledge to develop new technologies in Korea.

Over the decades, foreign technology transfer played a critical role in developing the knowledge base and technological development of Korea. The country has successfully materialised high rates of return for R&D activities through imitation and technology adoption.

THE MODEL OF TECHNOLOGY DEVELOPMENT FOR VIETNAM

Within a country, different levels of technological absorptive capabilities are likely to co-exist across sectors or even across firms in one sector due to heterogeneity in the production structure. Firms with different levels of complexity of production technologies exhibit different patterns in technology transfer and local innovation.

The scale of operation also accounts for variations in the behaviour of technological change at the firm level. Generally, large firms are more likely to produce sophisticated products whereas small firms are more likely to produce unsophisticated ones. This may also account for differences in technological behaviour between the two groups of firms. Such diversification supports the co-existence of industries/firms at different levels of technology development in a country at any stage of technology development.

In general, production technology dictates the direction of technological effort and the stage of technology development of a country is determined by the operational level of the bulk of business in the country.

Figure 47 illustrates a common, simplified trajectory for technology development in Vietnam. This framework analyses and integrates the technological trajectories over time.

The conclusions we can draw from this model include that the focus of the country in terms of technology development is different at various stages of development.

For enterprises in the early stage of development, the adoption of technology may be more conducive to their rapid growth. However, with technological advancement and accumulation, enterprises should shift from relying on technology adoption to pursuing independent R&D to achieve sustainable and stable development.

Countries cannot rely on a single way to innovate and promote company growth. The evidence shows that businesses that pursue independent R&D, as well as adopted technology, continue to innovate and grow. The imitation of advanced technologies is an important learning process to enable technological catch-up, but it is not enough. Active innovation through domestic R&D is crucial for successful technological catch-up.

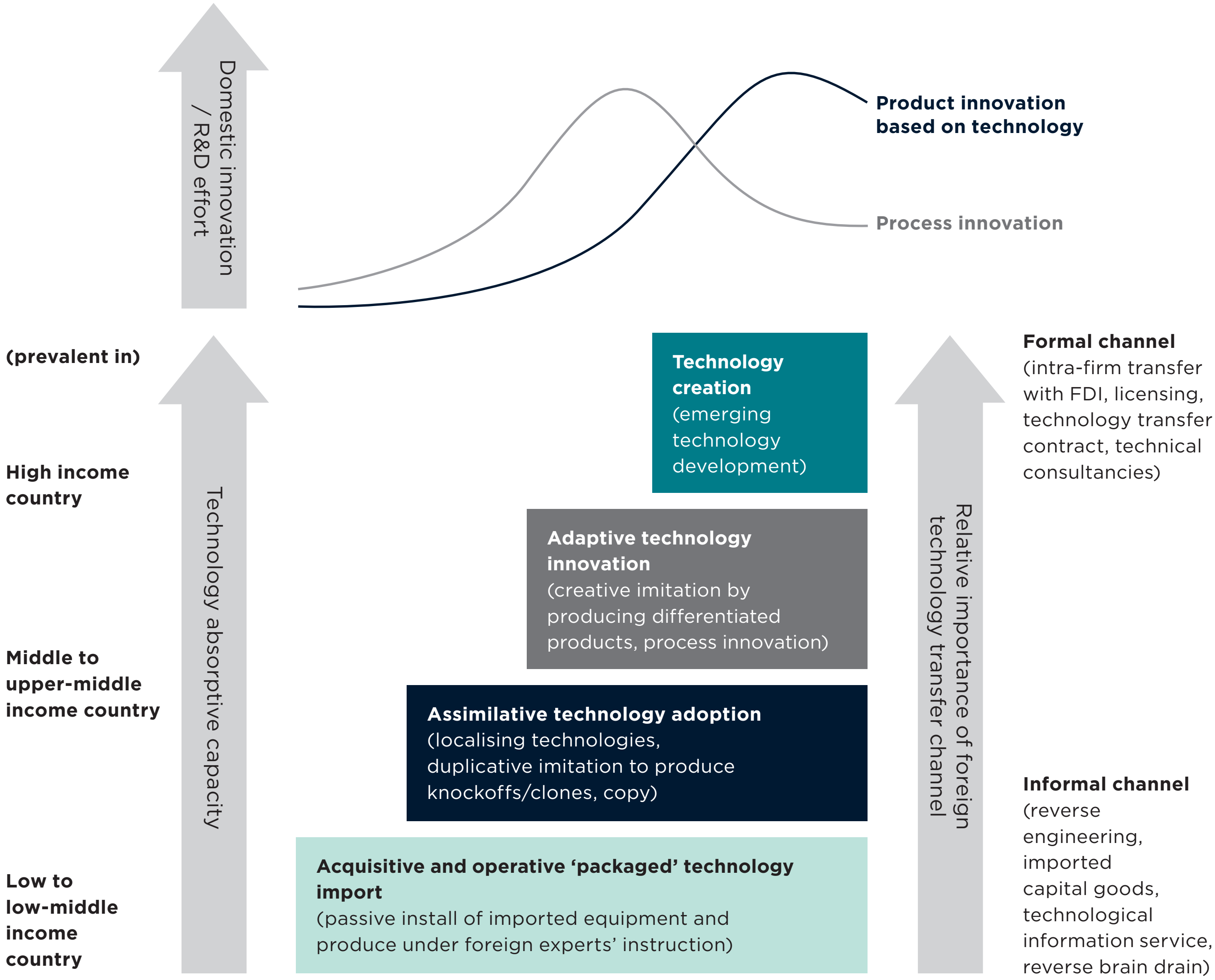


Figure 47. Technology trajectory for industries in developing countries

Source: Authors' illustration

6 Data gap analysis and innovation approach

The previous chapters of this report have examined the current situation and impact of technology development on the Vietnamese economy. The results of the two economic models developed for this project show that the economic growth of the nation has benefitted substantially from investment in R&D and technology-adoption-related activities such as buying new machines/equipment, creating or acquiring intangible assets, and training staff.

The analysis, however, is by no means a comprehensive picture of what is happening in Vietnam. In this section, we would like to: (i) briefly explain the limitations of the two models in terms of underlying assumptions and data; and (ii) review ways to more comprehensively measure and evaluate the impact of innovation in Vietnam.

6.1 LIMITATIONS OF THE ECONOMIC MODELS USED IN THIS REPORT

CONDITIONAL FRONTIER MODEL

The model results suggest that high rates of technology investment and adoption are the key explanations to Vietnam's economic growth over the last two decades. However, in trying to understand how technology innovation has driven growth, the current framework still fails to capture several indirect impact channels of economic growth. Some of the indirect impact channels not measured in the model include:

- **Strengthening capital intensity effects:** Firms invest in new capital based on their future income expectations. The introduction of new technologies can increase investment returns and thus stimulate firms to undertake further investment. In history, the introduction of breakthrough technologies such as electricity has often unleashed investment booms and given way to the expansion of economic outputs.
- **Quality upgrading of existing products and introducing new products:** Though quality-improvement impacts are partly captured in the model through the change in prices for final products, there are spillover effects that are not captured by the model. The introduction of new or upgraded products can cause consumers to alter their consumption basket, and thus stimulate demand. New products that serve as intermediate inputs for other firms may also give rise to productivity gains.
- **Transforming economic structures:** New technologies are normally the catalyser of profound structural reforms. Technology innovations can unleash a reorganisation of the supply chain through increased specialisation and globalisation, which in turn amplifies productivity gains. Technology innovations can also give rise to new economic activities and accelerate the decline of older activities. In the short or medium term, these changes can create hardship for workers whose tasks become redundant, but in the long term, the deployment of workers in emerging industries will be the main growth engine for Vietnam's economy.

DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM MODEL

Modern macroeconomics rely heavily on DSGE models of the economy due to their ability to: (i) incorporate dynamics (i.e. a time dimension); (ii) deal with stochastic uncertainty; and (iii) study general equilibrium effects. Although this model can be a powerful tool to facilitate evidence-based policy development, the model is a simplification of the real world that relies on a number of assumptions, and many of the key modelling parameters were not able to be estimated due to data limitations.

The DSGE model in this report has the advantage of capturing the long-term impacts of R&D investment by introducing a separate channel of impact for R&D activities. The sophistication of the model, however, limits its ability to provide more disaggregated impacts on different sectors or different geographical regions in Vietnam. The model also does not explicitly distinguish between private and public R&D investments. In addition, the underlying conceptual approaches assume that there is only one type of endogenous innovation, which can be interpreted as product or process innovation, but marketing and organisational innovations are exogenous.

Another limitation comes from the use of a closed-economy DSGE model to conduct the analyses. Although this kind of model allows us to isolate the impact of domestic R&D expenditure on economic growth, it also limits the ability for the model to capture the technology adoption impacts from international sources such as FDI or machine/equipment imports. Technology adoption has become the main source of economic growth for Vietnam, according to the conditional frontier model results, but the DSGE model in its current form only captures technology adoption impacts from the exogenous part of TFP growth. For our analyses, this limitation does not make a big difference for replicating and predicting the cyclical movements of the Vietnamese economy, but it is probably important for evaluating the impacts of Vietnam's innovation policies.

Both models would be substantially improved if more specific data were available

To measure productivity accurately, one has to use appropriate variables that are good at proxying for the input and output quantities used in production. After all, productivity is a physical notion of the quantity of outputs produced with respect to the quantity of inputs used. If these underlying variables are measured incorrectly, then the analysis will provide biased results. In the Vietnamese context, there are several instances of such measurement inaccuracy.

On the output side, the two main notions that can be used are gross output and value added. Both measures are evaluated dollar values and include both a quantity component (the quantity of outputs produced) and a price component (the values at which the outputs have been sold on the market). In general, price information is not available at the firm level, and the best we can do is deflate the price values by accounting for inflation. This procedure makes quantity comparisons across time periods consistent but does not resolve problems associated with the price dispersion across firms. Of course, the availability of firm-level price data would improve our estimation of productivity. Therefore, more specific price data are needed for back-to-back quantity versus monetary outputs, to ensure estimations of productivity provide a complete picture of outcomes.

The input side of production also has data availability issues. For example, the Vietnamese data report the number of employees (the quantity of labour); however, it is difficult to adjust this quantity by the quality or education of the workers. By all accounts what one is interested in when looking at the 'quantity' of labour is the number of workers adjusted by a measure of the human capital of the workers. This is especially true for sectors and firms that are using advanced technologies.

The conditional frontier model has data limitations relating to the proxy used for the technological efforts of firms, namely development investment. This proxy provides useful results; however, it cannot differentiate the impact of different technology-related activities from the impact of firm growth. Ideally, the model would consider multiple proxies for the technological efforts of firms – such as R&D expenditure, or the numbers of innovations conducted (which can be divided into different innovation types), patents and trademark applications, among others. These kinds of data are currently only available at the macro (or country) level, but not at the micro (or firm) level.

Another limitation of the conditional frontier model is that the technology indicators only capture the visible inputs of the technological capacities of firms. In reality, the level of efficiency of turning inputs into outputs, or moving or catching up to the frontiers, also depends on appropriate skills and know-how within firms. Overall, the availability of firm-level data about technological efforts, quality of labourers and know-how would further improve the precision of the empirical results from the conditional frontier model.

As for the dynamic stochastic general equilibrium model, due to the data limitations, some of the main parameters of the model are assumed to be similar to previous research in the DSGE literature. However, most of these studies are conducted for developed countries. One example in the model is that the value of the technology diffusion rate is assumed to be similar to that in the United States. As such, surveys to evaluate and estimate the technology diffusion rate in Vietnam will significantly improve the fitness of the model to Vietnam's economy.

6.2 A COMPREHENSIVE AND SYSTEMIC APPROACH TO MEASURING INNOVATION ACTIVITY AND PERFORMANCE

While the two economic models deployed in this project represent a powerful way of explaining the contribution of R&D and technology adoption to productivity, GDP and economic growth, the models have limitations in benchmarking innovation activity and innovation system performance. As pointed out in the previous chapters, technology creation and adoption are only two major parts of the much bigger process of innovation. Innovation plays an important role in the development process and its contribution to economic growth is significant in a low-middle-income economy like Vietnam. A more comprehensive and systematic approach is therefore needed to benchmark innovation activity and its impact on the economic growth of the nation.

Such a modelling approach would need to be underpinned by data that examine firm behaviours as well as the interactions between different agents in the economy in terms of innovation activities and all the outcomes of these activities. However, these types of data are often biased or not available at scale. After determining the best way to systematically measure innovation activity and performance, it will also be necessary to identify and address data gaps to achieve this modelling approach.

As innovation is a multidimensional phenomenon, appropriate classifications are useful in terms of systematically capturing the phenomenon. Therefore, the following evaluation of innovation measures shall consider different sub-components of innovation classified by different criteria. As an example, the Global Innovation Index divides its indicators into input and output sub-components.[2] Meanwhile the OECD classifies innovation factors into internal and external factors.[12]

In the following section, we briefly review measures of innovation according to two main sub-components: (i) factors that affect innovation (external versus internal), and (ii) innovation efforts (within-firm innovation versus technology transfer/diffusion). More specifically, we will discuss in detail the four main pillars for measuring and evaluating innovation in Vietnam: (i) internal factors affecting innovation; (ii) external factors affecting innovation; (iii) internal innovations; and (iv) innovations from linkages with other organisations. Under each pillar, we describe several dimensions and indicators that can be used to measure and evaluate innovation. Based on the identified pillars, dimensions and indicators, we also evaluate the data gaps that should be addressed to better capture the innovations of firms in Vietnam.

PILLAR 1: INTERNAL FACTORS AFFECTING INNOVATIONS

Firm objectives

A firm's innovation activities are chiefly driven by the firm's objectives. Currently available measures of firm innovation often ignore this dimension due to the following two assumptions. Firstly, it is assumed the market is competitive. Secondly, it is assumed that all firms aim to maximise their profits. However, these assumptions are often not true in practice, especially in developing countries.[70] Of course, in the long term the primary objective of many firms will fall under the category of profit maximisation. However, in the short term, firms can hold diverse and varying objectives for their firm in general as well as for their innovation activities. It would therefore be useful to survey firms and classify their objectives to understand the readiness of firms to innovate and contextualise their innovation performance.

Management capacity

Management capacity refers to managerial skills within firms, the ability to apply management methods and techniques, as well as the know-how of management. These qualities are hard to measure directly but can be measured through proxies, such as the number of people with managerial qualifications or experience in management positions. Surveys with relevant experts can also help identify the extent to which firms apply management methods/techniques. These data may help to identify best practice models of management and assist in the harmonisation of management methods and techniques across firms in Vietnam, particularly as management processes are digitalised.

Know-how of firms

The workforce needs more than simple skills and qualifications to conduct their work effectively. Workers also need know-how on specific production processes, business functions and technologies, to execute business operations and produce products or services with desirable qualities.[70] Know-how is hard to measure, especially since firms may want to keep this knowledge confidential from competitors. Proxies are needed to measure know-how, such as subjective evaluations on the ability of a firm and its workforce to: (i) operate the firm's current technologies under normal conditions; (ii) maintain and improve current technologies; and (iii) internalise new technologies.

Another issue is that know-how is not a permanent factor for firms. Knowledge of specific technologies or production processes does not guarantee the firm can succeed in other technologies or processes. Therefore, the adaptability of firms should also be measured. In this case, past experiences of technology upgrading as well as subjective evaluations of firms' adaptability can be used as proxies.

Human capital

For firms in developing countries, the main areas of innovation are technology adoption and upgrading rather than R&D, as R&D activities require a different set of firm resources. Although the main resources required for all areas of innovation are human capital and finance, the characteristics of these resources differ depending on the area of innovation. For example, the skills of labourers in R&D are different from labourers that implement technology. Therefore, we have to measure appropriate skills for firms at different stages of technology upgrading.

Indeed, the two dimensions of a firm's human capital and know-how overlap, which means we can measure both together as described in Table 3. The measures include both quantity measures (e.g. educational qualifications) and quality measures related to labourers in firms. Of course, the know-how of firms can be stored outside of the workforce; however, the perceptions of the workforce can provide a good reflection of firms' capacities in practice. The key desirable information in the know-how dimension is the capability of firms in technology adoption or internally upgrading. GSO data currently only partly covers the measures listed in Table 3, through subjective assessments of firms. However, data on the magnitude and real practices of technology adoption and upgrading within firms have not been collected by GSO. Meanwhile, data on the standard qualifications, professional skills and seniority of labourers are still not regularly available.

Finance

The finance dimension covers both the availability of financial resources and the commitment to innovation activities. Therefore, we can collect information on the amount of:

- investment in technologies (including both production technology and management practices)
- investment in human capital
- expenditure on R&D (both in terms of fixed investments and recurrent expenditures).

Currently, data on finances for R&D are available for all firms in Vietnam for a number of years. However, there is no information of investment in human capital for innovations or the costs for buying patents or licenses.

R&D activities

R&D and technology creation are conventional measures of innovation, but they only reflect a small aspect of innovation for firms in developing countries. However, measuring R&D activities is still useful to reflect the overall capacity as well as the objectives of firms. The previous paragraph on 'Finance' mentions some additional R&D-related data that should be collected to comprehensively measure innovation.

We summarise the proposed indicators of dimensions of internal factors affecting the innovation of firms in Table 3. This Table also shows the data gaps that exist for this pillar.

Table 3. Dimensions and proposed indicators of internal factors affecting innovations

DIMENSION	PROPOSED INDICATORS	CURRENT DATA AVAILABLE AT SCALE	NOTE
Firm objectives			
	Current positions of products of firms in the market: market share, product positioning	No	
	Future perspectives: market share, product positioning	No	
	New markets	No	
	New business linkages such as being suppliers for other firms or involvement in the global value chain	No	
Management capacity			
	Qualifications of managers	No	Only available for a couple of years
	Experiences of managers	No	
	Application of management methods/techniques in management	Yes	
	Level of digitalisation in management	No	
Know-how of firms and human capital			
	Relevant qualifications of labourers	Yes	Only available for general qualifications for a couple of years
	Relevant experience of labourers	No	
	What methods of upgrading has the firm already applied in the past?	No	
	What methods of upgrading would the firm choose for new technologies?	No	
	What kind of performance improvement can the firm execute at present?	Yes	
	Subjective assessments of firm's managers on firm's technological capacities	Yes	
Finance			
	Investment in technologies (including both production technology and management practices)	No	Only investment in production technology available for a sample of firms
	Investment in human capital	No	
	Expenditure on R&D both in terms of fixed investments and recurrent expenditures	Yes	
R&D activities			
	Number and qualifications of labourers in R&D activities	Yes	No data of specific qualifications of labourers
	Number of patents/trademarks	Yes	

Source: Authors' analysis

PILLAR 2: EXTERNAL FACTORS AFFECTING INNOVATIONS

A number of external factors affect the innovation activities of firms. The Global Innovation Index (GII) 2020 report lists a number of macro and sectoral factors such as the regulatory environment and infrastructure.[71] Indeed, a number of these indicators are already available at the macro level as calculated in a number of global reports such as the GII or other reports that cover a number of economies including Vietnam. The GII mainly uses proxies for measuring infrastructure or environments, such as logistic performance as an indicator for general infrastructure.

