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Modelling structural change in global macroeconomic models

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Abstract

The global economy has experienced significant structural change over the past several decades and is expected to continue evolving in the future, driven by both supply- and demand-side forces. This paper focuses on the supply side, illustrating how productivity growth drives long-term structural change. We examine three scenarios: demographic change in the baseline, technological catch-up of developing countries toward the global productivity frontier, and global productivity growth in manufacturing driven by automation technology. We simulate the scenarios in a multi-region, multi-sector general equilibrium model (G-Cubed). The model captures not only the direct channel of different productivity growth across sectors, but also the indirect channels through sectoral and international linkages. The analysis highlights how asymmetric productivity growth across sectors and countries can reshape global economic structure over time, with important implications for economic growth, international trade, and the distribution of global economic powers.

Keywords: structural change, demographic change, productivity growth, technological catch-up, sectoral linkages, international linkages.

JEL codes: C68, F43, J11, O40, O41

I. Introduction

The global economy has experienced significant structural change since the Second World War. Advanced economies have shifted the composition of output and employment across sectors, initially from agriculture to manufacturing, and later from manufacturing to services. The service sector in advanced economies already accounted for the majority of output and employment in the late twentieth century. Over the past several decades, emerging economies have followed a similar path, experiencing rapid industrialization and growing services. This long-term pattern of structural change has been a central feature of economic development.

Today, while the broad economic structure of advanced economies has become relatively stable, structural change still occurs within advanced economies at a more disaggregated sector level. Emerging economies continue to undergo rapid structural transformation, with developing Asia serving as a prominent example. Low-income developing countries, although still heavily reliant on agriculture, are expected to eventually follow a similar path of structural transformation. As such, the world economy today remains far from a steady state. Substantial structural change will continue both within countries and across the global economy, driven by the technological catch-up process of developing countries.

Economic structural change has attracted considerable attention in economic research and policy discussion. There are three broad types of drivers for structural change: demand-side, supply-side, and institutions and policy (Matsuyama, 2008; Herrendorf *et al*., 2014; Van Neuss, 2019; Comin *et al*., 2021). On the demand side, non-homothetic preferences plays a crucial role. As household income rises, the share of consumption of food falls (Engel's law), shifting demand toward manufactured goods and services. On the supply side, differences in productivity growth across sectors change relative prices and the allocation of labour and capital. Both demand- and supply-side drivers are necessary to explain the observed patterns of structural change. Herrendorf *et al*. (2014) show that the decline in agriculture is largely explained by income-driven preferences, while the shift from manufacturing to services is primarily driven by supply-side factors (fast productivity growth in manufacturing) in the United States. In addition, institutions and policy such as subsidies, trade protection, and labour market regulations can influence the speed and direction of structural change.

The traditional supply-side explanation emphasizes relative productivity growth across sectors in a closed economy, which serves as a direct channel for structural change. Van Neuss (2019) identifies input–output linkages and international comparative advantage as additional channels. Both channels operate on the supply side, but function as indirect drivers of structural change. These channels are particularly important in a world that is deeply interconnected both domestically and globally. The input–output channel extends the supply-side explanation from aggregate production to inter-sector linkages. Structural change is not only a function of final demand but also of intermediate input use across sectors. Sectors that rely more on inputs from fast-growing sectors may grow indirectly, even without direct demand-side or supply-side advantages. The international linkage channel extends the supply-side context from a closed economy to an open economy. Comparative advantage between open economies can influence the path of structural change by reinforcing certain sectors such as resource-based or manufacturing exports due to global demand.

Structural change is not only a consequence of economic growth but also a source of economic growth (Matsuyama, 2008). Sectoral reallocation can enhance or dampen overall economic growth, depending on the productivity dynamics of sectors gaining or losing labour and capital (Ngai and Pissarides, 2007). Also, the differences in the nature of production across sectors, such as economies of scale, also play a critical role (Matsuyama, 2008). It is typically assumed that non-agricultural production benefits from increasing returns to scale, giving rise to multiple steady states. As a result, the equilibrium path depends on initial conditions, a key insight in the literature on poverty traps. In addition, Rodrik *et al*. (2016) emphasize that the quality of structural transformation depends not only on economic fundamentals such as resources and technology, but also on institutional and policy frameworks. In Asia, structural change has contributed positively to economic growth, as labour moved from low-productivity agriculture to higher-productivity manufacturing and services. In contrast, in Africa and Latin America, labour has often shifted from more productive sectors to informal services, resulting in growth-reducing structural change.

Currently, several important global forces are reshaping structural change, such as the transition away from fossil fuels on the demand side, and digitization and automation on the supply side, as well as demographic change, which can drive structural change on both demand and supply sides. Against this global backdrop, this paper revisits this long-standing topic and focuses on productivity growth on the supply side. The study simulates several scenarios of sectoral productivity growth in a large-scale general equilibrium model of the global economy, in which economies are connected through international trade and capital flows, and sectors are linked through input–output relations. The paper closely relates to the literature on the relationship between structural change and economic growth, and also echoes the insights of Van Neuss (2019) by providing a quantitative analysis of both direct and indirect channels through which productivity growth drives structural change.

This paper follows the approach used in the G-Cubed model (McKibbin and Wilcoxen, 1999, 2013) to generate bottom-up projections of global economic growth from the sector level, describes the method of endogenizing structural change, and discusses the importance of incorporating endogenous structural change in macroeconomic projections and policy evaluation. The

G-Cubed approach to modelling economic growth and structural change differs from standard single-sector dynamic stochastic general equilibrium models in two important aspects. First, the model is not assumed to start at a steady state or be on a balanced growth path. Instead, the calibration year of the model is taken to be an initial point on a stable manifold transition path toward a long-run neoclassical steady state that is reached centuries in the future. Second, economic growth in the model is driven by productivity growth at the sectoral level and then aggregated to generate economic projections. Sectoral productivity growth is projected through a catch-up mechanism (Bagnoli *et al*., 1996; McKibbin *et al*., 2007, 2009; Stegman and McKibbin, 2013; Liu and McKibbin, 2025). More specifically, growth in sectoral labour productivity is exogenously projected for the United States from 2018 to 2100. For other countries, productivity level gaps for each sector in each other country relative to the United States in 2018 are estimated, and time-varying catch-up rates are specified to govern the convergence of each sector's productivity toward its US counterpart. This time-varying catch-up rate reflects assumptions about the ability of countries to adopt new technology and is intended to reflect the empirical evidence in the convergence literature. Therefore, convergence rates for labour productivity are heterogeneous across sectors and countries and over time.