Although indicators at the sectoral level are less available, we can still combine a number of indicators at the sectoral level with currently available data. For example, access to export markets or imported inputs can be sourced from customs data, while the market structure can be estimated from the enterprise censuses. In addition, the availability of preferential policies for firms can be sourced from current regulation documents. Current regulation documents also reveal how regulations change; for instance, recent changes that reduce barriers to doing business.

However, indicators are scarce at the firm level, including the interaction of existing sectoral indicators with firms (for example, availability and access to preferential policies or finance for technology upgrading). External factors directly affect firms' behaviours in innovation activities as well as the outcomes of such activities. Therefore, it is crucial to better understand how external factors affect firms' innovation behaviours and outcomes, using both available and new data as described in Table 4.

PILLAR 3: INTERNAL INNOVATIONS

All proposed data gaps described under Pillar 1 and 2 only reflect static aspects of a firm's innovation. Another important aspect is how firms conduct their innovation efforts.

Innovation efforts are easier to measure, as they are often tangible behaviours such as importing technologies. However, several aspects of these behaviours should be measured, including: (i) the features of the innovation, and the behaviours; (ii) magnitude; (iii) mechanisms; (iv) time; (v) resources; (vi) deterministic factors; and (vii) outcomes. Proposed indicators for these aspects are listed in Table 5. Innovation behaviours across all six business functions should be investigated, including: (i) the production of goods or services; (ii) distribution and logistics; (iii) marketing and sales; (iv) information and communication systems; (v) administration and management; and (vi) product and business process development.

Currently, data availability at scale only covers limited innovation activities of firms. Specifically, the GSO surveys only ask for the general functions of physical technologies; for example, technologies for refining steel in general, not specific technologies (e.g. open-hearth furnaces, basic oxygen furnaces) or the sources and amount of investment in the technologies. Indeed, the survey asks for investment in equipment but there is no additional information to determine whether the investment activities are classified as innovation-related activities, or simply the replacement or expansion of their production. It would also be useful to know the amount invested in development or technology upgrading that is conducted in-house.

PILLAR 4: INNOVATIONS FROM LINKAGES WITH OTHER ORGANISATIONS

There are three main actors that a firm interacts with in innovation-related activities: (i) foreign sources, (ii) domestic research institutions, and (iii) other firms. The main type of interaction with these actors is technology transfer. Depending on a firm's capacities, choices and interactions with suppliers, the firm may choose technology transfer activities with different proportions of tangible and intangible assets.
There are four levels of technology transfer: (i) buying patents to develop a technology; (ii) mastering new technologies to be customised for a firm's specific needs and optimally applied; (iii) pilot implementation, adjustment and integration of new technology into the firm's current systems; and (iv) technology/ machinery operation. To enable a clear picture of technology transfer, data needs to be collected for each level of technology transfer as well as the seven dimensions described under Pillar 3 (see Table 6).

Table 4. Proposed indicators of external factors and firms' innovation activities

DIMENSION	PROPOSED INDICATOR	CURRENT DATA AVAILABLE AT SCALE
External factors affecting innovations		
	Subjective assessment of the availability of cutting-edge or advanced technologies for firms	No
	Supply of technology in the market	No
	Firms' perceptions on real accessibility to preferential policies from the government for innovations including taxes, access to credit and supporting information	Yes
	Firms' perceptions on finance accessibility	No
	Availability of specific skills required by firms in the labour market	No
	Market prospective	No
Firm's innovation behaviours		
	Which innovation activities do firm conduct?	Yes
	Magnitude: how substantial are the innovation activities?	Yes
	Mechanisms: how is each innovation activity conducted?	No
	Time: how long does it take?	No
	Resources: costs, both in terms of finance and human capital for the innovation activity	Yes
	Why: why firms undertake innovation activities, and deterministic factors that firms consider when getting involved in such innovation activities?	No
	Underlying objectives of each innovation: anticipated outcomes for the firm	Yes
	Real outcomes: what are the real outcomes, compared with the anticipated outcomes?	No

Source: Authors' analysis

Table 5. Proposed indicators of firms' innovation activities

DIMENSION	PROPOSED INDICATOR	CURRENT DATA AVAILABLE AT SCALE
Firm's innovation behaviours		
	Which innovation activities do firm conduct?	Yes
	Magnitude: how substantial are the innovation activities?	Yes
	Mechanisms: how is each innovation activity conducted?	No
	Time: how long does it take?	No
	Resources: costs, both in terms of finance and human capital for the innovation activity	Yes
	Why: why firms undertake innovation activities, and deterministic factors that firms consider when getting involved in such innovation activities?	No
	Underlying objectives of each innovation: anticipated outcomes for the firm	Yes
	Real outcomes: what are the real outcomes, compared with the anticipated outcomes?	No

Source: Authors' analysis

Table 6. A matrix of measurement of technology adoption from foreign sources

LEVEL OF UPGRADING	FEATURES	MAGNITUDES	MECHANISMS	TIMES	RESOURCES	DETERMINISTIC FACTORS	OUTCOMES
i. Buying patents to develop technology	Buying what Types of patents	Finance Expected share of production of firm with new technologies	How to buy How much knowledge and skill transfer	How long does it take from the initial decision to stably produce new products or operate the new technology	Sources of finance and human capital	Why the firm selects and follows this type of upgrading	New sales Product quality Reduction in employment, inputs Productivity increase Both expected and real outcomes
ii. Mastering new technologies to be customised for a firm's specific needs, and optimally applied	Buying what Types of tech. Modern level of technology, gap to cutting-edge technology in the industries	Finance Expected share of production of firm with new technologies	How to buy Supports from providers in term of operating, training, or customising				
iii. Pilot implementation, adjustment, integrating new technology into current systems	Buying what Types of tech. modern level of technology, gap to cutting-edge technology in the industries	Finance Expected share of production of firm with new technologies	How to buy Supports from providers in terms of operating or training				
iv. Technology / machinery operation	Buying what Types of tech. modern level of technology, gap to cutting-edge technology in the industries	Finance Expected share of production of firm with new technologies	How to buy Supports from providers in term of operating, training, or skilled technicians				

Source: Authors' analysis

Technology diffusion

One information type that relates to technology transfer across firms is technology diffusion, (i.e. the speed of spreading a technology across firms in an industry). Currently, data in Vietnam do not allow us to derive this kind of information. To have this kind of information, specific technologies need to be tracked. There are GSO surveys that collect information about the technologies of specific firms over time; however, as discussed previously, the definition of technologies is very broad and does not look at specific technologies (i.e. open-hearth furnaces for steel making). In addition, the time period of the data collection is still too short to demonstrate a complete technology diffusion process. Consequently, long-term data of diffusions of specific typical technologies in different sectors should be collected. This can be done by selecting some cutting-edge technologies in each industry and observing their application in firms over time, at least over 10 years.

MEASURING INNOVATION OUTCOMES

An important related measure of innovation is the outcomes of innovations. As discussed above, objectives of innovation can be specific to firms and we have to evaluate the real outcomes and their objectives. However, there are common objectives that firms aim for when executing innovation activities, and these are described in more detail below.

Productivity

As discussed above, a number of measurements on inputs and outputs, especially in physical terms, can improve the estimation of productivity significantly. However, one should be cautious when using productivity in evaluating innovation outcomes as it may not be the first priority of firms under certain circumstances.

Product quality

This output of innovation is somewhat ambiguous. It depends on the firm's objectives as to whether product quality is an outcome of the innovation. In the case that it is, we need to measure it. It is, however, difficult to measure product quality. Following Verhoogen (2020), we propose two ways to measure product quality:[70]

- Product ratings: This is a direct way of measuring product quality. However, it is hard to construct a standard rating system for each product.
- Pricing: It is a general argument that price correlates with a product's quality. However, several factors determine a product's price. Therefore, one should take caution when using prices to measure a product's quality.

Product innovation

Innovations can result in adding new products or differentiated products to the previously existing set of products of firms. Indeed, it is ambiguous to define what are new or newly differentiated products. However, if a product still serves the same market segments or keeps the same functions, changes in the product are attributed to changes in quality. Therefore, product innovation and product quality are distinguished by two features: whether the product serves a different market segment, and whether products have new functions.

Participation in global value chains and linkages with FDI firms

Links with global value chains or FDI firms are often not regarded as an outcome of innovations. However, we add this indicator of innovation outcomes, as engagement in the global value chain as well as linkages between domestic and FDI firms in Vietnam are weak, compared with regional peers such as Malaysia and Thailand. Therefore, we can see this indicator as one of the outcomes of innovation, especially for manufacturing firms.

We propose two dimensions of links with the global value chain and FDI firms: (i) proportions of output in the global value chain, and (ii) moving up. For moving up of linkages with FDI firms, we can measure the tier orders of firms, including first, second or third tier suppliers to FDI firms. Moving up in the global value chain can be measured by the ratio of value added to revenue. Currently, information on this dimension is available for a sample of manufacturing firms for the period from 2010 to 2019.

Data gaps for measuring innovation outcomes

Some innovation outcomes of firms can currently be measured such as productivity, product innovation or participation in global value chains. However, data of the quantities of production such as physical inputs or outputs, which can significantly improve measures of productivity, are not available. Meanwhile, data on product quality as well as product innovation are not available at scale.


Sign Here

7 Policy implications – What do the findings mean for the Vietnamese Government?

7.1 POLICY RECOMMENDATION 1: IMPROVE TECHNOLOGY ADOPTION AMONG BUSINESSES

Improving the capability of firms to adopt new technologies and innovate within their organisations (through structural, strategic and cultural change) would bring the most economic benefit to Vietnam at this point in the country's development.

Designing an effective system to support enterprises, especially SMEs, in capturing the benefits of new technology needs to take into account different levels of business capability in technology adoption. Improving business capabilities will require policies to support business education on how to best utilise new technologies, with the education adapting as the technological capabilities of the firms improve and grow.

A World Economic Forum (WEF) report listed 60 emerging technologies in 2017, which have critical roles in transforming businesses and their operations.[72] However, the WEF report also shows that the level of technology readiness will be dependent on the current stage of national infrastructure, adoption capacities and human resources. This again highlights the importance of governmental supports in preparing necessary conditions for businesses to adopt such technologies.

In particular, a number of measures can be considered:

1. Develop sectoral strategies/ policies for technology adoption

As mentioned above, there is significant diversity in the levels and impacts of technology adoption activities on the industries of Vietnam. As a result, policies/strategies need to take into account Vietnam's specific sectoral charateristics to improve technology adoption in these industries. For example, access to new technology from international sources is essential for innovation in sectors such as telecommunications, banking and aviation. However, sectors such as health or transportation can develop significant endogenous capability and customise technologies to the Vietnamese context.

2. Stimulate technology imports

One prerequisite for technology adoption is the ability to access international technology and information. Therefore, technology transfer policies will need to focus on the provision of technical information to enterprises. Relevant technical information includes information on the sources, costs and appropriateness of foreign technologies for local industry. This information will also need to be backed by the provision of technical extension services to help Vietnamese firms absorb new technologies into their business processes.

It is critical to provide up-to-date information to local enterprises on sources of technology that are suitable for their specific level of development. In particular, SMEs with limited technology capabilities should be supplied with information on the origin, cost and appropriateness of foreign technologies and technical supports/ consultancy services to help SMEs adopt these new technologies. Programs to support, analyse and appraise technologies through technology transfer consultancy services are also very effective for SMEs.

Firms with greater technological capacities, that have the potential to participate in creative imitation or technology creation activities, need more in-depth supports such as: comprehensive information on licenses, technologies and markets; in-depth reports on technologies, technology development and technology application in international markets; or feasibility studies on technology transfer and adoption in Vietnam.

The government also needs to develop policies to promote businesses to actively adopt and master technologies through various technology transfer channels such as licensing, purchasing industrial designs, hiring foreign experts, testing, and collaborating on research with foreign research organisations, MNCs or others.

3. Accelerate digital transformation and Industry 4.0 technology adoption

The adoption of digital technologies can facilitate frontier technology adoption and at the same time enable R&D activities, and thus enable technology creation. Digital transformation requires timely action to keep pace with rapid technological change, and updated capacities in areas such as skills and culture.

The application of digital technologies also requires an awareness of the business and its current stage of technological capacity. Following the four levels of technology development described in Figure 48, businesses at different levels of technological development will focus on different digital technologies and thus will need different supports.

- **Businesses at the acquisitive and operative 'packaged' technology import level:** Supports need to be focused on helping digitisation (i.e. digitising current process or rigid technologies with a low level of complexity that does not heavily affect human resources, culture or the organisation).
- **Businesses at the assimilative technology adoption level:** Supports should be focused on providing experts and technical consultant services to help business adopt more complex technologies.
- **Businesses at the adaptive technology innovation and technology creation level:** Businesses at this level focus more on adapting existing technologies or modifying/creating new technologies, which will result in the transformation in both production process and business organisation. Supports at this level should be focused on R&D activities and facilitating access to core technologies across different industries.

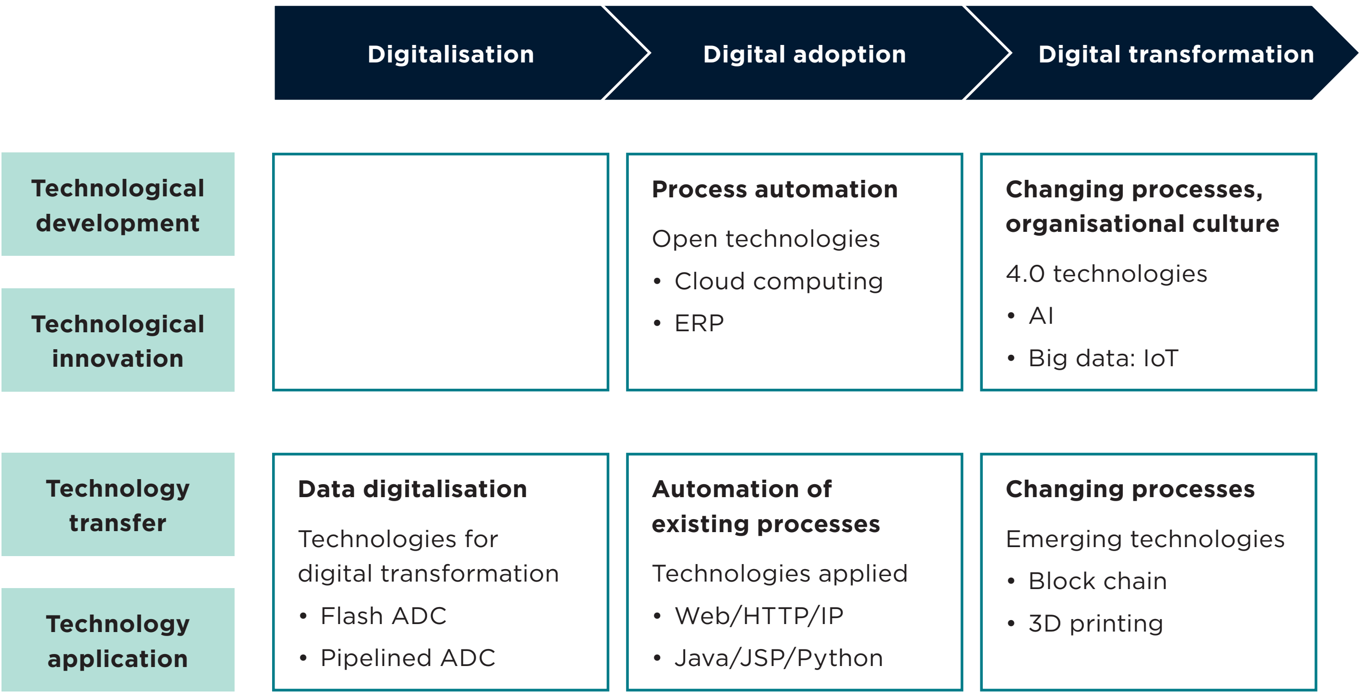


Figure 48. Digital transformation with technology development levels

Source: Authors' illustration.

4. Improve 'spillover' effects and forward and backward linkages

FDI has proven to be critical to technology transfer and development. However, its impact varies greatly with the economic characteristics and technology adoption capability of the host economy.

Policies targeting more technology transfer and spillover impacts should be emphasised. In effect, investment promotion policies should not only focus on bringing in new investment and generating employment. The policies should also encourage MNCs to upgrade their activities in Vietnam beyond simple assembly, so that local firms – both state-owned enterprises (SOEs) and private SMEs – benefit more from FDI in terms of productivity improvement and knowledge transfer.

It is necessary to develop better links between investment promotion policy, and productivity improvement and innovation policy. A government measure like the Local Industrial Upgrading Programme in Singapore pays the differences in salaries of engineers and technicians of transnational and MNCs to work for two years in local SMEs, in order to develop the critical skills and knowledge necessary for upgrading their technological and innovation capabilities. This type of policy may be of great benefit to Vietnam.

Vietnam needs a shift in FDI attraction strategy/policies. In particular, initiatives should be focused on encouraging FDI firms to: (i) invest in R&D activities; (ii) transfer technologies to Vietnam's partners; (iii) increase local components in final products; and (iv) collaborate with Vietnam partners to develop supporting industries. The government should also be selective and restrict projects that utilise backward technologies or have negative impacts on the environment or natural resources.

On the other hand, positive externalities arising from FDI (such as technology transfer, and an uplift in skills and education) do not happen naturally. Just attracting technology-intensive businesses to Vietnam is not enough for Vietnam to receive flow-on benefits. Analysis in the previous sections of the report shows that although FDI investment brings great benefits to Vietnam in terms of growth, exports and employment, it is often unsuccessful in building connections with the domestic economy.

MNCs, in general, transfer different kinds and levels of technology depending on the corporate strategies and technological capability of the host country. This is why transfers in developing countries with low skills and capabilities tend to have lower technology content than in advanced countries, and subsequently the technology transfer benefits reflect the growth of skills and capabilities in the host economy. As with domestic capability building, there will be cumulative and self-reinforcing processes in technology upgrading via FDI.

Programs to enhance the 'absorptive capacities' of local firms – such as upgrading their abilities to select, utilise and upgrade external knowledge – could be implemented through various policy mechanisms like technology-specific and government-subsidised training courses and consultancy services (by foreign and local experts in the industry, not just university professors). The government should target those domestic firms that have higher capacities in technology adoption to act as long-term suppliers to MNCs and improve their capabilities to maximise productivity spillovers.

Another consideration is that location matters for spillovers and forward and backward linkages. As a result, there needs to be localised development policies. The government needs to incorporate regional development policies that promote and facilitate efforts to locate foreign and domestic firms in the same cities and regions within host economies to maximise the extent and impact of backward linkages.

7.2 POLICY RECOMMENDATION 2: IMPROVE TECHNICAL EFFICIENCY AMONGST BUSINESSES

It will also be important for businesses to optimise the use of technologies being adopted. Being an efficient and competitive producer does not require generating frontier technologies (though at a high level this is vital). It does, however, entail using technologies effectively. We can call this effective use 'technological capability' in a broader sense.

Improving technological capacity will require measures to strengthen firms' capabilities related to the effective deployment and use of technology, in particular the firms' management and organisational capabilities. Management and organisational capabilities are core competencies and critical inputs for innovation because the benefit of these competencies enable businesses to identify new technological opportunities, develop a plan to exploit the opportunities, and then cultivate the human resources necessary to execute the plan. Measures of management and organisational capabilities also seem to be missing in most innovation indices, even the Global Innovation Index.

To improve technical efficiency amongst businesses, it is critical to strengthen technology-support institutions. These include institutes on MSTQ (metrology, standards, testing and quality), R&D institutes (universities and research organisations) and SME-support agencies. In Vietnam there are many such support institutions. Unfortunately, a large number of these institutions function poorly with inadequate equipment, and poorly motivated and remunerated staff. Their services are often out of touch with the needs of the industrial sector and are offered passively. Yet once developed well, technology-support institutions can provide vital knowledge, information and services to private firms, particularly when the firms themselves are technologically capable and aware.

Moreover, programs to increase the awareness and capacity of managers and employees are also key for efficiency improvement.

7.3 POLICY RECOMMENDATION 3: PROMOTE R&D AND EMERGING INDUSTRIES TO LIFT UP THE TECHNOLOGY FRONTIER

R&D investment increases the capability for technology adoption and provides the opportunity for increasing technology creation as Vietnam develops. The most efficient focus for R&D efforts is in promoting technology adoption and adaptation across all industries and stages: importation, reverse engineering, adoption and adaptation.

At the moment, the proportion of R&D expenditure over total GDP in Vietnam is relatively low. In the future, Vietnam should increase investment in R&D, both from public and private sources. Favorable policies should also be developed to encourage business to invest more in R&D activities for both domestic and FDI firms.

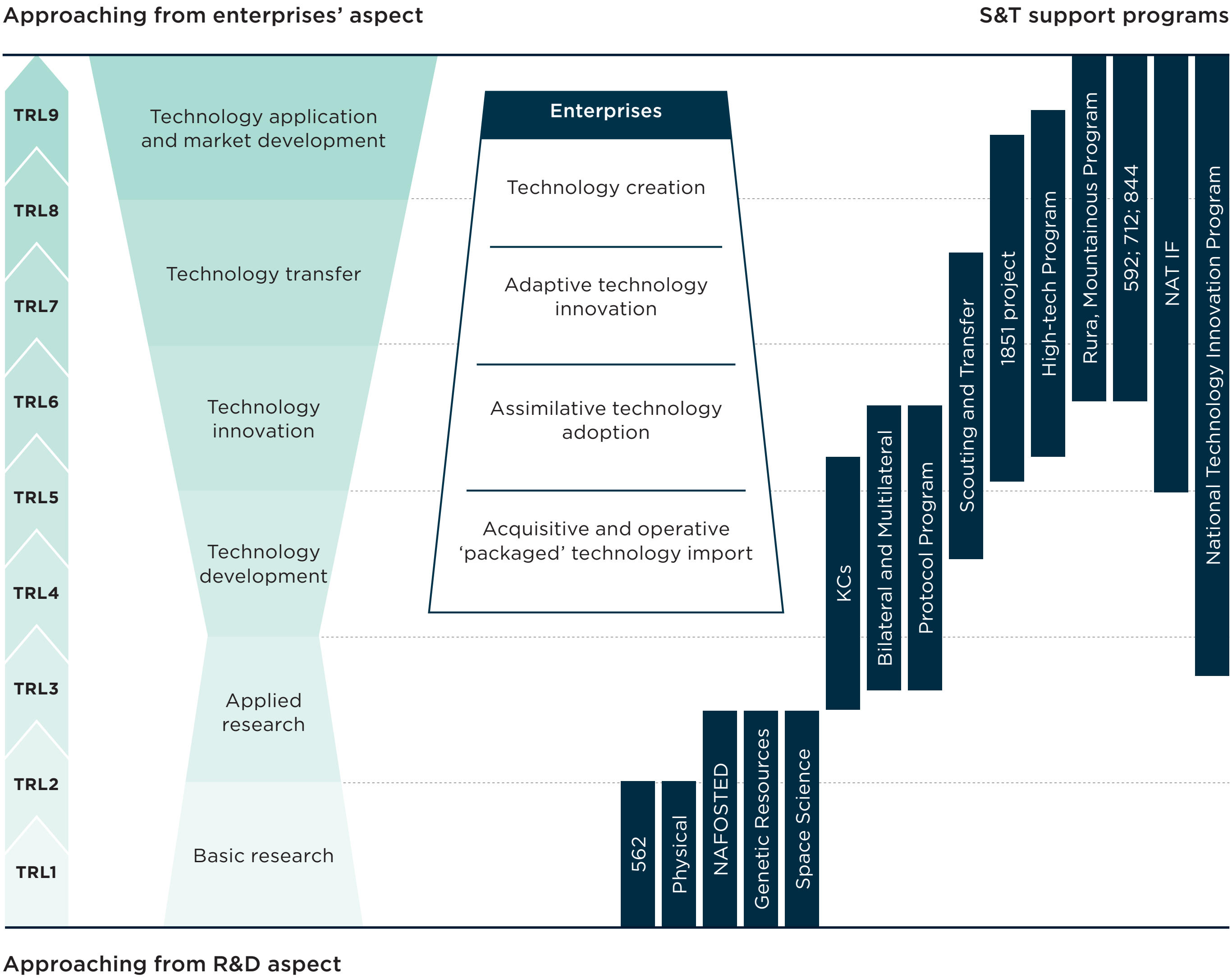
In Vietnam, various programs have been developed to support R&D across the country. A summary of these programs is shown in Figure 49.

Given limited resources, priority areas for R&D investment will need to be identified based on industries of greatest potential over the medium- to long-term. The priority areas would include both existing and emerging industries. R&D investment prioritisation will be the key for the country to leapfrog technological phases and avoid investing in increasingly redundant technologies and systems.

Support for industry clusters may also be considered. Industrial clusters are innovative environments. Geographic clusters of businesses in the same industry or clusters of organisations may offer complementary activities, enhanced by opportunities for training, development and collaborative research. This is an effective way to stimulate the spillover effect of technology adoption and creation across businesses.

Government support for industry clusters has had mixed results. However, the government can work with business and other stakeholders to develop a clear understanding of the sectors and technologies in which they have a comparative advantage, and select from these a small number of key priority areas on which to focus their investments for maximum impact.

IPR protection is another area that needs to be accounted for. Overall, Vietnam's IPR legislation is now relatively comprehensive, covering most aspects of the protection of IPR in accordance with international standards. However, the enforcement mechanisms still need to be strengthened, and more importantly, there needs to be policies to raise the awareness of the importance of IP protection among Vietnamese businesses.



NOTES:

KCs: Key Science and Technology Programs

NAFOSTED: Nation Foundation for Science and Technology Development

NATIF: National Technology Innovation Foundation

TRL: Technology Readiness Level

562: Basic Research Program

592: Development supporting program for S&T enterprises and government self-financial S&T organisations

712: Nation program to improve efficiency and quality of Vietnamese enterprises' products to 2020

844: Assistance policies on national startup ecosystem to 2025

Figure 49. R&D support programs in Vietnam

Source: Authors' review

7.4 POLICY RECOMMENDATION 4: DEVELOP HUMAN RESOURCES

The development of skills and human capability is a prerequisite for both technology adoption and technology creation. Skills can be developed via a variety of means: formal education; vocational training; on-the-job training; the importation of skills or movement of labour around regions. The relative importance of these sources varies by the economic structure, the nature of knowledge being utilised and the level of development or technology adoption capabilities of businesses.

Different technology adoption levels also require different local skill levels. In general, businesses that import 'packaged' and simple technologies may find it easier to transplant to a new setting. Using the technology effectively only requires training local employees in the necessary operational procedures. There is little local skill needed and little new learning generated.

In contrast, the adoption of a complex new engineering technology in an unpackaged form, with capital goods and licenses, may require substantial effort from local engineers and managers and may need to be supported by high levels of local content. This requires a high initial base of capabilities, entails a lot of technological and skill creation effort, and generates considerable new learning opportunities.

Countries with most firms at the initial stage of technology adoption may require basic schooling and literacy to absorb simple industrial technologies, while higher education becomes important as more complex knowledge is tackled and businesses move toward adoption and creative imitation. Industry 4.0 technologies, for example, require STEM (science, technology, engineering and mathematics) and a broad base of skills on the shopfloor. They also require highly trained technical personnel.

As such, the first step for policy makers is to evaluate the current skill levels, the skill levels needed (based on the intended technology adoption), and the gap between the two that would need to be remedied. This requires a thorough investigation at the enterprise and industry level, accompanied by an assessment of the capabilities, staffing, curricula and facilities in teaching institutions.

There may also be a need for a good competitiveness strategy that would entail the continuous monitoring of skills gaps, with industry working closely with education organisations to establish priorities and develop curricula.

7.5 POLICY RECOMMENDATION 5: DEVELOP POLICY INSTRUMENTS AND IMPLEMENTATION MECHANISMS TO SYNTHESISE AND STIMULATE TECHNOLOGY DEVELOPMENT EFFORTS

According to the Innovation Survey by the World Bank, a lack of government support is one of the three most important factors obstructing firms in their efforts to innovate.[40] Most current policy instruments are S&T infrastructure, regulations, training on operating skills, and industrial standards. Policy instruments like financial incentives in terms of matching-grants for developing advanced engineering, product design, product/process/marketing innovations and R&D, like those in Korea, Taiwan and Singapore, are needed.

In addition, Cirera and Maloney (2017) point out that in order for businesses to move towards the technological frontier, it is necessary to create a fully functional national innovation system (NIS).[14] A fully functional NIS will develop through strategies to link policies to implementation across ministerial portfolios and across both the public and private sectors.

Vietnam has a fragmented NIS. In Vietnam, various policies and programs have been developed to accelerate technology adoption across business in Vietnam (a brief summary can be found in Figure 50).

As in most countries, the responsibilities and functions that affect technology adoption in Vietnam are scattered over an array of ministries and institutions: finance, trade, industry, labour, education, science and technology and others. These ministries and institutions often have different objectives and do not communicate with each other on a regular and intimate basis.

In Vietnam, it is very important to align innovation policies with strategies for industry, import and export and national competitiveness in the medium and long term. There also needs to be co-ordination among national research and innovation programs to prevent duplication among similar national programs.

A shift in economic focus to productivity and technology also requires a regulatory shift. Vietnam needs not only to develop comprehensive policies but also to strengthen the implementation of the policies to ensure the consistency, synchronism and responsiveness across implementing agencies.

To better align the innovation activities across the various government ministries, the government may consider conducting a number of technology 'foresight' programs aimed at determining the future role of science and technology in Vietnam and the necessary steps needed to achieve a strong NIS. These programs may encourage participation from all parties concerned with science and technology – industrial leaders and researchers in academia, services, financial institutions and the government – and determine the driving forces of change and create scenarios for the future. A number of developing countries, including India, Korea, Thailand and several Latin American countries, are conducting similar exercises.

The main advantage of such a foresight exercise is that the process itself creates awareness of the current state of technology adoption in the country, identifies emerging global trends, and assists in gaining a greater understanding of the implications for national competitiveness and priorities. A foresight exercise may also help evaluate the strengths and weaknesses of the national innovation system and build consensus on what may be done, which, in turn, may mobilise resources and raise commitments.

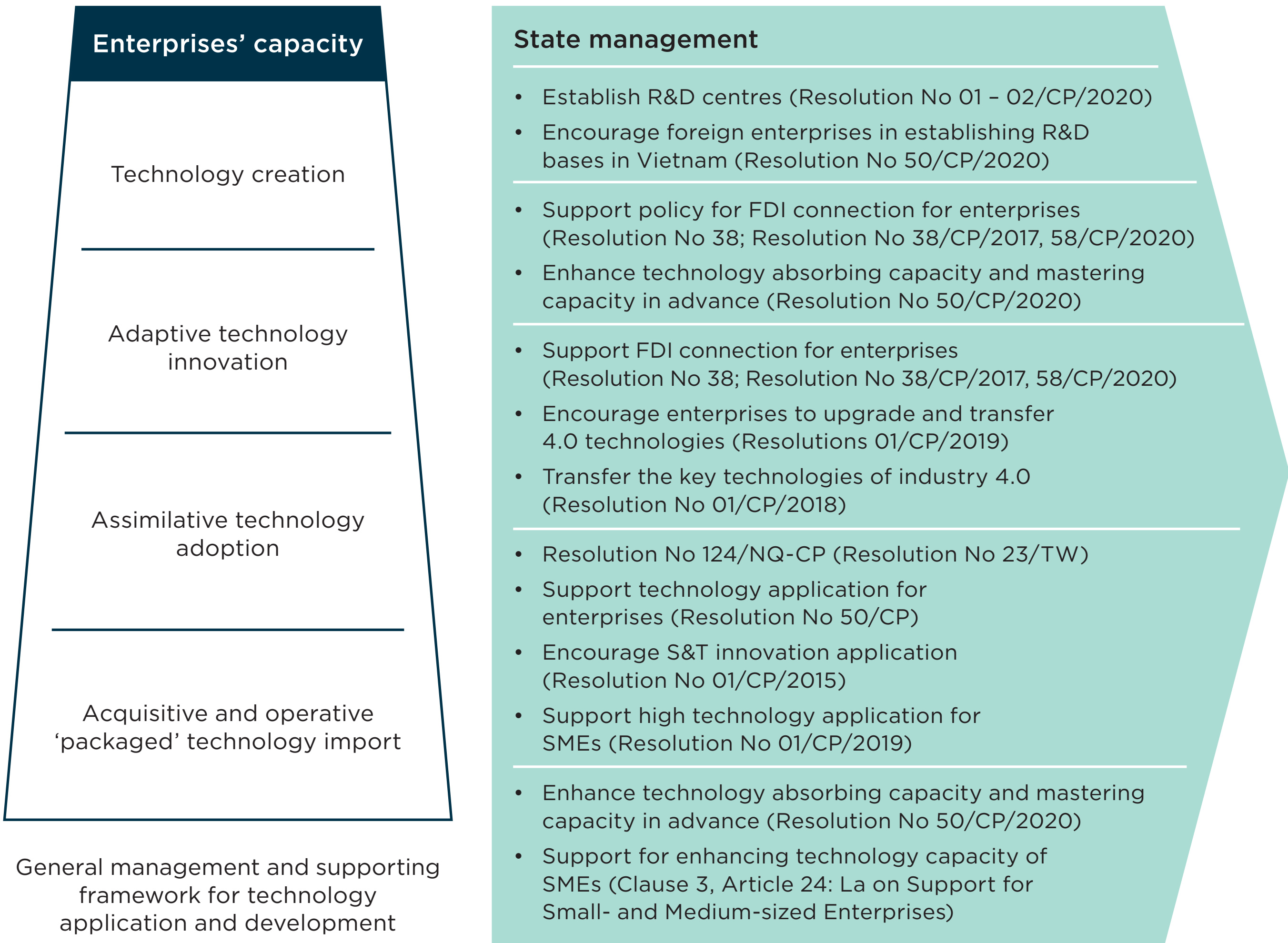


Figure 50. Different programs to support technology development in Vietnam

Source: Authors' review

Another critical issue is to strengthen the government's capabilities for implementation. As the economy and technology development process becomes increasingly complex, the government needs to develop in sync, and strengthen its own capabilities for effective implementation and for delegation to and co-operation with other actors. Implementation will only be pursued effectively if all related agencies consider implementation to be in their personal and professional interests.

There needs to be strong commitments, transparent and detailed regulations together with a monitoring and evaluation system to ensure the effective implementation of innovation policies. This will improve social trust to further encourage organisations, businesses and talents to invest in innovation.

Capacity building within implementing government agencies should be given a high priority as well. It is important to build capacity not only at the national level. Local-level agencies are quite important to implement policies in Vietnam. More significant budgets should be given to these agencies to enhance the skills of their personnel, employ more staff with updated technical backgrounds, improve performance incentives, and restructure outdated organisational work processes.

The Chinese experience

The medium-long-term strategic plan for China's science and technology development aims to achieve three strategic objectives:

- Create an economy based on innovation by focusing on developing indigenous innovation capabilities
- Develop and strengthen the innovation capabilities of Chinese enterprises
- Achieve breakthroughs in strategic development and fundamental research.

To achieve the above goals, the State Council has developed a new policy package that includes the following four pillars:

- **Strengthening financing packages for R&D activities:** This is not only through state funds but also through extensive tax incentives for S&T activities. It also includes government support activities for the development of financial tools for the financial market, and state funds to support the adoption of imported technologies.
- **Promoting innovation activities through legislative reform and standards:** This is through promoting the protection of IPRs, actively participating in the development of international standards on technology, and building infrastructure for R&D activities including key laboratories, science parks and technology business incubation centres.
- **Promoting the development of S&T human resources:** This is through training scientific leaders and talents, participating in programs for global science and technology, human resources including overseas nationals, reforming vocational and higher education systems, and raising public awareness about innovation and innovation activities.
- **Improving the management of state R&D activities:** This is by introducing a new evaluation system and strengthening co-ordination within the policy system.

These four policy pillars are the convergence of Chinese Government policies and policies of OECD countries.

Similarities can be found in Vietnam's policies including tax incentives for technology business incubation and science parks in universities, policies to encourage accelerated depreciation of equipment and machinery for R&D activities, and improvements in IP protection. The policy to acquire technology is seen as a tool to promote technology innovation and product innovation activities in China.

POSSIBLE ACTIONS FOR THE VIETNAMESE GOVERNMENT TO CONSIDER:

1.

Target investment and FDI policy to ensure greater levels of technology transfer to local firms.

2.

Implement programs to improve absorptive capabilities and awareness of domestic firms to adopt technologies in businesses.

3.

Upgrade production capability and efficiency through quality management tools (i.e. Kaizen, Lean, Six Sigma), and fast track the introduction of industrial and technical standards in factories (e.g. ISO).

4.

Increase the awareness and adoption of efficiency/productivity enhancement tools for management and business.

5.

Create a comprehensive database and a systematic methodology to prioritise R&D investment.

6.

Monitor innovation and technology adoption and identify clusters and emerging industries, possibly through the use of an industry mapping platform.

7.

Strengthen IPR protection through increasing IPR consultancy and IPR management.

8.

Improve the technology commercialisation process through strengthening the linkage between research and businesses.

9.

Select leading technology performers as technology models to show others how technology can be improved or developed locally and how it helps to build competitiveness.

10.

Incentivise R&D from the private sector (i.e. through matched funding) to accelerate participation of the private sector in R&D activities.

11.

Evaluate the current skill levels as well as create education–industry panels to inform skills development over the medium-long term to create education and training strategies.

12.

Attract foreign researchers/experts, especially Vietnamese experts who are currently living in foreign countries.

13.

Enhance the skills of the science and technology labour force through short-term training programs and on-the-job training.

14.

Undertake foresight exercises to identify specific areas of development, bring parties together, mobilise resources and raise awareness of the current state of technology adoption and creation in Vietnam.

15.