Once sectoral labour productivity growth projections have been generated, they are overlaid with exogenous assumptions about potential labour force growth for each country to generate two of the main sources of economic growth (quality and quantity of potential labour supply). Given these exogenous inputs for sectoral productivity growth by country, and labour supply growth by country, the model is then solved for the other drivers of growth, including sectoral capital accumulation and sectoral demand for other inputs of energy and materials, all endogenously determined.

International flows of goods and financial capital are critical to the nature and scale of growth across countries. Financial capital is assumed to be completely mobile and flows to the sectors and countries where its risk-adjusted return is highest. Labour is assumed to be somewhat less mobile: it flows freely across sectors within a country but not between countries. Physical capital is even less mobile: once installed, it is country- and sector-specific. Thus, in the G-Cubed model, economic growth of every country is partially determined by conditions outside the country, not just the country's own exogenous inputs, since all countries are linked through goods and asset markets.

While market forces eventually drive the model to a neoclassical steady-state growth equilibrium, the immobilities and slow adjustment processes described above mean that the transition may take many decades. This captures important empirical relationships, such as long periods of unemployment due to wage stickiness. Thus, structural change in each economy over time is driven by convergence of labour productivity across sectors and the endogenous decisions of households, firms, and governments over time.

The remainder of this paper is organized as follows. Section II outlines the G-Cubed model, while section III describes the model solution and the baseline. Section IV simulates a set of scenarios for sectoral productivity growth to illustrate the importance of endogenous structural change for macroeconomic projections. Section V concludes.

II. The G-Cubed model

The G-Cubed model is a hybrid of dynamic stochastic general equilibrium (DSGE) models and computable general equilibrium (CGE) models and was originally developed by McKibbin and Wilcoxen (1999, 2013). The 6M version of the G-Cubed model used in this paper disaggregates the global economy into 18 regions (some of which correspond to individual countries), and each regional economy into six sectors. Regions are linked through international trade and capital flows, while sectors are interconnected through input–output relations, with data mainly sourced from the GTAP 10 database (Aguiar *et al*., 2019) among others. Table 1 lists the regions and the sectors in the model.[1]

[1] The full documentation of the model is available at https://documentation.gcubed.com/.

Table 1: Regions and sectors in G-Cubed model 6M build 181.

Countries/regions	Sectors
United States (US)	Energy
Japan	Mining
Western Europe	Agriculture
Australia	Durable manufacturing
South Korea	Non-durable manufacturing
Other advanced economies	Services
China	
India	
Indonesia	
Philippines	
Vietnam	
Thailand	
Malaysia	
Rest of Asia	
Latin America	
Sub-Saharan	
Africa	
Middle East and North Africa	

Several key features of the G-Cubed model are highlighted. First, the model has a disaggregated production structure. Firms in each sector in each country produce goods using primary factor inputs of capital (K) and labour (L) as well as intermediate inputs of energy (E) and materials (M), which are themselves produced from inputs of individual commodities. These sectoral links exist within and between countries.

Second, the model accounts for stocks and flows of physical and financial assets. For example, budget deficits accumulate into government debt, and current account deficits accumulate into foreign debt. The model imposes intertemporal budget constraints on all households, firms, governments, and countries. Thus, a long-run stock equilibrium is obtained through the adjustment of asset prices, such as the interest rate for government fiscal positions or real exchange rates for the balance of payments. However, the adjustment towards the long-run equilibrium of each economy can be slow, occurring over many decades.

Third, firms and households in the model must use money issued by central banks for all transactions. Thus, central banks in the model set short-term nominal interest rates to target macroeconomic outcomes (such as inflation, unemployment, exchange rates, etc.) based on Henderson–McKibbin–Taylor monetary rules (Henderson and McKibbin, 1993; Taylor, 1993). These rules are designed to approximate actual monetary regimes in each country or region in the model. These monetary rules tie down the long-run inflation rates in each country and allow short-term policy adjustments to even out fluctuations in the real economy.

Fourth, nominal wages are sticky and adjust over time based on country-specific labour contracting assumptions. Firms in each sector hire labour up to the point that the marginal product of labour equals the real wage defined in terms of the output price level of that sector. Any excess labour enters a pool of unemployed workers. Unemployment or, alternatively, excess demand for labour causes the nominal wage to adjust to clear the labour market in the long run. In the short run, unemployment can arise due to structural supply shocks or changes in aggregate demand in the economy.

Fifth, rigidities prevent the economy from moving quickly from one equilibrium to another. These rigidities include the nominal stickiness of wages mentioned above as well as slow adjustment of sector-specific capital stocks due to convex adjustment costs in investment. The transition path is also affected by a lack of complete foresight in expectation formation by monetary and fiscal authorities following particular monetary and fiscal rules. Short-run adjustment to economic shocks can differ significantly from long-run equilibrium outcomes. Focusing on short-run rigidities is essential for assessing the impact over the first decades of a major shock.

Finally, the model features heterogeneous households and firms. Firms are modelled separately within each sector. There are two types of consumers in the economy and two types of firms within each sector in each region. One group of consumers and firms bases its decisions on forward-looking expectations, using the solution of the model in future periods to form those expectations. The other group is myopic and does not use information about future periods.

III. The baseline

Because the model does not begin at a steady state or a balanced growth path, the first step is to construct a baseline transition path. The path begins from a recent observation of the world economy. Then, driven by projections of labour force growth, sectoral productivity, and other key variables, the model is solved at an annual frequency for a full transition path toward a long-term steady state imposed many decades in the future. This section describes the overall process.

(i) Drivers of growth

Distinguishing growth drivers by sector is critically important when analysing economic growth and structural change. There are several sources of growth within each economy: increases in the supply of labour, capital, and other inputs; increases in the quality of inputs; efficiency improvements of input use (technical change); and reallocation of inputs across sectors. For the world economy as a whole, an additional source of growth is the reallocation of inputs among countries.

Without sectoral disaggregation, it is not possible to consider the impact of productivity growth in particular sectors on aggregate productivity growth or to analyse economic growth and structural change due to the reallocation of inputs across sectors or economies. Previous work with G-Cubed (Bagnoli *et al*., 1996; McKibbin *et al*., 2007, 2009; Stegman and McKibbin, 2013; Liu and McKibbin, 2025) has highlighted the importance of accounting for the contribution of sectoral productivity growth to aggregate productivity growth and demonstrated the heterogeneous impact of productivity growth in different sectors on aggregate productivity growth. This point is particularly relevant when convergence assumptions are used to project long-run productivity growth.