Develop a database on technology adoption and creation, especially firm-level information, through a requirement for technology information for business tax declaration or through the business survey by the GSO.

16.

Further improve the two economic models developed in the project using new data available.

8 Conclusion

VIETNAM AND A TIME TO SHIFT ECONOMIC FOCUS

Vietnam has made remarkable economic advancement over the last four decades to become a lower-middle-income country with high rates of inclusive growth. The path for Vietnam from lower-middle-income status to high-income status, however, will not be easy. In particular, those lower-middle-income countries that have successfully achieved high-income status in comparatively short periods of time have strategically switched their focus from export market development and capital accumulation to increasing TFP across all industries (Figure 51).

Similarly, if Vietnam is to sustain high GDP growth and improve income levels for citizens on a path to national high-income status, there will need to be a progression beyond being a low-cost labour market with a heavy reliance on FDI for export growth and capital accumulation. Economic advancement will require a shift in focus to enhance TFP and technology-driven efficiency.

Lower-middle-income country

- Low cost labour market for manufacturing and other low-skilled labour-intensive industries
- A large proportion of the population employed in agriculture
- Increasing capital accumulation and enabling infrastructure
- Increasing urbanisation
- Population-wide education and health services
- Enabling transport, water and communication infrastructure

→

Actions required for economic advancement

- Industry policy to improve total factor productivity through technology adoption
- Improvements in infrastructure and public social services
- Investment in higher level education across the population
- Development of local innovation systems and IP protections
- Greater service sector employment
- Macro-economic controls to limit inflation

→

Upper-middle-income country

- Increasing technology-intensive industry and government services with higher levels of productivity
- Increasing skilled and service industry employment
- Adoption of best-practice technologies and systems
- Higher levels of capital accumulation
- Lower proportion of the population employed in agriculture
- Technology transfer through FDI-funded industry

Figure 51. Actions required for economic advancement to upper-middle-income status

Source: Authors' illustration

TECHNOLOGY ADOPTION IS THE KEY TO MOVE FORWARD

Total productivity growth, driven by technological intensification, is increasingly recognised as the growth pathway for developing countries like Vietnam.

The results of the conditional frontier model show that the greatest economic gains in Vietnam can be made through technology adoption and adaptation. Adopting and copying technologies from more advanced nations will provide greater spending efficiency at Vietnam's current stage in development compared to pouring funds into the development of expensive new-to-world technologies.

Still, in recent years, the new wave of digital technology is changing the processes of technology development, accelerating the rate of technological change. The COVID-19 pandemic and other future pandemics have also increased the importance of digital preparedness and thus the requirement for adopting more sophisticated technologies at a much faster pace.

As such, Vietnam will also need to increase the investment in technology creation and development over the coming decade. R&D-related investment amongst businesses will also be the key to upgrading their capabilities in adopting frontier technologies and leapfrogging older technologies. The dynamic stochastic general equilibrium model in the report also proves the long-term impact of R&D investment on the economic growth of Vietnam. Active innovation through domestic R&D is crucial for successful technological catch-up.

ACTIONS TO FACILITATE TECHNOLOGY DEVELOPMENT

Research has shown that the low technology development activity observed in developing countries is not due to some irrationality of firms and governments. Rather, barriers to technology adoption are significantly higher for developing economies, and this has a significant impact on technology development levels. Fostering technology development in developing countries, thus, requires a reconsideration of innovation policies in order to construct a functional national innovation system and build private-sector capability. These policies must be tailored to the local economic conditions. Moreover, the focus of the country in terms of technology development must change to suit the various stages of development.

The actions listed in this report provide ideas for Vietnam's policy makers and heads of industry to consider as they tackle investment decisions for the next phase of development.

Technology adoption and creation is key to Vietnam maintaining rapid and sustainable growth. It will also allow Vietnam to leapfrog to the next phase of development. Strong leadership and institutions will be critical to Vietnam's ability to grab these opportunities and unblock bottlenecks to further economic development.

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Appendix A
Conditional frontier model to capture impact of technology adoption and technological change in economic growth

A.1 OVERVIEW

In this brief document, we highlight the methodology used to analyse the economic growth trends of the Vietnamese economy. We used firm level data based on the 2- digit industry classification for this analysis.* We propose an aggregation of the output per worker of the sectors into economy-wide productivity growth. This aggregation allows us to decompose the overall economy output per worker growth into various components. The first component is a shift of the workforce across sectors. The other components include an aggregation of effects that happen at the industry level: a capital deepening component, a technical change component, a technical efficiency component and an embodied technical change component. The analysis follows the analytical model outlined in Filippetti and Peyrache (2013).[60]

A.2 CONDITIONAL FRONTIER MODEL

Consider $n = 1,\ldots,N_{jt}$ firms in industry $j = 1,\ldots,J$, in time period $t = 1,\ldots,T$, (this is a possibly unbalanced panel). Y^{jt} is the $1 \times N$ vector of output; K^{jt} is the $P \times N$ matrix of inputs (where P is the number of inputs; in our case capital); Z^{jt} is the $K \times N$ vector of conditioning technological variables (where K is the number of variables; in our case capital investment); and L_{jt} is the $1 \times N$ vector of labour quantities (total number of full time equivalent employees). The time index means that each one of these matrices is observed in each time period $t = 1,\ldots,T$; while the industry index means that there is such a panel dataset for each industry j. The panel does not need to be balanced and in fact in our empirical application it is not. The dataset is therefore represented as:

$$\left(\boldsymbol{Y}^{jt}, \boldsymbol{L}^{jt}, \boldsymbol{K}^{jt}, \boldsymbol{Z}^{jt}\right),\ t = 1,\ldots,T,\ j = 1,\ldots,J \tag{1}$$

If we normalise the dataset by the quantity of labour (i.e. we divide all variables by the quantity of labour of each observation), then we can consider variables in their intensive form (we use capital letters for the extensive form and lower case letters for the intensive form):

$$\left(\boldsymbol{y}^{jt}, \boldsymbol{k}^{jt}, \boldsymbol{z}^{jt}\right),\ t = 1,\ldots,T,\ j = 1,\ldots,J \tag{2}$$

where $y_n^{jt} = Y_n^{jt} / L_n^{jt}$, $k_n^{jt} = K_n^{jt} / L_n^{jt}$ and $z_n^{jt} = Z_n^{jt} / L_n^{jt}$. Since there is only one output, y_n^{jt} is the output per worker of firm n in industry j in time period t. Similarly, k_n^{jt} is the capital per worker of firm n in industry j in time period t. Therefore, the model is simplified to the production of output per worker by means of capital per worker. Capital per worker is a measure of the capital intensity of the firm and output per worker is a measure of labour productivity. If output per worker is aggregated from the firm level to the industry level and then the whole economy (as we shall do in a moment), then the result of this aggregation will be to look at the Gross Domestic Product (GDP) per worker of the economy which is a key variable to check the state of the economy.

We started the selection of variables by looking at a large pool. To run the model we need to account for a measure of output, some measure of inputs and technological capabilities. In this model, the gross revenue is used as a proxy for output. We include the number of employees and assets as the two main inputs. We include both variable and fixed assets as the proxies for two types of capital). Development fund is used as a proxy for technology adoption effort.

* We follow GSO and use VSIC1993 to classify industries.

In order to obtain an aggregate measure of the labour productivity of each industry we will make use of the average values of the previous variables for each industry (see Forsund and Hjalmarsson, 1979).[61] The industry average output is (we use an upper bar in the notation to mean that it is the mean across firms):

$$\overline{\boldsymbol{Y}}^{jt} = \frac{1}{N_{jt}} \sum_{n} Y_n^{jt} \tag{3}$$

The industry average input is:

$$\overline{\boldsymbol{K}}^{jt} = \frac{1}{N_{jt}} \sum_{n} \boldsymbol{K}_n^{jt} \tag{4}$$

The industry average technological capability is:

$$\overline{\boldsymbol{Z}}^{jt} = \frac{1}{N_{jt}} \sum_{n} \boldsymbol{Z}_n^{jt} \tag{5}$$

If we were to express these quantities in their intensive form (normalising by the labour quantity), then the industry average labour productivity would be:

$$\overline{y}^{jt} = \frac{\sum_n Y_n^{jt}}{\sum_n L_n^{jt}} = \sum_n \frac{Y_n^{jt}}{L_n^{jt}} \frac{L_n^{jt}}{\sum_n L_n^{jt}} = \sum_n w_n^{jt} y_n^{jt} \tag{6}$$

and the industry capital intensity:

$$\overline{k}^{jt} = \frac{\sum_n K_n^{jt}}{\sum_n L_n^{jt}} = \sum_n \frac{K_n^{jt}}{L_n^{jt}} \frac{L_n^{jt}}{\sum_n L_n^{jt}} = \sum_n w_n^{jt} k_n^{jt} \tag{7}$$

Where $w_n^{jt} = L_n^{jt} / \Sigma_n L_n^{jt}$ is the labour share of firm *n* in industry *j* in time period *t*. We consider the average firm to be the benchmark against which we measure productivity change and use a constant returns to scale reference technology for the variables in extensive form, which corresponds to a non-increasing returns to scale technology for the variables in intensive form.

The first quantity we want to compute is the output shortage due to unconditional technical efficiency (TE) and it is calculated as:

$$TE^{jt} = D^{jt}\left(\overline{x}^{jt}, \overline{y}^{jt}\right) \quad \begin{array}{ll} \max & \beta \\ s.t. & x^{jt}\lambda \leq \overline{x}^{jt} \\ & y^{jt}\lambda \geq \overline{y}^{jt} + \beta \\ & 1_N \lambda \leq 1 \end{array} \tag{8}$$

We use the shortage function in its intensive form since it represents the maximal expansion of the industry labour productivity given the current resources. The conditional technical efficiency score (CE) is calculated as:

$$CE^{jt} = D^{jt}\left(\overline{x}^{jt}, \overline{y}^{jt}\right) \quad \begin{array}{ll} \max & \beta \\ s.t. & x^{jt}\lambda \leq \overline{x}^{jt} \\ & y^{jt}\lambda \geq \overline{y}^{jt} + \beta \\ & z^{jt}\lambda \leq \overline{z}^{jt} \\ & 1_N \lambda \leq 1 \end{array} \tag{9}$$

The impact of the conditioning variables is $ZE^{jt} = TE^{jt} - CE^{jt}$. These two effects are represented in Figure 1 and Figure 2.

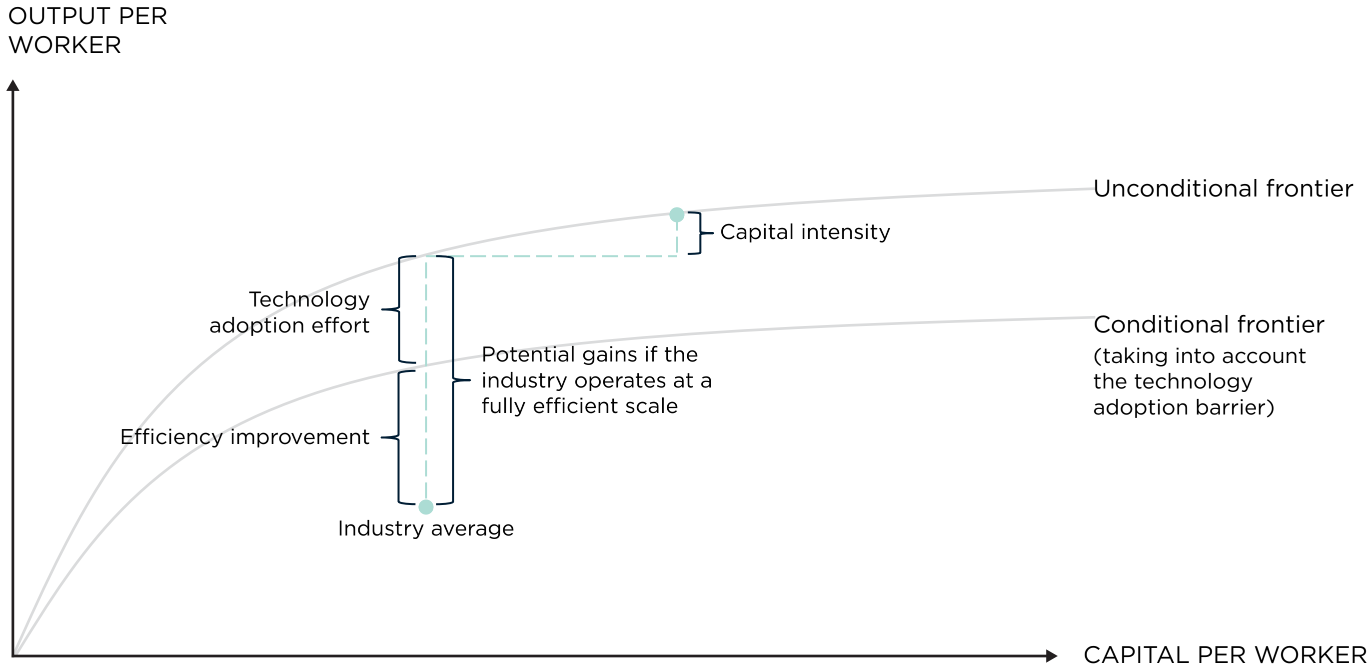

Figure 1. Conditional frontier static model

Source: Filippetti and Peyrache (2013)[60]

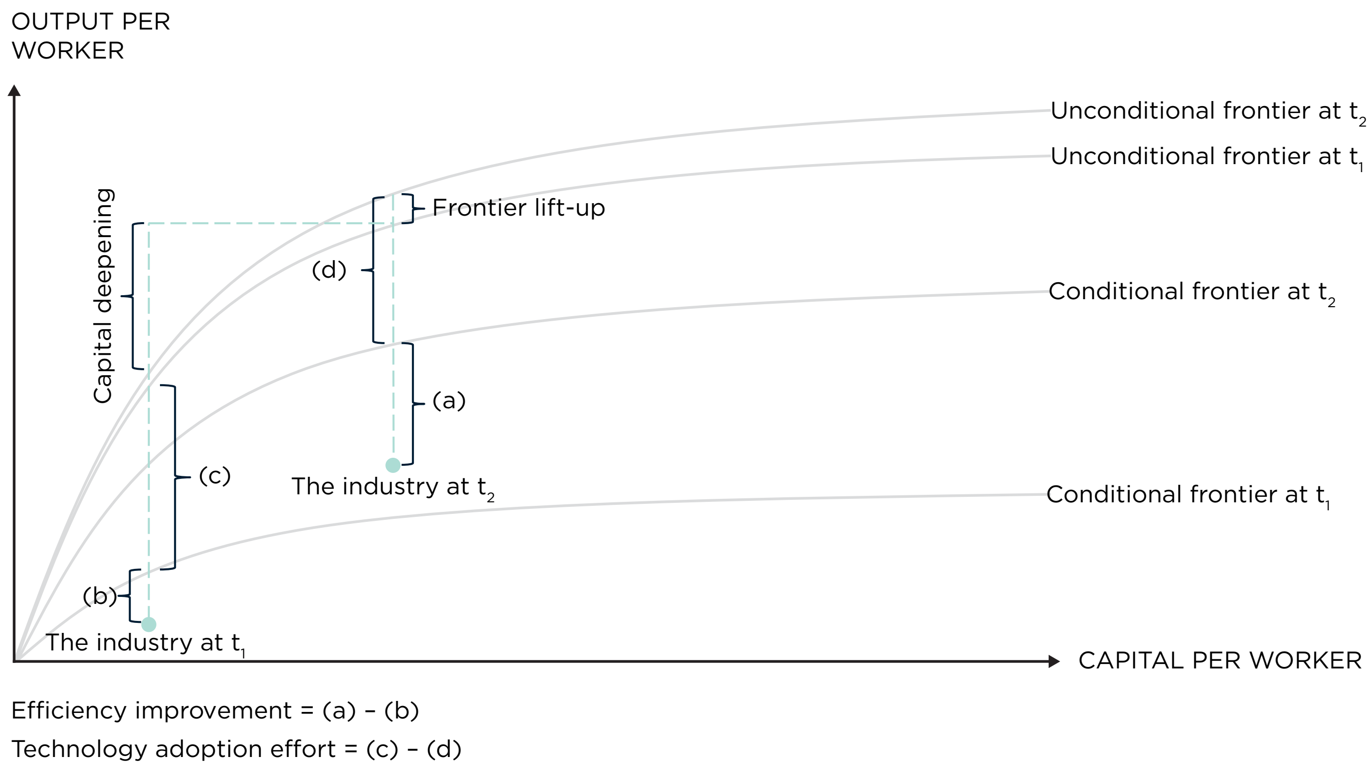

Figure 2. Conditional frontier dynamic model

Source: Authors illustration

There are two frontiers to which we project the average firm of the industry. The conditional frontier is the one that takes into account the level of the technological variables *z*. The unconditional frontier is the one that assumes that the level of these technological variables is already optimal in order to boost labour productivity. Any shortage of output due to the technological variables *z* is accounted as a shift in the conditional frontier relative to the unconditional frontier. The interpretation of the previous quantities is straightforward, since it is in terms of the output per worker loss. For example, if $TE^{jt} = 100$ this means that the labour productivity (intended as output per worker) of that industry could be increased by 100 units, if the industry were to be reorganised efficiently and all its firms were operating on the efficient frontier. This component includes two main effects: the first effect is connected to the labour productivity level of the firms that operate in the industry; the second effect is connected to the efficient allocation of the capital endowment of the industry across the different firms (to exploit economies of scale). These two effects are accounted for into a single number TE^{jt}. This technical efficiency effect is static and we should look to what happens when time lapses.

We represent these changes in Figure 1 and 2. In Figure 1, the average firm of industry A is represented with a star and is compared to Industry B. If we compare this average firm with firms of similar capital-labour ratio and similar values of technological capabilities, then the industry is projected to the industry conditional frontier. This projection accounts for industry inefficiencies, such as misuse of resources or a firm size distribution that does not make efficient use of economies of scale and allocation of resources. This efficiency effect represents the potential gain in output that would be possible if the industry were to be reorganised efficiently. On the same Figure, we can benchmark Industry A to firms in the industry that have an optimal level of technological capabilities. Since technological capabilities are assumed to have a non-negative effect on production, the unconditional frontier will be composed by firms that have the highest level of technological capabilities. This is the group of firms in the industry that makes the best use of technology. The gap between the unconditional and the conditional frontiers is called a technological gap. This means that if industry A were to adopt the same level of technology as the best firms in the industry, then the output of the industry would be increased by a quantity equal to this technology gap between the unconditional and the conditional frontier. Finally, the movement along the unconditional frontier towards industry B implies an increase in the capital intensity of the industry (the capital-labour ratio). Therefore, the gap between the level of production of industry B and the level of production of industry A (after projection onto the unconditional frontier) represents a capital deepening effect. The three components sum up to the total output gap between Industry A and Industry B.

In Figure 2 the dynamic model is represented. Here we are comparing the same industry in two different time periods in terms of the change in the output per worker. Industry A in time period *t* can be projected onto its own unconditional frontier, represented by $\mathrm{T}(t)$. When we look at the same industry in time period $t+1$, the overall difference in the output per worker can be ascribed to three different components. First, there is the movement due to the projection of industry A in time period *t* onto the unconditional frontier of time period *t* $\mathrm{T}(t)$. Second there is the shift in the unconditional frontier itself due to technical change. This accounts for any improvement in the efficiency of production over time. Finally, there is a component associated with capital deepening, which is represented as a movement along the unconditional frontier. It should be noted that these components are not necessarily positive, since, for example, an industry may fall behind compared to its own best practice firms: this would entail a negative technical efficiency change component.

In order to account for changes in output per worker, we should resort to the Luenberger indicator (see, for example, Briec and Kerstens, 2004). The Luenberger productivity indicator nicely decomposes into meaningful components and therefore it is a good tool in the analysis of the main components of productivity change. The Luenberger productivity indicator for the industry between time *t* and time *t*+1 is computed using the following two programs:

$$
\begin{aligned}
D^{j,t+1}\left(\overline{x}^{jt},\overline{y}^{jt}\right) = \quad & \max \quad \beta \\
& s.t. \quad x^{j,t+1}\lambda \leq \overline{x}^{jt} \\
& \qquad\; y^{j,t+1}\lambda \geq \overline{y}^{jt} + \beta \\
& \qquad\; 1_N\lambda \leq 1
\end{aligned}
\tag{10}
$$

$$
\begin{aligned}
D^{jt}\left(\overline{x}^{j,t+1},\overline{y}^{j,t+1}\right) = \quad & \max \quad \beta \\
& s.t. \quad x^{jt}\lambda \leq \overline{x}^{j,t+1} \\
& \qquad\; y^{jt}\lambda \geq \overline{y}^{j,t+1} + \beta \\
& \qquad\; 1_N\lambda \leq 1
\end{aligned}
\tag{11}
$$

The Luenberger productivity indicator in time period *t*+1 represents the change in labour productivity due to an increase of the productive efficiency of the industry (either via technical efficiency change or technical change) between time period t and time period *t*+1, and it is computed as:

$$
\begin{aligned}
PC^{j,t+1} = & \frac{1}{2}\left[D^{j,t+1}\left(\overline{x}^{jt},\overline{y}^{jt}\right) - D^{j,t+1}\left(\overline{x}^{j,t+1},\overline{y}^{j,t+1}\right)\right] \\
& + \frac{1}{2}\left[D^{jt}\left(\overline{x}^{jt},\overline{y}^{jt}\right) - D^{jt}\left(\overline{x}^{j,t+1},\overline{y}^{j,t+1}\right)\right]
\end{aligned}
\tag{12}
$$

The interpretation of the productivity indicator is in terms of the absolute increase or decrease in the labour productivity of the industry due to two main components: the increase in the efficiency of the industry itself; and a component due to the shift of the production frontier, i.e. a technical change component. For example, if $PC^{j,t+1} = 10$, this means that without changing the capital per worker of the industry (therefore keeping other things constant), the output per worker of the industry has increased by 10 units between time period *t* and time period *t*+1. Since we know that the only two sources of this change are the efficiency of the industry and the technical change component associated with a shift in the efficient production frontier, we can follow the now standard decomposition of this indicator into these two main effects.
The productivity indicator can be decomposed into a technical efficiency change component (TEC):

$$TEC^{j,t+1} = D^{jt}\left(x^{jt},y^{jt}\right) - D^{j,t+1}\left(x^{j,t+1},y^{j,t+1}\right) \tag{13}$$

and a technical change component (TC)

$$
\begin{aligned}
TC^{j,t+1} = & \frac{1}{2}\left[D^{j,t+1}\left(x^{jt},y^{jt}\right) - D^{jt}\left(x^{jt},y^{jt}\right)\right] \\
& + \frac{1}{2}\left[D^{j,t+1}\left(x^{j,t+1},y^{j,t+1}\right) - D^{jt}\left(x^{j,t+1},y^{j,t+1}\right)\right]
\end{aligned}
\tag{14}
$$

The interpretation of these two numbers is similar to the one provided by the Luenberger productivity indicator and they signal the number of additional units of productivity that the industry was able to increase between time period *t* and time period *t*+1. This means that for each industry *j* in each time period $t = 1,\ldots, T-1$

$$PC_{j,t+1} = TEC_{j,t+1} + TC_{j,t+1}$$

The technical efficiency change component can be further decomposed into the conditional and unconditional efficiency components:

$$
\begin{aligned}
TEC^{j,t+1} &= \left(CE^{jt} - CE^{j,t+1}\right) + \left(ZE^{jt} - ZE^{j,t+1}\right) \\
&= \Delta CE^{j,t+1} + \Delta ZE^{j,t+1}
\end{aligned}
\tag{15}
$$

These two components represent the contribution of the accumulation of technological capabilities as represented by the change in the conditional score ($\Delta ZE^{j,t+1}$) and the change in the efficiency of operation of the industry ($\Delta CE^{j,t+1}$). The overall decomposition of the industry productivity change is:

$$PC^{j,t+1} = TC^{j,t+1} + TEC^{j,t+1} = TC^{j,t+1} + \Delta CE^{j,t+1} + \Delta ZE^{j,t+1} \tag{16}$$

To summarise, the labour productivity of the industry will benefit from: the shift in the production frontier between the two time periods, as measured by the technical change component $TC^{j,t+1}$; the increase in the efficiency of operation of the industry $\Delta CE^{j,t+1}$ due to increases in the firm productivity and a better configuration in terms of scale economies; the more widespread use of technological equipment and technological capabilities as measured by $\Delta ZE^{j,t+1}$.

Although the previous decomposition already provides a number of insights in the productivity trends of each industry, we shall add an additional component connected to the deepening of capital. When new capital investment takes effect, the capital intensity (capital per worker) of the industry increases and one expects that this will increase the labour productivity (output per worker) of the industry by using the substitution possibilities that exist between capital and labour. Output per worker will benefit from an increase in productivity as much as by an increase in the capital intensity of the industry (i.e. capital per worker). Since we compute productivity change via the Luenberger indicator, the residual change in output per worker will be due to a deepening of capital (i.e. an increase in the capital per worker, or capital intensity of the industry). Output per worker change for industry *j* between time period *t* and time period *t*+1 is:

$$\begin{aligned} \overline{y}^{j,t+1} - \overline{y}^{jt} &= PC^{j,t+1} + KD^{j,t+1} \\ &= TC^{j,t+1} + TEC^{j,t+1} + KD^{j,t+1} \\ &= TC^{j,t+1} + \Delta CE^{j,t+1} + \Delta ZE^{j,t+1} + KD^{j,t+1} \end{aligned} \tag{17}$$

This means that any increase in labour productivity can be ascribed either to a deepening of capital or to an increase in the productivity of the industry. Since the left-hand side of this equation represents the absolute change in the labour productivity of the industry, the right hand side is expressed in the same unit of measurement, i.e. the number of units of increase in the value added per worker.

Adding gross value added across all industries in the economy will provide the GDP of the economy. GDP per worker is a key indicator underpinning the material growth of the economy and the sustainability of a high standard of living. Clearly all the critical issues associated with the use of GDP as a measure of welfare apply here. We also should notice that the denominator does not take into account either working rights or job satisfaction of workers. This means that two countries with the same level of labour can have very different welfare outcomes if workers have very different job satisfaction. This is to say that both the numerator and denominator of this ratio are a very crude measure of the materialistic welfare of a nation which is rooted into the national accounts.

A.3 DATA SOURCE AND VARIABLE SELECTION

A.3.1 DATA SOURCE

The data of the analysis comes from the Business survey from the General Statistic Office of Vietnam (GSO). The Enterprise Survey was conducted by GSO and its sub-institutions to collect information on enterprises operating in Viet Nam at the end of each year since 2000.

This is a firm-level survey of a representative sample of an economy's private sector across all geographic regions. These include enterprises established and regulated by the Enterprise Law; Cooperatives society/co-operatives union/people's credit funds operating under the Cooperative Law and established enterprises which are subjected to the regulation of specialised laws such as Law on Insurance and Law on Securities.

The Enterprise Census only covers formal enterprises in Viet Nam. The household business sector, comprising unregistered household enterprises, is large in terms of number and estimated at nine million. It contributes an estimated 23 percent of GDP (Doumer et al. 2017). However, the collection of data on household businesses was not conducted by GSO systematically. Therefore, the household business sector was not included in this study and analyses results in this report are only representative for the formal enterprise sector.

Since data in the project is collected from various sources, noise and errors are typically present in the data, especially for micro data. The data cleaning process detects, validates, corrects or removes any inaccurate, incomplete or irrelevant data to make the data consistent and relevant for the purpose of the analysis. In this project, we have conducted the following data cleaning steps:

- Generate variables that have consistent value across years: the questionnaires were changed across years. This step includes screening all the questionnaires of the survey and making sure that the values are consistent across years (through adding/subtracting values of sub-indicators or transforming data like taking the absolute value)
- Match the sector code (VISIC 1996 and VSIC 2007) and provincial code (before and after 2004) to create a longitudinal dataset
- Remove unwanted observations: these include duplicated observations (i.e. firms with duplicated tax codes), observations with unrealistic values (i.e. firms with a negative number of employees or total assets smaller or equal to total fixed asset), observations with incomplete information (i.e. firms without a tax code, firms without revenue, labour information)
- Outlier detection: since most data in the dataset is highly skewed, the outliers cannot be detected through normal methods such as the box-and-whisker method. The Hiridoglou and Berthelot method is used with the thresholds to be determined according to each variable.**
- Correlation check: the numerical data was pairwise tested for cross-correlation and none of investigated pairs had a correlation that exceeded 0.9

In total, the sample covers 4.54 million observations for 19 years from 2001 to 2019. The statistic summary of the data at the national level is in **Table 7**. Detailed description of the data by industries are in the supplementary excel file. In total, about 6% of observations were removed.

** Further treatment for outliers is specified in the model description above.

Table 7. National statistics summary table by year, 2001-2019

YEAR	VARIABLE	N	MEAN	STANDARD DEVIATION	MEDIAN	MIN	MAX	RANGE	SKEW	KURTOSIS
2001	Output	38181	2953.81	21473.57	212.11	-73117.41	1854145.36	1927262.77	34.70	2008.71
	Labour	38181	80.00	387.57	9.00	1.00	23200.00	23199.00	24.78	994.00
	Fixed_asset	38181	7418.61	79865.58	311.93	0.00	10526062.59	10526062.59	72.64	8349.95
	Shortterm_ asset	38181	31605.69	991808.83	1709.35	4.16	116992396.90	116992392.74	109.26	12258.10
	Development_fund	38181	1491.04	60743.08	0.00	0.00	11441062.71	11441062.71	176.09	32969.15
2002	Output	46865	2968.19	21049.47	236.00	-94392.57	2121596.09	2215988.66	38.59	2716.02
	Labour	46865	76.78	418.87	10.00	1.00	44475.00	44474.00	43.14	3398.63
	Fixed_asset	46865	8338.97	70736.78	480.36	0.00	4793791.84	4793791.84	33.67	1641.04
	Shortterm_asset	46865	33337.12	1161407.74	2088.52	2.09	154211518.24	154211516.15	122.11	15270.07
	Development_fund	46865	2538.31	22440.67	8.35	0.00	2323649.57	2323649.57	47.90	3572.51
2003	Output	59809	2929.83	21641.81	251.43	-152360.09	2134097.22	2286457.30	43.15	3221.72
	Labour	59809	71.84	405.31	10.00	1.00	45473.00	45472.00	50.05	4370.09
	Fixed_asset	59809	7662.82	66914.39	466.66	0.00	5164519.32	5164519.32	37.03	2062.04
	Shortterm_asset	59809	31472.01	1247108.26	2196.51	2.01	204469330.81	204469328.80	141.90	20745.21
	Development_fund	59809	3931.86	184533.35	46.26	0.00	44068224.76	44068224.76	228.48	54377.33
2004	Output	69145	3058.59	25723.78	276.68	-202820.44	2821901.53	3024721.97	53.44	4529.21
	Labour	69145	69.26	415.56	10.00	1.00	49756.00	49755.00	57.04	5706.25
	Fixed_asset	69145	7308.64	62382.58	469.57	0.00	5400696.76	5400696.76	37.19	2144.57
	Shortterm_asset	69145	31854.66	1452912.35	2338.12	1.95	277904301.83	277904299.88	159.40	26710.32
	Development_fund	69145	2324.79	20316.70	0.00	0.00	1791703.30	1791703.30	39.53	2365.07
2005	Output	87270	3157.80	86672.87	251.34	-60301.99	24154940.80	24215242.79	250.22	69157.54
	Labour	87270	62.40	484.51	10.00	1.00	85967.00	85966.00	93.70	13798.04
	Fixed_asset	87270	7651.17	262802.59	379.72	0.00	69095800.38	69095800.38	224.02	56271.78
	Shortterm_ asset	87270	30631.22	1416453.66	2323.55	1.81	315071306.20	315071304.39	177.42	34532.01
	Development_fund	87270	2599.86	55257.22	0.00	0.00	12303059.03	12303059.03	162.23	32602.56
2006	Output	104599	2938.13	87571.60	245.47	-107648.06	26713751.31	26821399.37	274.66	82920.33
	Labour	104599	55.97	451.47	10.00	1.00	87225.00	87224.00	103.67	17083.01
	Fixed_asset	104599	6076.14	99715.99	303.92	0.00	26676513.25	26676513.25	191.97	49359.77
	Shortterm_asset	104599	29009.69	1442334.11	2230.94	1.67	345266871.29	345266869.62	191.40	39976.64
	Development_fund	104599	2165.67	84076.58	0.00	0.00	26355362.51	26355362.51	295.30	92302.26
2007	Output	124184	2773.11	89348.81	239.40	-201699.93	29424595.48	29626295.42	292.53	94996.42
	Labour	124184	49.75	417.33	7.00	1.00	87225.00	87224.00	105.18	18405.07
	Fixed_asset	124184	6450.38	129822.25	430.61	0.00	40798200.29	40798200.29	253.58	78592.90
	Shortterm_asset	124184	27261.42	1509432.31	2948.98	1.55	396733256.51	396733254.95	209.12	48020.40
	Development_fund	124184	743.02	14188.72	0.00	0.00	2427214.37	2427214.37	75.01	8953.89

YEAR	VARIABLE	N	MEAN	STANDARD DEVIATION	MEDIAN	MIN	MAX	RANGE	SKEW	KURTOSIS
2008	Output	148914	2899.52	93117.07	258.27	-224153.84	26975383.97	27199537.81	232.11	60797.67
	Labour	148914	46.22	438.20	8.00	1.00	86669.00	86668.00	116.67	20040.23
	Fixed_asset	148914	6965.77	308503.01	414.66	0.00	104790540.54	104790540.54	295.99	94897.43
	Shortterm_asset	148914	29057.23	1707372.38	3010.26	1.43	474783691.43	474783690.00	212.05	50324.23
	Development_fund	148914	3348.38	133869.41	502.19	0.00	43044699.00	43044699.00	269.73	80205.94
2009	Output	192730	2149.60	48997.14	292.52	-183886.07	17843047.48	18026933.55	280.28	95935.70
	Labour	192730	38.75	345.66	8.00	1.00	80950.00	80949.00	122.52	24227.50
	Fixed_asset	192730	5937.18	391976.15	442.86	0.00	170194310.25	170194310.25	424.89	184387.73
	Shortterm_ asset	192730	22812.87	1252658.86	2880.94	1.17	472684516.82	472684515.65	317.28	112097.33
	Development_fund	192730	2863.69	31656.39	658.47	0.00	7710945.30	7710945.30	120.84	22991.01
2010	Output	232970	2271.06	54898.68	298.14	-791366.45	18655315.23	19446681.67	235.27	69242.19
	Labour	232970	35.46	384.69	8.00	1.00	95137.00	95136.00	146.14	30757.36
	Fixed_asset	232970	6312.57	428469.87	485.97	0.00	199999985.57	199999985.57	440.54	204102.44
	Shortterm_asset	232970	25335.87	1425792.15	3734.90	1.09	512638213.11	512638212.02	283.51	89339.03
	Development_fund	232970	1567.76	29224.56	0.00	0.00	5551877.17	5551877.17	91.89	12648.53
2011	Output	273576	2187.50	32075.35	322.40	-192282.00	10776030.00	10968312.00	168.75	48897.53
	Labour	273576	33.63	346.45	7.00	1.00	86669.00	86668.00	130.16	25973.57
	Fixed_asset	273576	5619.28	84095.30	555.00	0.00	15728061.00	15728061.00	95.77	13519.26
	Shortterm_asset	273576	32958.15	1253977.09	4191.00	1.00	523525270.00	523525269.00	303.00	116619.14
	Development_fund	273576	3047.82	32182.34	790.00	0.00	6633660.00	6633660.00	86.49	11537.33
2012	Output	313664	1878.65	22643.54	192.96	-295367.12	3646677.36	3942044.48	69.30	7494.70
	Labour	313664	32.21	280.98	7.00	1.00	84660.00	84659.00	122.68	29384.83
	Fixed_asset	313664	4488.33	77183.01	103.64	0.00	16472995.92	16472995.92	108.69	18214.24
	Shortterm_asset	313664	19618.90	468420.56	2007.12	0.08	121611819.87	121611819.78	160.44	31925.76
	Development_fund	313664	2328.43	338757.20	0.00	0.00	189001757.70	189001757.70	553.73	308901.45
2013	Output	337873	1872.19	33866.95	250.71	-286310.95	15181309.93	15467620.88	287.37	121435.66
	Labour	337873	30.21	274.02	6.00	1.00	76391.00	76390.00	112.56	23644.66
	Fixed_asset	337873	3532.79	84105.93	323.86	0.00	38576544.32	38576544.32	311.55	134109.83
	Shortterm_ asset	337873	21022.76	604872.57	3570.29	0.15	137432705.43	137432705.28	157.14	29011.86
	Development_fund	337873	1835.04	35362.51	437.94	0.00	11345790.47	11345790.47	208.57	59408.25
2014	Output	360483	1862.68	35878.63	212.31	-232432.87	12541591.28	12774024.15	202.49	58041.08
	Labour	360483	29.46	283.77	6.00	1.00	82237.00	82236.00	111.90	24108.72
	Fixed_asset	360483	3494.48	86360.73	289.84	0.00	33407469.36	33407469.36	220.50	71433.38
	Shortterm_asset	360483	22720.05	1018057.83	3112.24	0.36	502179552.14	502179551.77	359.49	166785.03
	Development_fund	360483	995.71	60292.20	0.00	0.00	26636318.41	26636318.41	349.69	140844.24