(ii) Baseline projections

The first step in solving the model is to calculate a baseline solution. To do so, we begin by making assumptions about the future course of key exogenous variables. We take the underlying long-run rate of world potential labour supply growth plus productivity growth to be 1.4 per cent per annum and the long-run real interest rate to be 3.6 per cent. We also assume that tax rates and the shares of government spending devoted to each commodity remain unchanged.

Economic growth in the G-Cubed model depends on the growth of inputs within individual sectors of each region. There are two key exogenous inputs to the growth rate of each sector. The first is the economy-wide potential labour supply. The potential labour force growth rates are derived from the working-age population projections from the United Nations Population Prospects 2024. The second is the productivity growth rate of each sector within each region. Although exogenous to the model solution, the sectoral productivity projections are calculated using a catch-up model (Barro, 1991) outside the model. We assume that each sector in the United States is at the productivity frontier. These sectors have an exogenous rate of productivity growth over the next century (1.4 per cent). The annual catch-up rate to the world frontier is assumed to close the gap between an individual country's sector and the frontier sector by 2 per cent per year.

The initial sectoral productivity data are obtained from the Groningen Growth and Development database (Timmer *et al*., 2015). The baseline also includes variations in the catch-up rates of different economies, given the most recent growth experiences.

We then assume that productivity in each sector in each country is a proportion of the level of productivity of the equivalent sector in the US. We also assume that each sector in each country will catch up to the US sector in terms of productivity growth, closing the gap by 2 per cent each

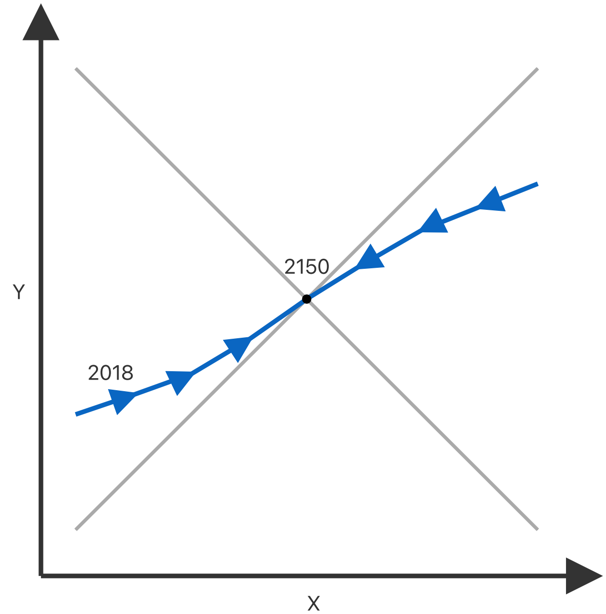


Figure 1: Model solution.

year. The initial productivity gaps and the rates of catch-up are critical for the calculation of sectoral productivity growth over time.

Given the exogenous inputs for population growth and sectoral productivity, we can solve the model. The other drivers of growth, including capital accumulation and sectoral demand for other inputs of energy and materials, are all endogenously determined.

In addition, the underlying assumptions that are critical to the nature and scale of growth across countries include: financial capital flows to where the return is highest; physical capital is sector-specific in the short run; labour can flow freely across sectors within a country but not between countries; and that international trade in goods and financial capital is possible subject to existing tax structures and trade restrictions.

Thus, in the G-Cubed model, the growth of any particular country is not solely determined by the exogenous inputs specific to that country. This is because all countries are interconnected through goods and asset markets. This interdependence is a key feature of the model, reflecting its global perspective and its ability to capture the complex and interconnected nature of the global economy.

(iii) Solving for the transition path

The exogenous inputs are one part of the solution requirements. We must also calibrate the base year of the solution trajectory to the actual data we observe in the database. This is challenging because forward-looking variables in the 2018 data depended on expectations people held at the time about the current and expected future paths of the exogenous variables in the model (e.g. exchange rates, equity prices, human capital). Since those expectations may differ from the paths we impose in the baseline, we need a procedure for reconciling any potential differences. This difficulty arises in all intertemporal models and is not unique to G-Cubed.

To address this problem, most intertemporal models assume that the model starts in a steady state and simply replace the values of intertemporal variables in the actual data with those from the solution for the model. In G-Cubed, however, we assume that the observed data in 2018 is not from the model's steady state but is a solution for the model on the stable manifold transitioning towards a steady state (as shown in Figure 1). The idea is stylized in the following figure, where 2150 is a stylized steady-state year of the model, and 2018 is the benchmark year for the baseline projection.

To reconcile the 2018 database with the transition path, we add a set of constants, one for each co-state variable, to the model's co-state equations. For example, the constants for Tobin's q for each sector in each country are added to the arbitrage equation for each sector's q. Similarly, constants for each real exchange rate are added to the interest arbitrage equation for each country, and a constant for human wealth is added to the equation for human wealth.

To calculate the constants, we use Newton's method to find a set of values for them that will make the model's co-state variables in 2018 exactly equal to their 2018 historical values. After the constants have been determined, the model will reproduce the base year exactly, given the state variables inherited from 2018 and the assumed future paths of all exogenous variables. The adjustments are, in effect, integration constants that introduce fixed transformations between the historical data and the model's co-state variables.

One additional problem is to solve consistently for both real and nominal interest rates since the real interest rate is the nominal interest rate from the money market equilibrium less the *ex ante* expected inflation rate. To produce the expected inflation rate implicit in historical data for 2018, we add a constant to the equation for nominal wages in each country.

Finally, we can construct the baseline trajectory by solving the model for each period after 2018 given any shocks to variables, shocks to information sets (announcements about future policies), or changes in initial conditions.

IV. Structural change

Structural change is captured in the model through relative sizes of regional economies, relative sizes of sectors within each region, and sectoral factor intensities of capital, labour, energy, and materials. We first illustrate the impact of our catch-up assumptions by comparing baseline results without and with other countries catching up to US productivity levels. We then examine the effects of a total factor productivity (TFP) shock applied to the manufacturing sectors across all regions.

(i) Baseline without technology catch-up

Figure 2 shows the baseline projections for real GDP in a baseline without any accelerated growth for less developed economies due to technological catch-up.

In the absence of technological catch-up, regional differences in real GDP growth are primarily driven by variations in labour force growth rates. For example, China, Japan, and South Korea are projected to have negative labour force growth through most projection years, while South Asia (India and Rest of Asia) and Africa are expected to experience strong labour force growth. Even without catch-up, several regions change in size rankings through the projection years, largely reflecting these population dynamics.

Within an individual region, the relative sizes of sectors change along the baseline. To illustrate, Figure 3 shows the projections of output growth for each of the six sectors in the US. Similar analyses can be performed for other regions.

In the baseline projection, the growth rate of the US economy is driven by three main factors: convergence to the steady state, the long-term rate of technological progress (assumed to be 1.4 per cent per annum), and growth in the US labour force. The growth dynamics depend on the initial state for each sector, patterns of international trade and financial capital flows, as well as differences in sectoral factor intensities. Figure 4 shows how factor intensities differ across sectors and how those differences change as the structure of the US economy evolves. Note that sectoral capital intensity is defined as the annual depreciation rate (10 per cent) times the sector's capital stock as a percentage of sectoral output. This measure of capital intensity better aligns with the definitions of other factor intensity measures.

Two points stand out in Figure 4. First, there are large differences in factor intensities across sectors and these differences tend to persist over time. Second, these factor intensities change over time. For example, capital intensity of the energy sector declines from almost 36 per cent to just under 30 per cent between 2025 and 2050. These changes in factor intensities become even more pronounced with the introduction of technology catch-up to the baseline. The decline in energy

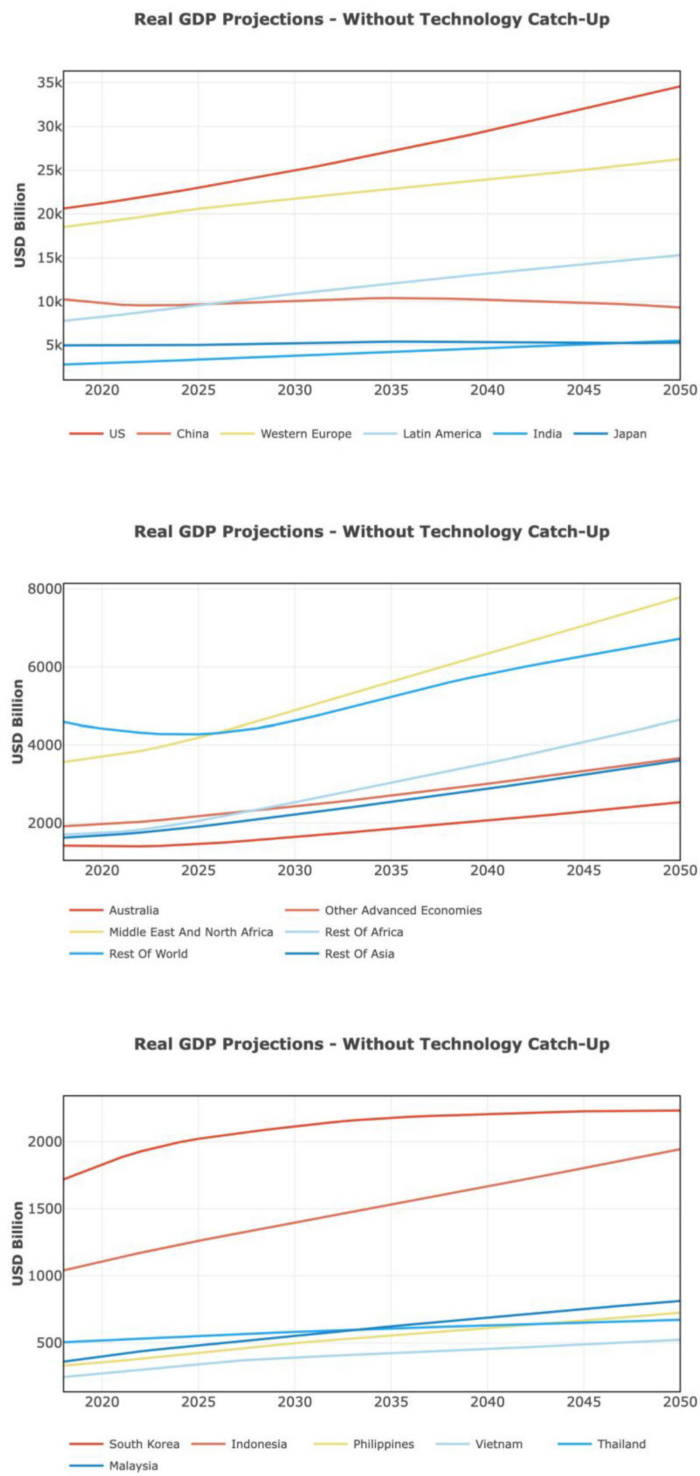


Figure 2: Real GDP without technology catch-up (billions of 2018 US dollars).

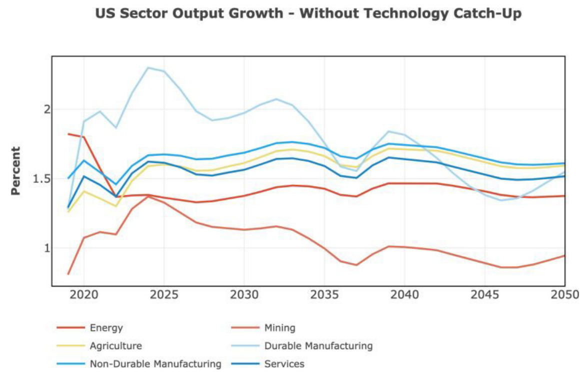
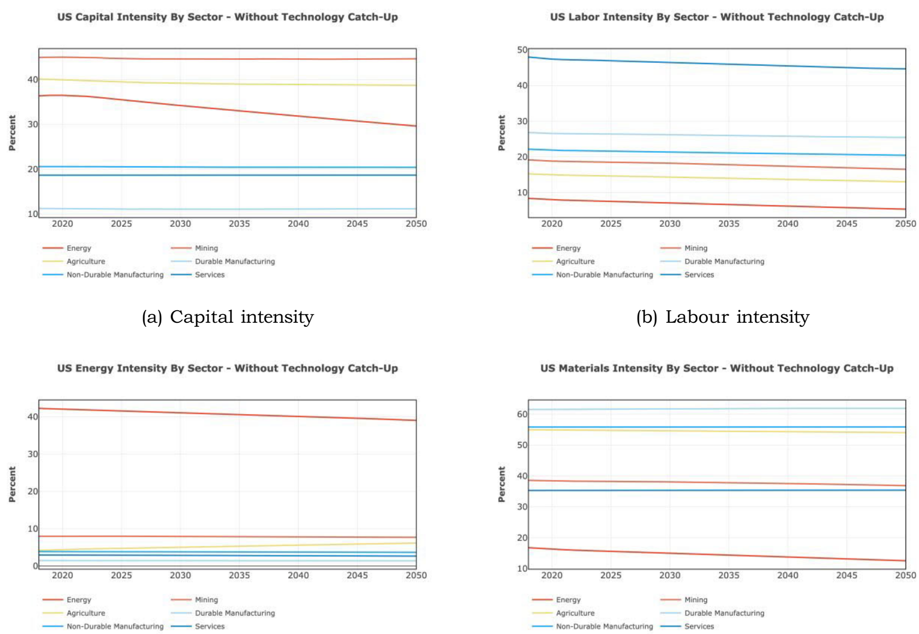


Figure 3: Sector output growth rates for the US.