YEAR	VARIABLE	N	MEAN	STANDARD DEVIATION	MEDIAN	MIN	MAX	RANGE	SKEW	KURTOSIS
2015	Output	386561	1818.41	32980.24	141.95	-351206.52	10188597.22	10539803.74	171.33	44085.49
	Labour	386561	28.90	292.96	6.00	1.00	85206.00	85205.00	111.78	23929.09
	Fixed_asset	386561	3409.06	81992.69	239.97	0.00	28482133.83	28482133.83	204.65	57942.78
	Shortterm_asset	386561	20728.32	623061.04	3068.57	0.07	131351105.02	131351104.95	151.96	26288.95
	Development_fund	386561	1303.39	91515.12	0.00	0.00	54142106.79	54142106.79	539.70	317130.05
2016	Output	431600	1901.58	27747.49	185.40	-294615.64	8581915.07	8876530.71	137.38	32326.48
	Labour	431600	27.42	278.64	5.00	1.00	82297.00	82296.00	108.92	23503.28
	Fixed_asset	431600	3898.34	69164.95	455.62	0.00	22137314.46	22137314.46	177.61	47355.26
	Shortterm_asset	431600	21999.02	500543.85	4439.01	0.55	155478254.88	155478254.33	191.65	46565.15
	Development_fund	431600	2133.31	81328.54	479.07	-712.55	47736860.10	47737572.66	492.90	279192.69
2017	Output	367700	2422.30	40992.26	226.81	-299733.84	17652415.49	17952149.33	249.55	97081.72
	Labour	367700	32.38	305.42	6.00	1.00	77332.00	77331.00	90.57	15868.61
	Fixed_asset	367700	6417.52	1874935.90	29.65	0.00	1136201410.11	1136201410.11	605.22	366748.80
	Shortterm_ asset	367700	21842.31	1928109.69	2076.04	0.07	1136215790.13	1136215790.06	559.00	328082.43
	Development_fund	367700	1540.74	166241.95	0.00	-803.87	95877534.70	95878338.57	530.27	301824.43
2018	Output	482002	2007.47	24465.53	225.21	-167318.39	5505411.08	5672729.47	80.58	11939.19
	Labour	482002	25.88	252.83	5.00	1.00	70291.00	70290.00	87.31	15920.65
	Fixed_asset	482002	2841.53	60363.31	69.84	0.00	30840972.76	30840972.76	305.18	144337.33
	Shortterm_asset	482002	16411.34	504578.51	2220.25	0.07	199542483.40	199542483.33	269.46	89081.84
	Development_fund	482002	1501.87	39228.80	297.86	0.00	22364485.13	22364485.13	418.73	225378.90
2019	Output	505047	2014.44	30540.74	260.70	-255809.50	8056459.20	8312268.70	124.41	23997.46
	Labour	505047	25.11	261.99	5.00	1.00	63721.00	63720.00	83.55	12704.55
	Fixed_asset	505047	2880.71	70572.74	0.00	0.00	33985871.59	33985871.59	274.21	114445.29
	Shortterm_asset	505047	17534.38	448991.56	2035.21	0.06	241322583.65	241322583.58	362.22	175908.57
	Development_fund	505047	1559.42	40905.86	344.19	0.00	16853938.81	16853938.81	297.27	109366.89

A.3.2 VARIABLE SELECTION

The standard approach for measuring output is to use either the gross output or the value added. Value added was not available in the dataset and we had to compute it by looking at the use of intermediates. The results are not drastically different when using gross output instead of value added. In general, gross output gives a more direct link to the interpretation of the various quantities as a production function rather than using a value-added notion of output that returns a restricted profit function version of the production frontier. On the other hand, gross value added has the advantage that it can be summed across firms and sectors and will return the overall GDP of the economy. In this sense value added is easier to aggregate than gross output.

For the inputs we use the total quantity of labour (this is reported directly in the dataset) and we proxy the quantity of capital with the deflated total asset value of the firm. This should proxy for machinery, buildings and other equipment used during the production process. We differentiate cash reserves and financial instruments from the definition of capital. These quantities have an effect on firm performance if the credit market is in some way constrained.

Finally, we use the development fund as a proxy for the technology adoption effort of the firm: firms with higher levels of investment in equipment, training, buying licensing and other intangible assets will likely also be the ones that are the using the most technologically advanced capital equipment. We tried to look at other potential variables that may proxy for the level of technological capability of a firm (such as R&D effort), but either the variables were not available or they had an excessive number of missing observations. Moreover, the level of R&D is more likely to proxy for the ability to produce new knowledge and technology rather than proxying for technology adoption embedded in capital equipment. This second effect is likely to be more important in a fast-growing country such as Vietnam.

All nominal variables were deflated with producer price indices to get real values.

A.4 OUTLIER DETECTION AND PARTIAL FRONTIER METHOD

As mentioned, in this study, a non-parametric frontier estimate is chosen to benchmark compare the relative performance of the average industry level and the frontier business in the industry. In contrast to parametric modelling, there is no need to specify a mathematical form for the production function beforehand, since the method simply seeks the points that maximise output given inputs (output-oriented measure) or minimise inputs given output (input-oriented measure). Hence, it overcomes restrictions on production specifications, distribution of random variables and no production function is required. Non-parametric efficiency such as Data Envelopment Analysis (DEA) efficiency results do not depend on the above formulation of the production function. However, the major drawback of the method is the fact that there is no adjustment for outliers.

In this analysis, we have applied various methodologies to detect and address the outlier problem. First, we remove all the outlier observations, we use the inter-quantile range method. The method is preferable because it does not depend on the mean and standard deviation of the dataset. The inter-quantile range is the central 50% or the area between the 75th and the 25th percentile of the distribution. A point is considered as outlier if it is above the 75th or below the 25th by a factor of 1.5 times the inter-quantile range.

In addition, we utilise the non-convex non-parametric estimate - the Free Disposal Hull (FDH) methodology. Compared to other existing methods the FDH requires minimal assumptions with respect to the production technology. In particular, the FDH frontier does not require convexity and thus reduces the possibility of over-estimating due to the fact that the estimated frontier is convexified across outliers.

Last but not least, the partial frontiers are applied. These non-parametric deterministic methods do not envelop the entire data set in the process of analysis. These estimates are more robust to extreme values of outliers by using a concept of expected minimum/maximum input or output functions. In particular, these approaches generalise FDH by allowing for superefficient observations to be located beyond the estimated production-possibility frontier. Hence, the estimated frontier will not entirely be shaped by few abnormal observations, which might represent artifacts of measurement error. This renders partial frontier approaches less vulnerable to outliers than DEA or FDH. The reported result in this Appendix is using *alpha* = 0.7. The results using other *alphas* are also available.

A.5 PRE-ANALYSIS USING QUANTILE REGRESSION

Quantile regression is an econometric tool in which a specified quantile (or percentile) of the conditional distribution of the response variable is regressed on subject characteristics. Thus, while a regression coefficient from a conventional OLS regression model describes how the mean response changes with a one-unit change in the independent variable, a regression coefficient from a quantile regression model describes how the specified quantile of the response changes with a one-unit change in the independent variable.

There are several reasons to use quantile regression:

- It fully demonstrates the relationship of responsors and predictors on each quantile of the responsors;
- It relaxes the assumptions of the classical regression model;
- Estimators of quantile regression have good large sample asymptotic properties.

The tables show the results of five different regressions: (i)The Ordinary Least Square regression; (ii) The 0.2 quantile regression; (iii) The 0.5 quantile regression (this is different with the OLS – while OLS looks at the mean of the sample, 0.5 quantile regression looks at the median); (iv) The 0.7 quantile regression; and (v) The 0.9 quantile regression.

Dependent variable is the log of output while Independent variables include log of labour, log of capital (fixed and variables), log of total development fun and time trend – the time trend represents the technological change.

Other statistics include:

- *N*: number of observations in the sector for the whole time period;
- R^2 and *Adjusted* R^2: coefficient of determination: proportion of the variance of the dependent variable that is explained by the independent variables;
- *Residual* − *Std. Error*: average variability of the residual from the linear model;
- *F* − *Statistic*

Table 8 presents the result of both Ordinary Least Square and Quantile regression for the whole period from 2001 to 2019. The impact of technology adoption is captured by the coefficient magnitude of Tech_Adopt variable, which shows statistically significant positive impact to output generation of firms. The magnitude of impact is stable across all quantiles as well. In other words, technological adoption effort, which is proxied by the total amount of development fund that a firm secures, has a statistically significant impact on a firm's value-added growth.

Looking across time, **Table 9** to **Table 12** presents the results of a similar exercise for every five year period: 2001-2006, 2006-2011, 2011-2015, 2015-2019. Interestingly, the impact of technology adoption increases over time, especially in the last five years.

The results at the sectoral level are also available.

Table 8. Ordinary least squares and quantile regression for 2001-2019

	DEPENDENT VARIABLE:				
	REAL OUTPUT PER WORKER - 2001-2019				
	OLS	QUANTILE REGRESSION			
	(Mean)	(0.2)	(0.5)	(0.7)	(0.9)
Labour	0.88***	0.84***	0.89***	0.91***	0.91***
	(0.001)	(0.001)	(0.0004)	(0.001)	(0.001)
Capital	0.22***	0.24***	0.19***	0.19***	0.19***
	(0.0005)	(0.001)	(0.0003)	(0.0004)	(0.0004)
Tech_Adopt	0.03***	0.04***	0.04***	0.03***	0.03***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Tech_Change	0.04***	0.04***	0.04***	0.04***	0.04***
	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0001)
Constant	1.46***	0.90***	1.66***	1.96***	1.96***
	(0.004)	(0.01)	(0.003)	(0.004)	(0.004)
Observations	1,942,231	1,942,231	1,942,231	1,942,231	1,942,231
R2	0.78				
Adjusted R2	0.78				
Residual Std. Error	0.77 (df = 1942226)				
F Statistic	1,731,725.00*** (df = 4; 1942226)				

Note: *p<0.1; **p<0.05; ***p<0.01

Table 9. Ordinary least squares and quantile regression for 2001-2006

	DEPENDENT VARIABLE:				
	REAL OUTPUT PER WORKER - 2001-2006				
	OLS	QUANTILE REGRESSION			
	(Mean)	(0.2)	(0.5)	(0.7)	(0.9)
Labour	0.73***	0.77***	0.71***	0.68***	0.68***
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
Capital	0.43***	0.41***	0.39***	0.41***	0.41***
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
Tech_Adopt	−0.08	0.09***	−0.04*	0.03**	−0.03***
	(0.125)	(0.002)	(0.016)	(0.002)	(0.02)
Tech_Change	0.05***	0.06***	0.04***	0.04***	0.04***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Constant	0.86***	0.39***	1.09***	1.34***	1.34***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
Observations	128,389	128,389	128,389	128,389	128,389
R2	0.82				
Adjusted R2	0.82				
Residual Std. Error	0.82 (df = 128384)				
F Statistic	144,054.70*** (df = 4; 128384)				

Note: *p<0.1; **p<0.05; ***p<0.01

Table 10. Ordinary least squares and quantile regression for 2006-2011

	DEPENDENT VARIABLE:				
	REAL OUTPUT PER WORKER - 2006-2011				
	OLS	QUANTILE REGRESSION			
	(Mean)	(0.2)	(0.5)	(0.7)	(0.9)
Labour	0.80***	0.76***	0.81***	0.83***	0.83***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Capital	0.29***	0.29***	0.27***	0.27***	0.27***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Tech_Adopt	0.01***	0.01***	0.01***	0.002***	−0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Tech_Change	0.06***	0.09***	0.04***	0.03***	0.03***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	1.13***	0.48***	1.52***	1.85***	1.85***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Observations	541,272	541,272	541,272	541,272	541,272
R2	0.79				
Adjusted R2	0.79				
Residual Std. Error	0.69 (df = 541267)				
F Statistic	498,414.20*** (df = 4; 541267)				

Note: *p<0.1; **p<0.05; ***p<0.01

Table 11. Ordinary least squares and quantile regression for 2011-2015

	DEPENDENT VARIABLE:				
	REAL OUTPUT PER WORKER - 2011-2015				
	OLS	QUANTILE REGRESSION			
	(Mean)	(0.2)	(0.5)	(0.7)	(0.9)
Labour	0.83***	0.78***	0.85***	0.89***	0.89***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Capital	0.29***	0.31***	0.23***	0.22***	0.22***
	(0.001)	(0.001)	(0.0005)	(0.001)	(0.001)
Tech_Adopt	0.002***	0.02***	0.02***	0.01***	0.01***
	(0.001)	(0.001)	(0.0004)	(0.001)	(0.001)
Tech_Change	−0.05***	−0.09***	−0.02***	−0.01***	−0.01***
	(0.001)	(0.001)	(0.0005)	(0.001)	(0.001)
Constant	2.27***	2.12***	2.19***	2.47***	2.47***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
Observations	730,877	730,877	730,877	730,877	730,877
R2	0.77				
Adjusted R2	0.77				
Residual Std. Error	0.78 (df = 730872)				
F Statistic	606,678.70*** (df = 4; 730872)				

Note: *p<0.1; **p<0.05; ***p<0.01

Table 12. Ordinary least squares and quantile regression for 2015-2019

	DEPENDENT VARIABLE:				
	REAL OUTPUT PER WORKER - 2015-2019				
	OLS	QUANTILE REGRESSION			
	(1)	(0.2)	(0.5)	(0.7)	(0.9)
Labour	0.952***	0.968***	0.959***	0.942***	0.942***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Capital	0.147***	0.137***	0.134***	0.147***	0.147***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Tech_Adopt	0.052***	0.064***	0.058***	0.049***	0.049***
	(0.001)	(0.001)	(0.0005)	(0.001)	(0.001)
Tech_Change	0.046***	0.066***	0.044***	0.035***	0.035***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Constant	1.711***	0.889***	1.872***	2.304***	2.304***
	(0.020)	(0.030)	(0.018)	(0.020)	(0.020)
Observations	760,233	760,233	760,233	760,233	760,233
R2	0.799				
Adjusted R2	0.799				
Residual Std. Error	0.733 (df = 760228)				
F Statistic	754,397.200*** (df = 4; 760228)				

Note: *p<0.1; **p<0.05; ***p<0.01

A.6 A NOTE TO THE MODEL - SAMPLE ISSUES

In this model, we use the full sample to estimate the unconditional frontier and use the reduced sample to estimate the efficiency decomposition:

$$TE^{jt} = ZE^{jt} + CE^{jt}$$

The left-hand side of this equation does not require to use the reduced sample, since it does not require the use of the Z-variables. Therefore TE^{jt} can be estimate using the full sample. Since the decomposition can be expressed as follows:

$$\frac{ZE^{jt}}{TE^{jt}} + \frac{CE^{jt}}{TE^{jt}} = 1$$

where the left-hand side is percentage contribution to the total technical inefficiency. These percentages can be calculated using the reduced dataset and then multiplied by the TE^{jt} of the full dataset (˜6 million) in order to obtain the decomposition for the full dataset.

To obtain changes in these variables is similar:

$$\Delta TE^{jt} = \Delta ZE^{jt} + \Delta CE^{jt}$$

and in percentage (note that the contribution could be negative...):

$$\frac{\Delta ZE^{jt}}{\Delta TE^{jt}} + \frac{\Delta CE^{jt}}{\Delta TE^{jt}} = 1$$

Again, ΔTE^{jt} can be computed using the full sample and then the decomposition of changes obtained by multiplying this number by the percentage contributions.

A.7 SECTOR CODES

LEVEL 1/ SECTION	LEVEL 2/ DIVISION	SECTOR/INDUSTRY
A	01	Agriculture and related service activities
A	02	Forestry products and related services
B	5	Fishing, aquaculture and related services
C	7	Mining of black metal ores
C	8	Mining other ores
C	10	Mining hard coal, lignite, and peat
C	11	Extraction of crude oil, natural gas and oil and gas exploitation services (except oil/gas exploration)
C	12	Uranium ores, Thorium ore
C	13	Mining of black metal ores
C	14	Quarrying and other mining
D	15	Manufacture of food and beverage
D	16	Manufacture of tobacco products, pipe tobacco
D	17	Textile
D	18	Manufacture of leather/fur clothes, leather tanning and dyeing
D	19	Tanning and preliminary processing of leather; Manufacture of suitcases, bags, saddle and shoes
D	20	Manufacture of wood and of products of wood and cork, except furniture (except beds, wardrobes, tables, chairs); manufacture of products of straw and plaiting materials;
D	21	Manufacture of paper and paper products
D	22	Publishing and production of recorded media of all kinds
D	23	Manufacture of coke coal, refined petroleum products and nuclear fuel
D	24	Manufacture of chemicals and chemical products
D	25	Manufacture of products from rubber and plastic
D	26	Manufacture of other products from other non-metallic minerals
D	27	Metal production
D	28	Manufacture of metal products (except for machinery and equipment)
D	29	Manufacture of machinery and equipment has not been classified yet
D	30	Manufacture of office equipment and computers
D	31	Manufacture of electrical machinery and equipment has not been classified yet
D	32	Manufacture of radio, television and communication equipment
D	33	Manufacture of medical instruments, precision tools, optical instruments and watches of all kinds
D	34	Manufacture of motor vehicles, trailers
D	35	Manufacture of other means of transport
D	36	Manufacture of beds, wardrobes, tables, chairs; Manufacture of other equipment not elsewhere classified
D	37	Recycling
E	40	Manufacture and distribution of electricity, gas, steam and hot water

LEVEL 1/ SECTION	LEVEL 2/ DIVISION	SECTOR/INDUSTRY
E	41	Water collection, treatment and supply
F	45	Construction
G	50	Sale, maintenance and repair of motor vehicles and motorcycles, motorbikes, fuel and engine retail
G	51	Wholesale and commission agents activities (except motor vehicles and motorbikes)
G	52	Retail trade, (except motor vehicles, motorcycles and other motor vehicles); repairing personal and household belongings
H	55	Hotel and restaurant
H	56	Food service activities
I	60	Land transport and transport via pipelines
I	61	Water transport
I	62	Air transport
I	63	Support activities for transport; activities of tourism organisations
I	64	Post and telecommunications
J	65	Financial intermediary activities (excluding insurance and retirement benefits)
J	66	Insurance and retirement benefits (except compulsory social insurance)
J	67	Activities to support monetary and financial activities
K	70	Science and technology-related activities
L	71	Activities related to real estate
L	72	Renting and leasing of machinery and equipment (without operators); of personal and household goods
L	73	Activities related to computers
L	74	Other business activities
M	75	State management and national security and defense; Compulsory social assurance
L	77	Renting and leasing of other machinery and equipment
N	80	Education and training
O	85	Human health and social work activities
P	90	Sport and cultural activities
Q	91	Activities of the Party, unions and associations
T	92	Garbage collection, improvement of public sanitation and similar activities
T	93	Other service activities
U	95	Working as hired labor in private households
V	99	Activities of international organisations and unions

Appendix B
Dynamic stochastic general equilibrium model to capture the impact of R&D and technology creation activities on economic growth

B.1 OVERVIEW

B.1.1 WHY USE A DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM MODEL?

In this project, we use a Dynamic Stochastic General Equilibrium approach. For a long time, General equilibrium (GE) modelling has been used as a methodology to analyse broad policy issues. In contrast to partial equilibrium models or input-output models (I-O models) which focus on one section of the economy only, GE models capture the entire economy and take into account the interactions and effects among its different agencies. GE models are also capable of capturing price movements and replicating the impact of capacity constraints.

GE models include Computational General Equilibrium (CGE) and Dynamic Stochastic General Equilibrium (DSGE) models. Both CGE and DSGE models fit economic data to a set of equations which aim to capture the structure of the economy and behavioural response of agents (firms, households, government).