(a) Capital intensity

(b) Labour intensity

(c) Energy intensity

(d) Materials intensity

Figure 4: Factor intensities in US sectors, without technological catch-up.

intensity reflects the assumption that labour productivity drives economic growth. According to a modified Rybzynski theorem (Rybczynski, 1955), sectors that are intensive in the increasing factor of production (labour) tend to expand while sectors that are less intensive (energy is relatively more capital intensive) tend to contract. All sectors can expand in an open economy, but capital-intensive sectors will expand less quickly.

(ii) Technology catch-up

The baseline trajectory of the economic structure can be further conditioned by introducing the catch-up of developing economies to more technologically advanced economies. Technological catch-up is modelled as a function of three components: projected rates of technological progress at the technology frontier for each sector; initial per cent gaps for each sector between each region and the technology frontier; and projected catch-up rates, expressed as the percentage of the technology gap that is closed by sector in each region.

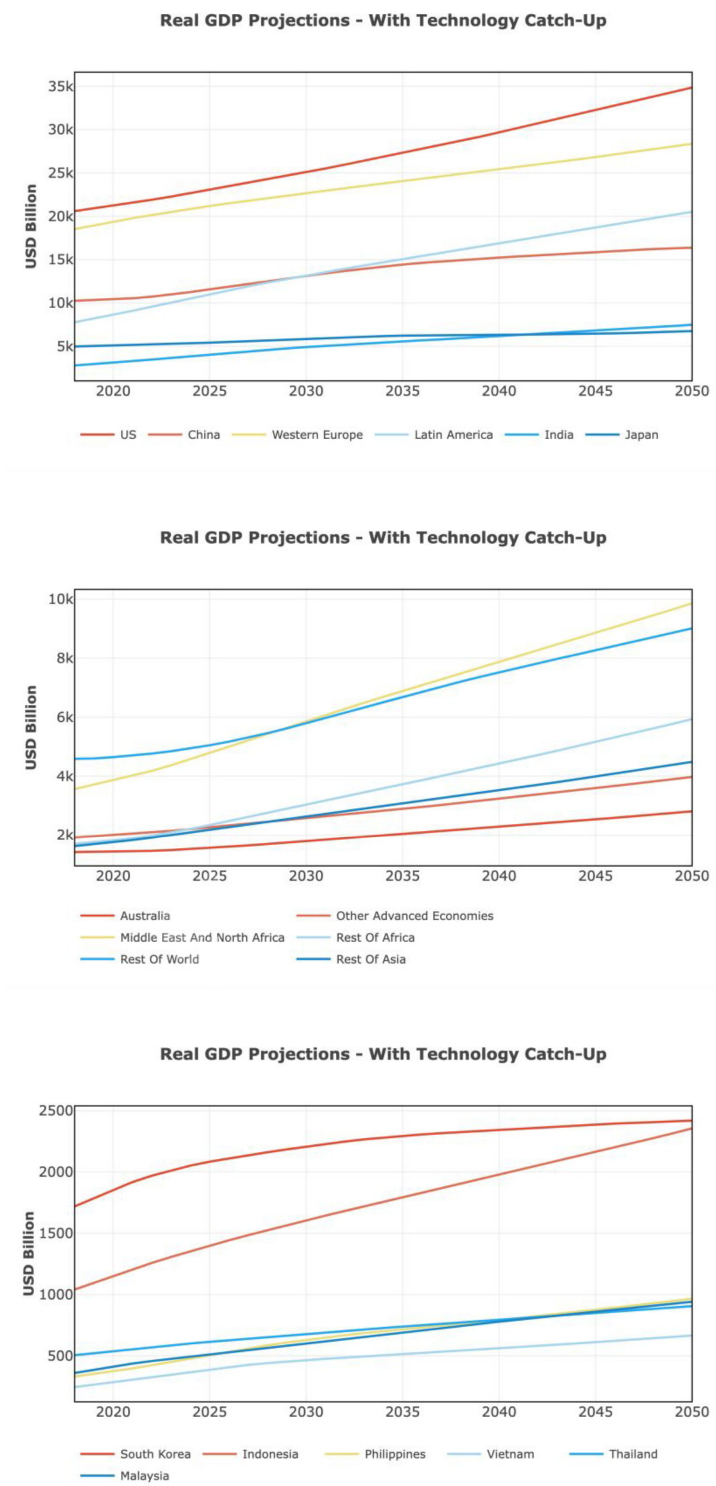
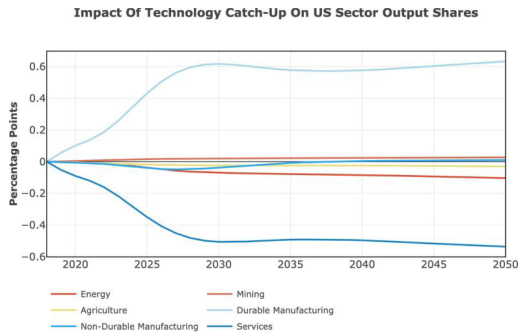
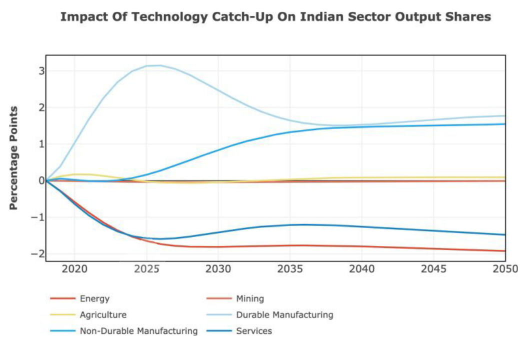


Figure 5: Real output with technology catch-up, measured in billions of 2018 US dollars.



(a) United States



(b) India

Figure 6: Impact of technology catch-up on sector output shares.

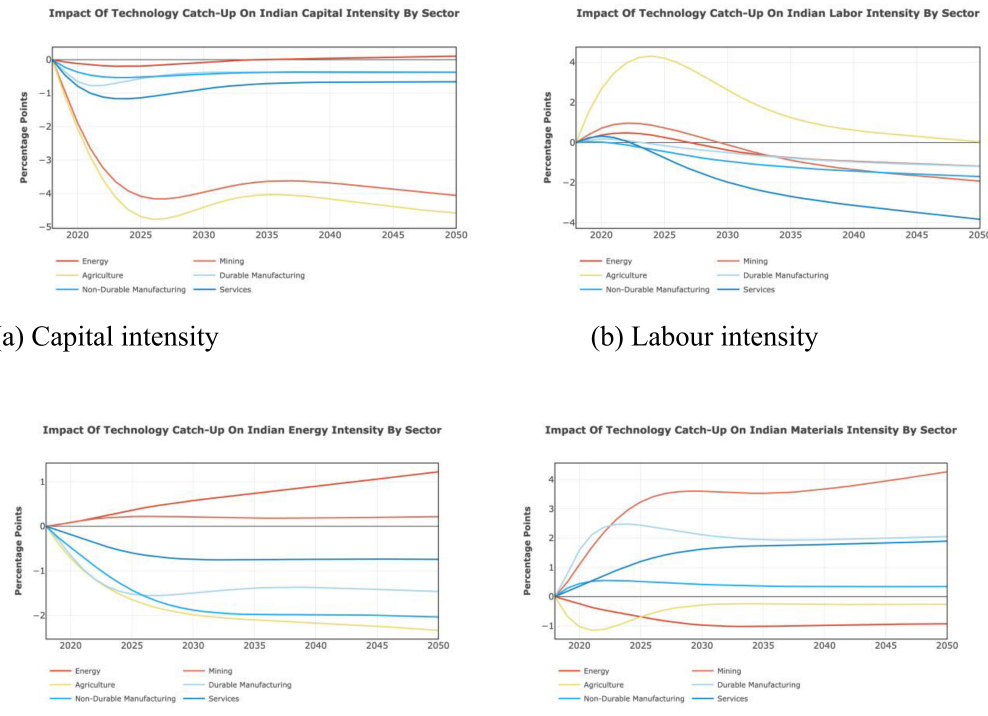
Sectors on the technology frontier experience no boost to productivity from the catch-up process. Their growth due to productivity will just reflect progress of the technology frontier. Sectors that are behind the technology frontier will get a boost to productivity but only if catch-up rates are not zero. Representing the catch-up process in this way gives a high degree of control over how labour-augmenting technical change feeds into growth paths for each sector in each region.

Figure 5 shows faster growth with technological catch-up for developing economies, including those with shrinking labour forces. India, with significant technology gaps and a 2 per cent rate of catch-up in each year, has a significantly accelerated growth path, compared to Figure 2, with real GDP projected to be almost 33 per cent higher in 2050 when taking technological catch-up into account. In the United States, every sector is assumed to be on the technology frontier and so it experiences no direct boost to growth from catch-up. However, international linkages cause the structure of the US economy to adjust in response to the accelerated growth of developing countries.

Figure 6 highlights the impact of technology catch-up on economic structure by comparing output shares between the United States and India. Note the significant differences in the impact of technology catch-up on the sectoral composition of the economy in India, as shown in the second panel. The output share of durable manufacturing, for example, is about 2 percentage points higher each year as a result of catch-up. The differences are a direct function of the sectoral technology gaps and the sectoral rates of catch-up. The durable manufacturing sector produces the goods that feed into the capital stock in all sectors. Therefore, a surge in demand for more capital implies a front loaded rise in the output of the durable goods sector.

The impact of technology catch-up on the baseline trajectories for factor intensities can be clearly seen in Figure 7, depicting the projections for India, a region strongly affected by the technology catch-up process.

To provide information on a broader range of countries, Tables 2 and 3 summarize the structural changes from 2025 to 2050 in the baseline trajectories caused by incorporating technology



(a) Capital intensity

(b) Labour intensity

(c) Energy intensity

(d) Materials intensity

Figure 7: Impact of technological catch-up on factor intensities in India.

Table 2: Percentage point changes in sector shares from 2025 to 2050.

Region	Australia	China	W. Europe	India	Japan	US
Energy	0.29	0.52	0.13	– 0.27	0.19	– 0.07
Mining	0.49	– 0.15	0.10	0.03	0.10	0.01
Agriculture	0.06	1.64	0.16	0.11	0.04	– 0.01
Durables	0.16	– 0.86	0.82	– 1.36	5.15	0.20
Non-durables	0.08	2.49	0.47	1.39	– 0.88	0.05
Services	– 1.07	– 3.65	– 1.68	0.10	– 4.60	– 0.19

catch-up for six regions in the model. Table 2 presents changes in relative sector sizes, while Table 3 shows changes in capital, labour, energy, and material intensities.

(iii) TFP shocks in manufacturing

Given a baseline trajectory, the G-Cubed model enables analysis of the impact of shocks to exogenous variables. Such shocks to the baseline also drive changes in the importance of each sector within each region and the factor intensities in those sectors. To illustrate, consider a scenario in which the growth of TFP is 1 percentage point higher in each year from 2030 to 2040 for the manufacturing sectors (durable and non-durable) of all regions. This TFP growth acceleration is anticipated from 2025.

Figure 8 presents the changes in sectoral output shares in the United States in this scenario. Note that the structures of the economies begin changing in 2025, as soon as the forward-looking agents learn of the accelerated TFP growth in the decade from 2030. Moreover, the anticipation effect is most pronounced in the years up to and just after the start of the TFP acceleration as

Table 3: Changes in economic structure between 2025 and 2050 due to technology catch-up.

Intensity	Sector	Australia	China	W. Europe	India	Japan	US
Capital	Energy	1.74	1.23	– 0.41	0.29	1.06	– 0.51
	Mining	– 0.34	– 0.80	– 2.37	0.03	NA	– 0.34
	Agriculture	0.87	– 4.68	– 1.69	0.11	– 2.50	– 0.71
	Durables	0.39	– 0.23	– 0.12	0.18	– 1.30	0.01
	Non–durables	0.26	– 0.33	– 0.19	0.15	0.02	– 0.04
	Services	0.15	– 0.02	0.11	0.48	– 0.56	0.06
Labour	Energy	0.06	– 1.44	– 1.34	– 1.44	0.59	– 0.30
	Mining	1.36	– 4.08	– 7.12	– 2.66	NA	– 0.68
	Agriculture	– 1.02	– 14.17	– 2.90	– 4.17	– 0.36	– 0.47
	Durables	– 0.22	– 3.86	– 2.41	– 1.03	– 9.06	– 0.21
	Non–durables	– 0.56	– 3.00	– 2.15	– 1.23	– 2.66	– 0.22
	Services	– 1.25	– 5.52	– 0.80	– 3.06	– 8.24	– 0.20
Energy	Energy	– 0.28	1.36	1.20	0.86	9.44	0.73
	Mining	0.23	– 0.61	0.61	0.00	NA	0.15
	Agriculture	– 0.12	– 1.28	– 0.70	– 0.69	– 2.56	0.15
	Durables	0.17	– 0.11	0.47	0.06	– 0.26	0.02
	Non–durables	0.23	– 0.21	– 0.09	– 0.60	0.21	0.06
	Services	0.08	0.87	0.06	– 0.14	0.15	0.05
Material	Energy	0.53	– 10.16	0.57	– 0.24	8.06	– 0.19
	Mining	0.83	– 5.78	– 18.44	1.03	NA	0.23
	Agriculture	0.82	– 8.99	– 1.52	0.43	– 2.25	– 0.08
	Durables	– 1.15	– 3.51	– 0.46	– 0.39	0.87	0.29
	Non–durables	0.19	– 4.19	0.07	– 0.17	1.32	0.26
	Services	0.04	– 0.66	0.32	0.70	0.19	0.13