GE models combine macro data with a series of equations to ascribe behavioural rules that determine the way the various economic agents respond to change. Since the models' behavioural rules are derived from economic theory rather than from time series data, they can overcome the practical difficulties associated with IOE modelling and the limiting assumptions inherent in I-O multiplier analysis (Horridge 2014). By focusing on the structure and detail of agent-specific behaviour, they also allow the CGE models to capture detailed economic relationships and connections that would be missed in econometric modelling exercises that are reliant on extensive historical data sets. This provides a framework to simulate policy changes and trace the impact on key economic variables such as output growth or inflation.

The main difference between DSGE and CGE models is in their stochastic nature. One of the fundamental features of DSGE models is the dynamic interaction among agencies. In the DSGE framework, in every period random exogenous events perturb the equilibrium conditions, injecting uncertainty in the evolution of the economy. Without these shocks, the economy would evolve along a perfectly predictable path, with neither booms nor recessions.

DSGE models are built on microeconomic foundations and emphasise agents' intertemporal choices. The dependence of current choices on future uncertain outcomes makes the models dynamic and assigns a central role to agents' expectations in the determination of current macroeconomic outcomes.

In addition, the models' general equilibrium nature captures the interaction between policy actions and agents' behaviour. Furthermore, a more detailed specification of the stochastic shocks that give rise to economic fluctuations allows one to trace more clearly the shocks' transmission to the economy.

In literature, many studies have shown the advantages of DSGE framework in analysing R&D impacts. Di Comite et al. (2015), for example, compared R&D modelling approaches in four macroeconomic models used by the European Commission for ex-ante policy impact assessment: one Dynamic Stochastic General Equilibrium (DSGE) model – QUEST; one Spatial Computable General Equilibrium (SCGE) model – RHOMOLO; one Computable General Equilibrium (CGE) model – GEM-E3; and one macro-econometric model – NEMESIS. The report critically compares particularly those parts of the four models that are relevant to R&D transmission mechanisms and interfaces for implementing policy shocks. They concluded that QUEST was the most suitable model for assessing the impact of R&D and innovation policies over time, as it is the only model with inter-temporal optimisation of economic agents.

B.1.2 HOW TO ASSESS THE IMPACT OF R&D - THE PROPOSED MODEL

In this project, we utilise the DSGE framework to assess the impact of changes in R&D investment and R&D productivity to economic growth and other macroeconomic indicators. In particular, our model focuses on specifying shocks to R&D and investigating what relations exist between the shock and growth or business cycles.

When dealing with R&D, the issue is how to deal with the time lag of R&D impact, which is a typical feature of the R&D process. In the literature, technology diffusion is defined as “the process by which an innovation is communicated through certain channels over time among the members of a social system” (Rogers, 2003). Studying the process of such diffusion involves investigating the course of a new idea as it is adopted or rejected temporally and used by participants in a society. This is of particular importance in developing countries like Vietnam.

Although it would be important to understand, the adoption process of new technology is not well understood, and the majority of work on this assumes that for rational or utility maximising consumers, eventually new technology would replace old (Venkatesh et al., 2003). MacVaugh and Schiavone (2010) explains that diffusion occurs progressively within one market when information and opinions about a new technology are shared among potential users through communication channels, through which users acquire a personal knowledge about new technology. Romer (1990) develops a model of technological change, which includes an endogenous pace of technology adoption. Comin and Gertler (2006) adopts the approach to connect business cycles to growth by using a variant model of Romer (1990). Stokey (2020) surveys relevant works in this topic by going through the models in detail, and admits that it is difficult to obtain a detailed data to support any empirical structural analyses.

In this project, we introduce the adoption agency which buys unadopted technologies from R&D sector and modifies them to become adopted technologies before firms can use them in their production to capture these time lags. We utilise the framework in Anzoategui et al. (2019) which extends the previous works by including technological adoption. We use this framework because we need to have a realistic period of diffusion of new technologies. This framework is also featured with endogenous adoption intensity. Through this framework, we can allow for productivity fluctuation over time and we can generate the speed of diffusion. The model also includes an exogenous TFP shock by adopting the bad luck hypothesis proposed by Fernald (2015).

Having said that, adopting Anzoategui et al. (2019) is deliberate. By using this approach, we explicitly model R&D and technological adoption. We also impose discipline on the lags in the diffusion process and utilise Vietnam’s macro series to estimate most parameters.

Our model can be summarised as in Figure 3. In the model, the driving force of long-term growth is endogenous productivity, driven by the adoption of new technologies generated by R&D sector. There are five key agents in the model. The five key agents are household, production firms and final-good firms, innovators and adopters.

The representative household consumes and saves in the form of capital and riskless bonds, which are in zero net supply. It rents capital to production firms. The household provides two types of labour: unskilled labour, which is used in the production of production goods, and skilled labour, which is used either for R&D or adoption.

Firms are monopolistically competitive and produce a differentiated output. There are two types of firms: (i) retailers and (ii) producers. Production firms use capital services and unskilled labour as inputs to produce their differentiated output.

There is a continuum of innovators that use skilled labour to create new technologies. On the other hand, there is a competitive group of "adopters" who convert unadopted technologies into ones that can be used in production. They buy the rights to the technology from the innovator at the competitive price, which is the value of an unadopted technology. They then convert the technology into use by employing skilled labour as an input.

In summary, endogenous productivity effects enter through the expansion in the variety of adopted technologies to produce production good is the driving force of long-term growth is the endogenous TFP mechanism.

We estimate key parameters for the model by using Vietnamese data, and then study the steady state values where there exists a value for the variables that is maintained over time

To study how the economy reacts to a sudden change, we use an impulse response function, which is the reaction of any dynamic system in response to an external change in a key parameter of the model. The impulse response describes the reaction of the system as a function of time and we can study how a change is generated and transmitted over time.

We also conduct counterfactual exercises by changing the values of parameters. In particular, we provide forecasts and counterfactual analyses on key variables including total output and consumption after R&D expenditure shock or shock to liquidity demand. Our forecasts are conditional, controlling for spending behaviours. We look at the effects of changing exogenous variables such as R&D expenditure and investment.

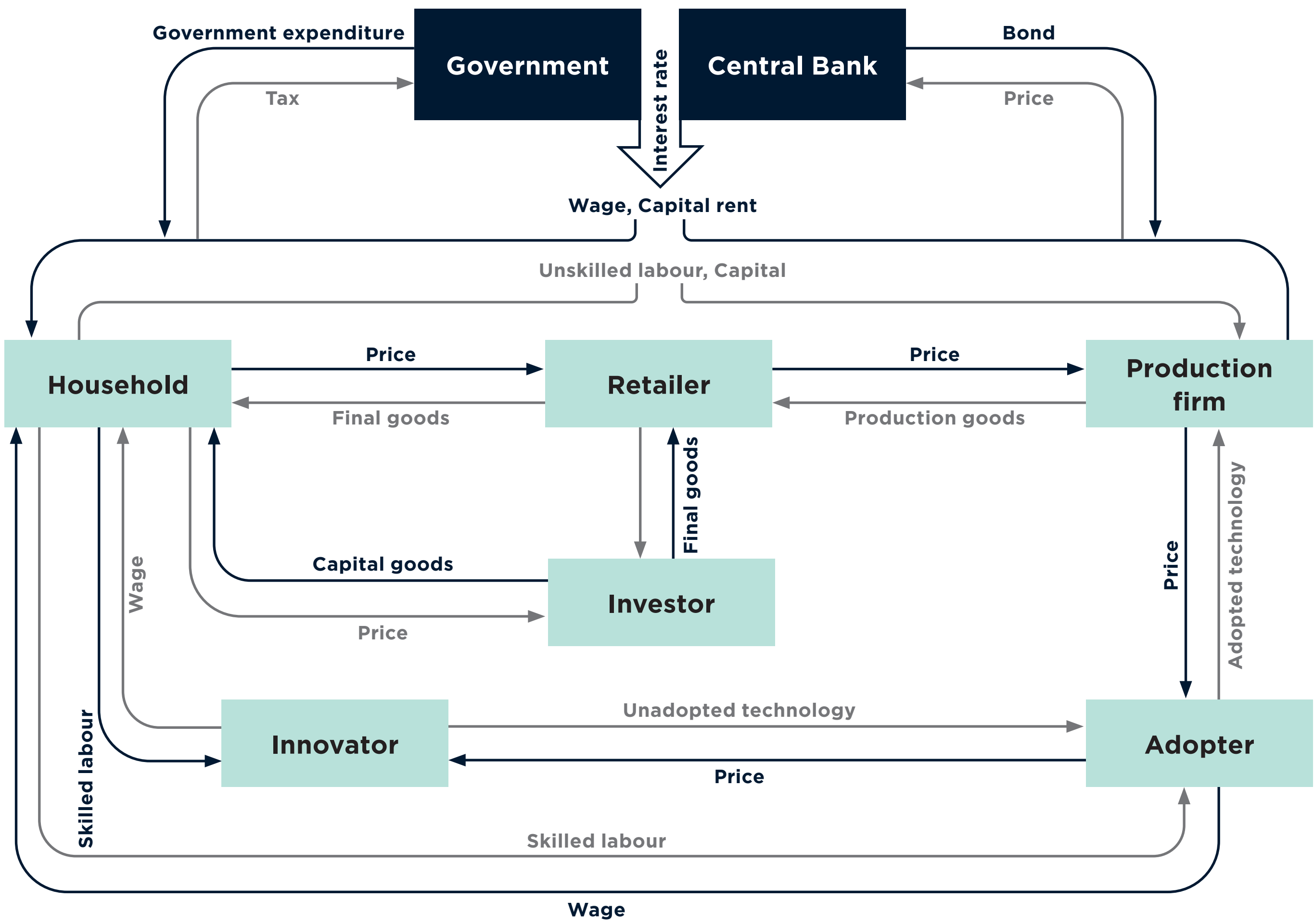

Figure 3. Dynamic stochastic general equilibrium framework

B.2 THE DYNAMIC STOCHASTIC GENERAL EQUILBIRIUM MODEL WITH SPECIFIC R&D AND TECHNOLOGICAL ADOPTION CHANNEL

In this section we summarise the New Keynesian DSGE model adapted from Anzoategui et al. (2019). In the model, time spans from $t = 0$ to $t = +\infty$. The agents in the model are households, production firms, retailers, innovators and adopters of technology. In what follows we describe each agent in the model and the conditions for equilibrium.

B.2.1 HOUSEHOLDS

In this model, a household supplies two types of labor in monopolistically competitive markets: unskilled labour, denoted as L_t^h, for producing intermediate goods, and skilled labor for R&D or adoption, denoted as L_{st}^h. It consumes and saves in forms of capital and riskless bonds. Suppose that the household has a preference for safe assets, which we motivate loosely as a preference for liquidity and capture by incorporating bonds in the utility function. We introduce a shock to liquidity demand ϱ_t.

Let C_t be consumption, B_t be holdings of the riskless bond, Π_t be profits from ownership of monopolistically competitive firms, K_t be capital, Q_t b the price of capital, R_{kt} be the rate of return, and D_t be the rental rate of capital. Then the households' maximisation problem is given by:

$$\max_{C_t, B_{t+1}, L_t^h, L_{st}^h, K_{t+1}} \mathrm{E}_t \sum_{\tau=0}^{\infty} \left\{ \log(C_{t+\tau} - bC_{t+\tau-1}) + \varrho_t B_{t+1} - \left[\frac{\upsilon\left(L_t^h\right)^{1+\varphi} + \upsilon_s\left(L_{st}^h\right)^{1+\varphi}}{1+\varphi} \right] \right\} \tag{1}$$

subject to

$$C_t = w_t^h L_t^h + w_{st}^h L_{st}^h + \Pi_t + R_{kt} Q_{t-1} K_t - Q_t K_{t+1} + R_t B_t - B_{t+1} \tag{2}$$

with $R_{kt} := (D_t + Q_t)/Q_{t-1}$. Let $\Lambda t,t{+}1 := \beta u'(C_{t+1})/u'(C_t)$ be the household's stochastic discount factor and $\zeta_t := \varrho_t / u'(C_t)$ be the liquidity demand shock in consumption units.

Assume the shock follows an exogenous process:

$$\zeta_t = (1 - \rho_\zeta)\bar{\zeta} + \rho_\zeta \zeta_{t-1} + \sigma_\zeta \epsilon_t^\zeta \tag{3}$$

Where ϵ_t^ζ is i.i.d. $\sim N(0,1)$.

Then we can express the first-order necessary conditions for capital and the riskless bond as, respectively,

$$1 = E_t\{\Lambda_{t,t+1} R_{kt+1}\} \tag{4}$$

and

$$1 = E_t\{\Lambda_{t,t+1} R_{t+1}\} + \zeta_t \tag{5}$$

B.2.2 RETAILERS

There is a continuum of retailers with mass 1. Each retailer i sells a differentiated output Y_t^i. Each retailer i converts Y_{mt}^i units of goods produced by production firms to one unit of final goods Y_t^i, according to the following simple linear technology:

$$Y_t^i = Y_{mt}^i \tag{6}$$

A final good composite is then the following CES aggregate of the differentiated final goods:

$$Y_t = \left(\int_0^1 \left(Y_t^i\right)^{\frac{1}{\mu_t}} di \right)^{\mu_t} \tag{7}$$

where $\mu_t > 1$ and $\log(\mu_t)$ follows an exogenous stochastic process:

$$\log(\mu_t) = (1 - \rho\mu)\mu + \rho\mu \log(\mu_{t-1}) + \sigma_\mu \epsilon_t^\mu, \tag{8}$$

where ϵ_t^{μ} is i.i.d. ~ $N(0,1)$.

Let p_{mt} be the real price of production goods, then the cost minimisation problem determines the real marginal cost as

$$MC_t = \frac{p_{mt}}{A_t^{\vartheta-1}} \tag{9}$$

We assume each firm sets its nominal price P_t^i on a staggered basis, as we describe later.

B.2.3 PRODUCTION FIRMS

There exists a continuum of production firms with measure A^t that each makes a differentiated product. The stock of types of goods adopted in production is represented by A_t. Thus, A_t measures the stock of adopted technologies.

Production firm j produces output Y_{mt}^j. Let K_t^j be the stock of capital firm j employs, U_t^j be how intensely this capital is used, and L_t^j the stock of labour employed. We allow for the change in capital intensity utilisation U_t^j so as not to mistakenly attribute all fluctuation of the Solow residual to endogenous technology change.

Then firm j uses capital services $U_t^j K_t^j$ and unskilled labour L_t^j as inputs to produce output Y_{mt}^j according to the following Cobb-Douglas technology:

$$Y_{mt}^j = \theta_t \left(U_t^j K_t^j\right)^{\alpha} \left(L_t^j\right)^{1-\alpha} \tag{10}$$

where θ_t is an aggregate productivity shock whose growth rate follows a stationary AR(1) process,

$$\log(\theta_t) = \rho_\theta \log(\theta_{t-1}) + \sigma_\theta \epsilon_{\theta,t}, \tag{11}$$

where $\epsilon_{\theta,t}$ is i.i.d. ~ $N(0,1)$.

Finally, we suppose that production firms set prices each period. That is, goods prices are perfectly flexible in contrast to final good prices.

Relating to factor demand, production firm j chooses capital K_t^j, utilisation U_t^j, and labor L_t^j to minimise costs given the relative price of the products composite p_{mt}, the price of capital Q_t, the rental rate D_t, the real wage w_t, and the desired markup ς.

The first-order conditions from the firm's cost minimisation problem for K_t^j, U_t^j, and L_t^j are then given by

$$\alpha \frac{p_{mt} Y_{mt}^j}{K_t^j} = \varsigma\left[D_t + \delta(U_t^j) Q_t\right] \tag{12}$$

$$\alpha \frac{p_{mt} Y_{mt}^j}{U_t^j} = \varsigma \delta'(U_t^j) Q_t K_t^j \tag{13}$$

$$(1-\alpha) \frac{p_{mt} Y_{mt}^j}{L_t^j} = \varsigma w_t \tag{14}$$

We endogenise the capital utilisation decision by assuming that the depreciation rate is dependent on capital utilisation U_t^j and allow ς to be smaller than the optimal unconstrained mark-up ϑ due to the threat of entry by imitators.

Then the total output of the production firm is the following CES aggregate of individual goods:

$$Y_{mt} = \left(\int_0^{A_t} \left(Y_{mt}^j\right)^{\frac{1}{\vartheta}} dj\right)^{\vartheta} \tag{15}$$

with $\vartheta > 1$.

Given a symmetric equilibrium for production products, it follows from equations (15) and (10) that to a first order we can express the aggregate production function for the final good composite Y_t as

$$Y_t = \left[A_t^{\vartheta-1}\theta_t\right](U_t K_t)^{\alpha}(L_t)^{1-\alpha}, \tag{16}$$

The term in brackets. $[A_t^{\vartheta-1}\theta_t]$ is the TFP, which is the product of a term that reflects endogenous variation, $A_t^{\vartheta-1}$, and one that reflects exogenous variation θ_t.

In short, endogenous change in productivity comes from the expansion in the variety of adopted technologies, measured by A_t. And because θ_t is stationary, the driving force of the long-term growth will be through the endogenous change, A_t.

B.2.4 INNOVATORS

There is a continuum of innovators with measure 1 that use skilled labour to create new technologies. Denote Z_t as the stock of technologies, and let L_{spr}^t be skilled labour employed in R&D by innovator p, and φ_t be the number of new technologies available at time t+1 that each unit of skilled labour at t can create. We assume φ_t is given by

$$\varphi_t = \chi_t Z_t L_{srt}^{\rho_z - 1} \tag{17}$$

where χ_t is an exogenous disturbance to the R&D technology, which follows an exogenous process

$$\log(\chi_t) = \left(1 - \rho_\chi\right) \log(\bar{\chi}) + \rho\chi \log(\chi_{t-1}) + \sigma_\chi \epsilon_t^\chi \tag{18}$$

where ϵ_t^χ is i.i.d. ~ $N(0,1)$, and L_{srt} is the aggregate amount of skilled labour working on R&D, which an individual innovator takes as given. The presence of Z_t represents the public learning by doing effect in R&D process. We assume $\rho_z<1$. This allows for constant returns to scale in the creation of new technologies for each inventor but diminishing returns at the aggregate level. Our assumption of diminishing returns is consistent with empirical evidence.

Let J_t be the value of an unadopted technology, $\Lambda_{t,t+1}$ the representative household's stochastic discount factor, and w_{st} the real wage for a unit of skilled labour. We can then express innovator p's decision problem as choosing L_{srt}^p to solve

$$\max_{L_{srt}^p} E_t \left\{\Lambda_{t,t+1} J_{t+1} \varphi_t L_{srt}^p\right\} - w_{st} L_{srt}^p = 0 \tag{19}$$

Then the optimality condition for R&D is then given by

$$E_t\{\Lambda_{t,t+1} J_{t+1} \chi_t Z_t L_{srt}^{\rho_z - 1}\} = w_{st} \tag{20}$$

The left side of equation (20) is the discounted marginal benefit from an additional unit of skilled labour, while the right side is the marginal cost. Given that profits from production goods are procyclical, the value of an unadopted technology, which depends on expected future profits, will be also be procyclical. This consideration, in conjunction with some stickiness in the wages of skilled labour which we introduce later, will give rise to procyclical movements in L_{srt}.