Note: Japan's mining sector is excluded (NA) because the sector is tiny and even minor changes can result in large percentage deviations, which are not meaningful for analysis.

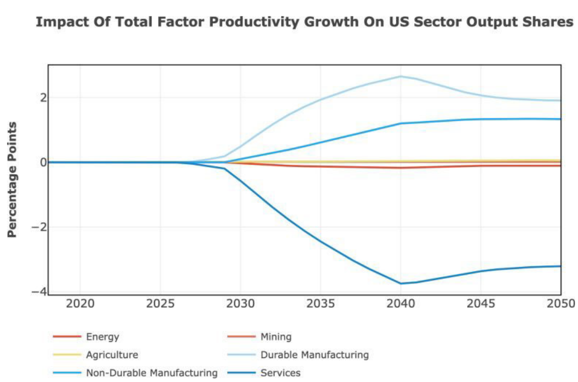
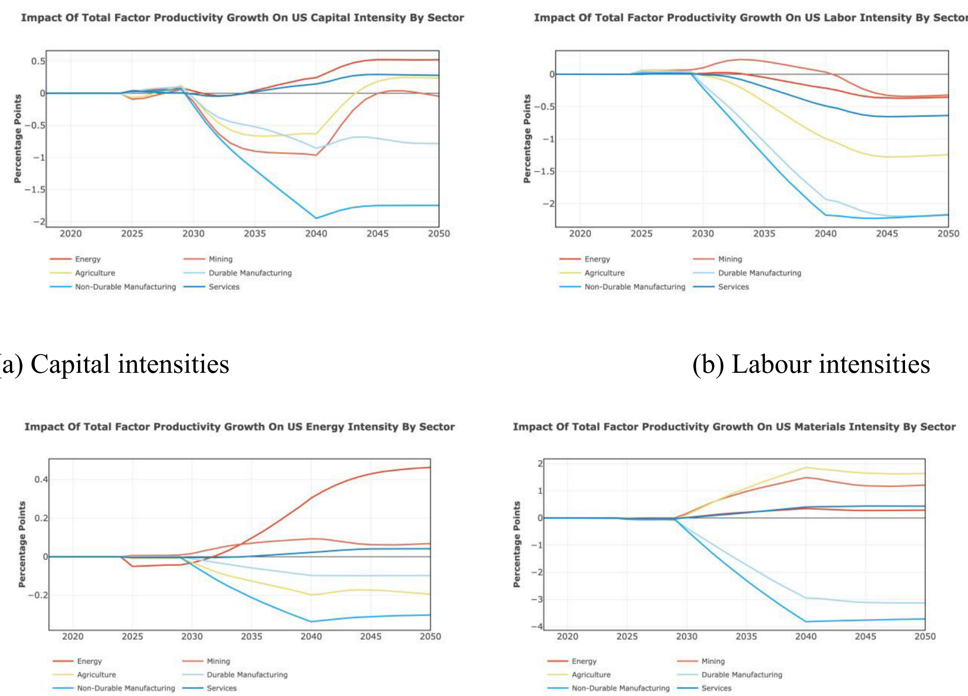


Figure 8: Impact of TFP acceleration on sector output shares in the US.

agents, anticipating the shocks and recognizing the impediments to change, bring forward their adjustments. The boost to TFP in the two manufacturing sectors causes their output shares to increase significantly. The increase to the share of durable manufacturing is somewhat larger, especially over the adjustment period, because the output from durable manufacturing is used in the production of raw capital, required as the other sectors in the economy expand. The output share of the services sector declines because that sector is least dependent on materials and capital as inputs to production.

Figure 9 presents the changes in factor intensities in the United States in this scenario. Because TFP enters the production functions multiplicatively, it increases output without requiring increases in the factors of production. Consequently, the factor intensities for the two manufacturing sectors decline across all four factors. With higher productivity in the durable manufacturing



(a) Capital intensities (b) Labour intensities

(c) Energy intensities (d) Materials intensities

Figure 9: Impact of TFP acceleration on factor intensities in the US.

Table 4: Percentage point changes in sector shares from 2025 to 2050.

Region	Australia	China	W. Europe	India	Japan	US
Energy	0.43	0.13	– 0.09	– 0.38	– 0.35	– 0.11
Mining	0.29	– 0.12	0.07	– 0.01	0.02	0.02
Agriculture	0.30	0.14	0.02	– 0.23	0.02	0.05
Durables	2.11	0.81	1.77	0.78	5.15	1.90
Non-durables	1.86	1.75	1.49	1.03	1.82	1.33
Services	– 5.00	– 2.71	– 3.26	– 1.18	– 6.67	– 3.19

sector, the cost of capital falls for other sectors. By the end of the adjustment period, this leads to the other sectors become somewhat more capital intensive. The capital deepening tends to cause the labour intensity of the other sectors to fall. The energy sector is capital-intensive, so a fall in the cost of capital tends to increase the energy intensity of energy by reducing the energy input cost. This reflects a Rybzynski theorem effect that an increase in the endowment of a factor of production (in this case capital) will tend to expand the relatively more intensive sectors in that factor. Other sectors would contract if total output is given, but because of openness to trade and capital flows, total economy-wide output is not constant. Other sectors will either contract or expand less.

Tables 4 and 5 shows the economic structural changes induced by the anticipated TFP acceleration for the manufacturing sectors between 2030 and 2040 for six regions. Table 4 presents changes in relative sector sizes, while Table 5 shows changes in capital, labour, energy, and material intensities.

Table 5: Changes in economic structure between 2025 and 2050 due to TFP acceleration in the 2030s.