B.2.5 ADOPTERS

We suppose there is a competitive group of 'adopters' who convert unadopted technologies into ones that can be used in production. Let J_t denote the value of an unadopted technology. The adopter buys the rights to the technology from the inventor at J_t and uses skilled labour to convert unadopted technology into use. An adopter succeeds in making a product usable in any given period with probability λ_t, which is an increasing and concave function of the amount of skilled labour employed, L_{sat}:

$$\lambda_t = \lambda(Z_t L_{sat}) \tag{21}$$

with $\lambda'>0, \lambda''<0$.

We augment L_{sat} by a spill-over effect from the total stock of technologies Z_t (i.e. the adoption process will be more efficient if the technological state of the economy improves). The practical need for this spill-over is that it ensures a balanced growth path: as technologies grow, the number of new goods requiring adoption increases, but the supply of labour remains unchanged. Hence, the adoption process must become more efficient as the number of technologies expands. Unlike the specification used for R&D, there is no separate shock to the productivity of adoption activities in equation (21).

The adoption process implies that technology diffusion takes time on average. If $\bar{\lambda}$ is the steady state value of λ_t, then the average time it takes for a new technology to be adopted is $\frac{1}{\bar{\lambda}}$. Away from the steady state, the pace of adoption will vary with skilled labour input L_{sat}. We turn next to how L_{sat} is determined.

Once in usable form, the adopter sells the rights to the technology to a monopolistically competitive goods producer that makes the new product using the production function described by equation (10). Let Π_{mt} be the profits that the production firm makes from producing the good, which arise from monopolistically competitive pricing. The price of the adopted technology, V_t, is the present discounted value of profits from producing the good, given by

$$V_t = \Pi_{mt} + \phi E_t\{\Lambda_{t,t+1} V_{t+1}\} \tag{22}$$

Then we may express the adopter's maximisation problem as choosing L_{sat} to maximise the value J_t of an unadopted technology, given by

$$J_t = \max_{L_{sat}} E_t\{-w_{st}L_{sat} + \phi\Lambda_{t,t+1}[\lambda_t V_{t+1} + (1-\lambda_t)J_{t+1}]\} \tag{23}$$

The first term in the Bellman equation reflects total adoption expenditures, while the second is the discounted benefit: the probability weighted sum of the values of adopted and unadopted technologies. The first-order condition for L_{sat} is

$$Z_t \lambda' \cdot \phi E_t\{\Lambda_{t,t+1}[V_{t+1} - J_{t+1}]\} = w_{st} \tag{24}$$

The term on the left is the marginal gain from adoption expenditures: the increase in the adoption probability λ_t times the discounted difference between the value of an adopted versus an unadopted technology. The right side is the marginal cost. The term $V_t - J_t$ is procyclical, given the greater influence of near term profits on the value of adopted technologies relative to unadopted ones. Given this consideration and the stickiness in w_{st} which we alluded to earlier, L_{sat} varies procyclically.

B.2.6 R&D AND TECHNOLOGY ADOPTION

Since Z_t denotes the stocks of technologies while A_t denotes the adopted technologies, the difference between the two represents the stock of unadopted technologies. R&D expenditure will help to increase Z_t while adoption expenditure will increase A_t. The differentiation between invention and adoption allow us to capture the lag between the creation and adoption of technologies.

In the model, we also allow for technology obsolescence. Let ϕ be the survival rate for any given technology. Then, the evolution of technologies is expressed as

$$Z_{t+1} = \varphi_t L_{srt} + \phi Z_t \tag{25}$$

where the term $\varphi_t L_{srt}$ reflects the creation of new technologies. Combining equations (25) and (17) yields the following expression for the growth of new technologies:

$$\frac{Z_{t+1}}{Z_t} = \chi L_{srt}^{\rho_z} + \phi \tag{26}$$

where ρ_z is the elasticity of the growth rate of technologies with respect to R&D.

On the other hand, the pace of adoption, given by λ_t, will also vary procyclically. Since λ_t does not depend on adopter-specific characteristics, we can sum across adopters to obtain the following relation for the evolution of adopted technologies:

$$A_{t+1} = \lambda_t \phi[Z_t - A_t] + \phi A_t \tag{27}$$

where $Z_t - A_t$ is the stock of unadopted technologies.

B.2.7 TECHNOLOGY DIFFUSION

The diffusion measure in the data corresponds to the number of companies at time $t+j$ that have adopted a single technology invented at some time t. Accordingly, the natural notion of diffusion in the model is the share of technologies invented at time t that have been adopted at time $t+j$.

Formally, denote by Z^t_{t+k} the mass of technologies that was invented at time t that survives (i.e., is not obsolete) at time $t+k$, and A^t_{t+k} the mass of vintage t technologies that have been adopted at time $t+k$. Then, we can define the fraction of vintage t technologies adopted at time $t+k$ by

$$m^t_{t+k} = \frac{A^t_{t+k}}{Z^t_{t+k}} \tag{28}$$

We define r and the speed of diffusion in the model as

$$r^t_{t+k} = \frac{m^t_{t+k}}{1-m^t_{t+k}} \tag{29}$$

and

$$v^t_{t+k} = \log\frac{r^t_{t+k}}{r^t_{t+k-1}} \tag{30}$$

B.2.8 INVESTMENT

Competitive capital producers/investors buy the final output to make new capital goods that can be sold to households who will in turn, rent the capital to firms. Let I_t be new capital produced, p_{kt} be the relative cost of converting a unit of final output to new capital, γ_y be the steady state growth in I_t.

We assume flow adjustment costs of investment: the adjustment cost function $f\left(\frac{I_t}{(1+\gamma_y)I_{t-1}}\right)$ is increasing and concave, with $f(1) = f'(1) = 0$ and $f''(1)>0$. The first-order condition for I_t relates the ratio of the market value of capital to the replacement price ("Tobin's Q") to investment, as follows:

$$\frac{Q_t}{p_{kt}} = 1 + f(X_t) + X_t f'(X_t) - E_t\Lambda_{t,t+1}(X_t)^2 f'(X_t) \tag{31}$$

where $X_t = \frac{I_t}{(1+\gamma_y)I_{t-1}}$

We assume that $\log(p_{kt})$ follows an AR(1) process with parameters ρ_{pk} and σ_{pk}. Finally, the law of motion for capital is

$$K_{t+1} = I_t + \big(1-\delta(U_t)\big)K_t \tag{32}$$

B.2.9 PRICE AND WAGE

Let ξ_p be the probability a firm cannot adjust its price, and let ξ_w be the probability a firm cannot adjust its wage. Conversely, let ι_p be the degree of indexing prices to past inflation, and let ι_w be the analogue for wages. The only difference from the standard model is that households in our economy supply two types of labour, skilled and unskilled. We assume that each type of labour has the same frequency of wage adjustment.

Denoting by π_t the inflation rate and by mc_t the marginal cost of final-goods producers in log deviation from steady state, the price Phillips curve is

$$\pi_t = \kappa mc_t + \frac{\iota_p}{1+\iota_p\beta}\pi_{t-1} + \frac{\beta}{1+\iota_p\beta}E_t[\pi_{t+1}] + \epsilon\mu_t \tag{33}$$

where $\kappa \coloneqq \frac{(1-\xi_p\beta)(1-\xi_p)}{\xi_p(1+\iota_p\beta)}$ and $\epsilon\mu_t$ is a shock to the final-goods mark-up that follows an AR(1) process with parameters ρ_μ and σ_μ.

The unskilled wage Phillips curve is

$$(1+\kappa_w)\widetilde{w}_t = \frac{1}{1+\beta}\left(\widetilde{w}_{t-1} + \iota_w \Pi_{t-1} - \left(1+\tilde{\beta}\iota_w\right)\Pi_t\right) + \frac{\beta}{1+\beta}E_t[\widetilde{w}_{t+1} + \Pi_{t+1}] + \kappa_w\left(\tilde{u}_{c,t} - \varphi\tilde{l}_t\right) + \epsilon\mu_{w,t} \tag{34}$$

where $\kappa_w := \frac{(1-\xi_w\beta)(1-\xi_w)}{(\varphi(1-1/\mu_w)^{-1}+1)\xi_w(1+\beta)}$ is the steady state wage mark-up. Variables $\tilde{u}_c$, $\tilde{w}$ and $\tilde{l}$ are, respectively, the marginal utility of consumption, unskilled wage, and hours in log deviation from steady state, and $\epsilon\mu_{w,t}$ is a shock to the wage mark-up that follows an AR(1) process with parameters $\rho_{\mu w}$ and $\sigma_{\mu w}$. The skilled wage Phillips curve is identical, replacing unskilled wage and hours for skilled equivalents.

B.2.10 MONETARY POLICY

The nominal interest rate R_{nt+1} is set according to the following Taylor rule:

$$R_{nt+1} = r_t^m\left(\left(\frac{\pi_t}{\pi_0}\right)^{\phi_\pi}\left(\frac{L_t}{L^{SS}}\right)^{\phi_y} R_n\right)^{1-\rho^R}(R_{nt})^{\rho^R} \tag{35}$$

where R_n is the steady state nominal rate, π_0 the target rate of inflation, L_t total employment, and L^{ss} steady state employment; φ_Π and φ_y are the feedback coefficients on the inflation gap and capacity utilisation gap, respectively, and $\log(r_t^m)$ follows an AR(1) process with parameters ρ^{mp} and σ^{mp}. We use the employment gap to measure capacity utilisation as opposed to an output gap for two reasons.

First, Berger et al. (2016) shows that measures of employment are the strongest predictors of changes in the interest rate. Second, the estimates of the Taylor rule with the employment gap appear to deliver a more reasonable response of the nominal rate to real activity within this model than does one with an output gap.

In addition, we impose the zero lower bound constraint on the net nominal interest rate, which implies that the gross nominal rate cannot fall below unity:

$$R_{nt+1} \geq 1 \tag{36}$$

This constraint is added as the test of the fitness of the model to Vietnamese data. The simulation results show that the zero lower bound does not affect the simulation results. This is another piece of evidence supporting the fitness of the model to the Vietnam context.

The resource constraint is given by

$$Y_t = C_t + p_{kt}\left[1 + f\left(\frac{I_t}{(1+\gamma_y)I_{t-1}}\right)\right]I_t + G_t \tag{37}$$

where government consumption G_t is financed by lump sum taxes and follows (in logs) an AR(1) process:

$$\log\left(G_t/(1+\gamma_y)^t\right) = (1-\rho_g)\bar{g} + \rho_g\log\left(G_t - 1/(1+\gamma_y)^{t-1}\right) + \epsilon_t^g \tag{38}$$

The market for skilled labour must clear

$$L_{st} = [Z_t - A_t]L_{sat} + L_{srt} \tag{39}$$

Finally, the market for risk-free bonds must clear, which implies that in equilibrium, risk-free bonds are in zero net supply $B_t = 0$.

B.3 EMPIRICAL AND COMPUTATIONAL STRATEGY

The majority of the 37 theoretical model parameters will be estimated using the Bayesian technique. Based on the state-space form, the log-likelihood function is evaluated using the Kalman filter.

We estimate all the standard parameters that appear in the conventional DSGE model with the exception of the mark-up in the final-goods sector. We calibrate the other technological parameters using evidence in the literature and long-run restriction.

The values for the calibrated parameters and the priors used for the estimated parameters have a central role in the analysis, and it is important to ensure that the parameters employed reflect economic circumstances in Vietnam. To that end, the parameter estimation procedure applied across different sets of values of calibrated parameters and estimated parameter priors. It was found that the convergence of the estimation procedure was particularly sensitive to the choice of steady state liquidity premium, Taylor Rule target inflation rate and the rate of capital depreciation. We chose the set of calibrated parameters that returned the set of estimated parameters that best fitted Vietnam macroeconomic data.

B.3.1 CALIBRATED PARAMETERS

We calibrate the steady state depreciation rate δ to be 0.02 and the steady state ratio of government expenditures to output to be 0.2 to match the data. The mark-ups on final (μ) and intermediate goods (ζ) are set to be 1.4 and 1.25, respectively. Both values are set to be consistent with prior literature, in particular with De Loecker and Warzynski (2012) for the former, and Anzoategui et al. (2019) for the latter, respectively. While the markup on final goods is higher than the normal range of estimates in the literature, as noted in Anzoategui et al. (2019), this reflects the export-oriented nature of the Vietnam economy, following the findings in De Loecker and Warzynski (2012) where mark-ups are higher for export oriented firms and industries. We set the parameter ϑ to 1.46 to produce an elasticity of substitution of 4.31 between intermediate goods, which is consistent with the estimates in Broda and Weinstein (2006).

Finally, we set the value of adoption elasticity ρ_λ between 0.5 and 0.7, which is lower than the calibrated value in Anzoategui et al. (2019). This lower value reflects the lag of development between Vietnam and the United States. **Table 13** presents the calibrated parameters and their values.

Table 13. Calibrated parameters

PARAMETERS	NAME	VALUE
SS capital depreciation	δ	0.02
SS government consumption/output	G/Y	0.291
SS final-goods markup	μ	1.4
SS intermediate-goods markup	ζ	1.25
Intermediate-goods elasticity of substitution	ϑ	1.46
Adoption elasticity	ρ_λ	0.7 - 0.5
SS liquidity demand	$\bar{\zeta}$	0.03/4
Obsolescence rate	$1-\phi$	0.08/4
SS adoption lag	$\bar{\lambda}$	0.05
Adoption elasticity	$\bar{\rho}_\lambda$	1.7 – 0.5

B.3.2 PRIOR DISTRIBUTION OF ESTIMATED PARAMETER

For the conventional parameters, we follow Anzoategui et al. (2019) and others and use similar priors to the literature. In general, this paper uses three types of the prior distribution. They are the beta, gamma and normal densities. **Table 14** lists the distributions, means and standard deviations for the priors.

For some priors, including the price index ι_p and Taylor rule inflation ϕ_π, the parameters we used are consistent with the literature such as Justiniano et al. (2010) and Anzoategui et al. (2019). We also set other priors to be different, to better fit the Vietnam context. For instance, we set a more conservative prior for the Taylor rule smoothing value ρ^R with a mean of 0.5 and standard deviation of 0.25.

For the prior inverse value of Frisch elasticity of labour supply φ, we use the gamma distribution with a mean of 0.5 and a standard deviation of 0.25. The reason for this is because of the high fraction of a number of under-35-year-old people in Vietnam, we believe that the Frisch elasticity of labour supply would be large, which reflects the strong response of labour supply to wage and the properties of aggregate data. In addition, we follow Justiniano and Preston (2010) and set the Calvo price prior to follow a beta distribution with a mean of 0.75 and a standard deviation of 0.1. For the consumption habit prior b, we use the beta distribution with a mean of 0.6 and standard deviation of 0.1.

Table 14. Prior distribution of estimated parameters

				PRIOR		POSTERIOR
PARAMETERS	NAME	DISTRIBUTION	MEAN	SD	MEAN	SD
Taylor rule smoothing	ρ^R	Beta	0.50	0.25	0.852	0.0004
Taylor rule inflation	ϕ_π	Gamma	1.50	0.25	1.326	0.0316
Taylor rule labour	ϕ_y	Gamma	0.30	0.10	0.963	0.0078
Inverse Frisch elast.	φ	Gamma	2.00	0.75	2.254	0.0443
Investment adj. cost	f''	Gamma	4.00	1.00	5.585	0.0603
Capital util. elast.	$\delta'(U)/\delta$	Gamma	4.00	1.00	3.780	0.0642
Calvo price	ξ_p	Beta	0.50	0.10	0.886	0.0034
Calvo wages	ξ_w	Beta	0.75	0.10	0.988	0.0005
Price indexation	ι_p	Beta	0.50	0.15	0.701	0.0142
Wage indexation	ι_w	Beta	0.50	0.15	0.144	0.0155
SS wage markup	μ_w	Normal	0.15	0.05	0.217	0.0014
Consumption habit	b	Beta	0.70	0.10	0.839	0.0130
R&D elasticity	ρ_z	Beta	0.60	0.15	0.897	0.0043
Capital share	α	Normal	0.30	0.05	0.389	0.0064
Discount factor	β	Gamma	0.25	0.10	0.613	0.0048
SS output growth	$100 \times \gamma_y$	Normal	1.50	0.15	1.386	0.0266

B.4 DATA SOURCE

In the empirical analysis we use the following quarterly macroeconomic time series. Note that in this model we do not detrend or demean the data prior to estimation.

To estimate the model, we use data from 2005:IV to 2018:IV. Real GDP (GDPC), the GDP deflator (GDPDEF), nominal personal consumption expenditures (PCEC), and nominal investment (FPI) data are produced by General Statistics Office at a quarterly frequency. Average weekly hours of work (AWHNONAG), employment of people aged 16 and over (CE16OV), and population of people aged 16 and over (CNP16OVA) are also released by the General Statistics Office at a quarterly frequency. For the interest rate (DFF), we take quarterly averages of the annualised overnight interbank daily data from the Central Bank of Vietnam, and divide by four to make the rates quarterly.

Table 15. Data source

DATA	SOURCE
Normal GDP at local currency	General Statistics Office
CPI index	IMF-IFS database
Central Bank overnight interest rate	Central Bank of Vietnam
R&D expenditure at local currency	MoST report
Average number of hours worked per week	General Statistics Office
Total investment	General Statistics Office
Total consumption	General Statistics Office
Total labour force	General Statistics Office
Total population over 16	General Statistics Office

Letting Δ denote the temporal difference operator, the correspondence between the standard macro data described above and our model observables is as follows:

- Output growth $= 100 \times \Delta ln((GDPC)/CNP16OV A)$
- Consumption growth $= 100 \times \Delta ln((PCEC/GDPDEF)/CNP16OV A)$
- Investment growth $= 100 \times \Delta ln((FPI/GDPDEF)/CNP16OV A)$
- Real wage growth $= 100 \times \Delta ln(COMPNFB/GDPDEF)$
- Hours worked $= 100 \times ln((AWHNONAG\ x\ CE16OV/100)/CNP16OV A)$
- Inflation $= 100 \times \Delta ln(GDPDEF)$
- Interest rate $= 1/4 \times$ Central bank interest rate
- Consumption growth $= 100 \times \Delta ln((PCEC/GDPDEF)/CNP16OV A)$

The R&D data used in estimating the model are from the Ministry of Science and Technology and measures the R&D expenditure of both the public and private sector. The data are annual, so in estimating the model and extracting model-implied latent variables. We use a version of the Kalman filter adapted for use with mixed-frequency data.

Appendices references

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For further information

Data61 Insight Team
Dr Pham Thu Hien
+61 7 3833 5517
hien.pham@data61.csiro.au

State Agency for Technology Innovation (SATI)
Dr. Nguyen Duc Hoang
Deputy Director General
+84 982 086088
ndhoang@most.gov.vn

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