Intensity	Sector	Australia	China	W. Europe	India	Japan	US
Capital	Energy	1.12	0.55	0.50	0.14	0.65	0.48
	Mining	– 0.04	0.34	0.58	0.22	NA	0.05
	Agriculture	– 0.16	2.28	0.95	1.56	0.98	0.30
	Durables	– 0.62	– 0.66	– 0.92	– 0.22	– 1.57	– 0.80
	Non-durables	– 1.03	– 0.61	– 1.32	– 0.25	– 1.32	– 1.77
	Services	0.21	0.76	0.43	0.31	1.11	0.24
Labor	Energy	– 0.21	– 0.65	– 0.35	– 0.69	– 0.02	– 0.37
	Mining	0.41	– 0.96	– 1.95	– 0.46	NA	– 0.38
	Agriculture	– 1.78	– 4.65	– 2.93	– 2.44	– 3.33	– 1.30
	Durables	– 0.94	– 1.21	– 2.30	– 0.47	– 3.66	– 2.22
	Non-durables	– 1.15	– 0.45	– 1.73	– 0.43	– 2.13	– 2.19
	Services	– 0.94	– 1.44	– 0.86	– 0.70	– 2.83	– 0.64
Energy	Energy	2.18	0.14	0.65	0.25	3.99	0.51
	Mining	0.09	– 0.14	– 0.07	0.00	NA	0.06
	Agriculture	– 0.62	– 0.02	– 0.16	– 0.27	– 1.10	– 0.18
	Durables	– 0.44	– 0.27	– 0.09	– 0.44	– 0.68	– 0.10
	Non-durables	0.32	– 0.30	– 0.61	– 0.57	– 1.35	– 0.30
	Services	– 0.01	0.28	0.03	– 0.07	0.11	0.05
Material	Energy	0.65	– 2.89	1.11	– 0.05	3.26	0.30
	Mining	0.93	– 1.35	– 5.19	1.07	NA	1.20
	Agriculture	3.23	0.39	2.42	1.77	6.48	1.64
	Durables	– 2.11	– 5.84	– 5.82	– 2.47	– 7.68	– 3.07
	Non-durables	– 1.53	– 5.90	– 5.59	– 2.60	– 4.76	– 3.68
	Services	0.67	0.52	0.68	0.50	1.00	0.46

Note: Japan's mining sector is excluded (NA) because the sector is tiny and even minor changes can result in large percentage deviations, which are not meaningful for analysis.

V. Conclusion

The global economy has experienced significant structural change since the Second World War, first in advanced economies and later in emerging economies. This transformation has shifted the economic structure from agriculture to manufacturing and then to services. Structural change is driven by three broad types of factors: supply-side, demand-side, and institutions and policy. Looking ahead, structural change is expected to continue. International differences in productivity and labour force growth will influence the global economic structure through international trade and capital flows. For example, developing countries can experience rapid growth if they successfully catch up to the global productivity frontier, with China as a prominent case. In addition, several major global forces are likely to drive structural change, including energy transition, digitization and automation technology, and demographic change. This paper focuses on the supply side, illustrating how productivity growth drives long-term structural change in the G-Cubed model.

We simulated three scenarios in the model, including demographic change in the baseline, technological catch-up of developing countries toward the global productivity frontier, and global productivity growth in manufacturing driven by automation technology. The baseline scenario shows that demographic change would change economic structure due to different factor intensities across sectors, and also reshape the distribution of global economic power because of demographic asymmetry. In the catch-up scenario, the initial productivity gaps and the catch-up rates can differ across sectors, resulting in different productivity growth across sectors. The model captures not only the direct channel of different productivity growth across sectors, but also the indirect channels through sectoral and international linkages. In the manufacturing productivity scenario, sector-specific differences in productivity lead to immediate structural change, which is also propagated through input–output linkages. Also, as the manufacturing share varies across economies, even a uniform growth rate in manufacturing does not result in identical structural adjustments, but generates asymmetric changes in manufacturing sectors across regions.

References

Aguiar, A., *et al.* (2019), 'The GTAP Data Base: Version 10', *Journal of Global Economic Analysis*, 4, 1–27, https://jgea.org/ojs/index.php/jgea/article/view/77, 10.21642/JGEA.040101AF.

Bagnoli, P., McKibbin, W. J., and Wilcoxen, P. J. (1996), 'Global Economic Prospects: Medium Term Projections and Structural Change', in N. Nakicenovic, W. Nordhaus, R. Richels, and F. Toth (eds), *Climate Change: Integrating Economics and Policy*, CP-96-1, International Institute for Applied Systems Analysis (Austria), 181–206, https://Www.Brookings.Edu/Articles/global-economic-prospects-medium-term-projections-and-structural-change/.

Barro, R. J. (1991), 'Economic Growth in a Cross Section of Countries', *The Quarterly Journal of Economics*, 106, 407–43, http://www.jstor.org/stable/2937943.

Comin, D., Lashkari, D., and Mestieri, M. (2021), 'Structural Change with Long-run Income and Price Effects', *Econometrica*, 89, 311–74, https://onlinelibrary.wiley.com/doi/abs/10.3982/ECTA16317.

Henderson, D. W., and McKibbin, W. J. (1993), 'A Comparison of Some Basic Monetary Policy Regimes for Open Economies: Implications of Different Degrees of Instrument Adjustment and Wage Persistence', *Carnegie–Rochester Conference Series on Public Policy*, 39, 221–317, https://www. sciencedirect.com/science/article/pii/016722319390011K.

Herrendorf, B., Rogerson, R., and Valentinyi, A. (2014), 'Growth and Structural Transformation', ch. 6in P. Aghion, and S. N. Durlauf (eds.), *Handbook of Economic Growth*, vol. 2, Elsevier, 855–941.

Liu, W. L., and McKibbin, W. (2025), 'Long Term Projections of the World Economy', CAMA Working Paper Series Paper, forthcoming.

McKibbin, W. J., and Wilcoxen, P. J. (1999), 'The Theoretical and Empirical Structure of the G-Cubed Model', *Economic Modelling*, 16, 123–48, https://www. sciencedirect.com/science/article/pii/S0264999398000352.

— — (2013), 'A Global Approach to Energy and the Environment: The G-Cubed Model', ch. 15in P. B. Dixon, and D. W. Jorgenson (eds), *Handbook of Computable General Equilibrium Modeling SET*, Vols 1A and 1B, Elsevier, 995–1068, https://www.sciencedirect.com/science/article/pii/B9780444595683000158

McKibbin, W. J., Pearce, D., and Stegman, A. (2007), 'Long Term Projections of Carbon Emissions', *International Journal of Forecasting*, 23, 637–53, https://www. sciencedirect.com/science/article/pii/S0169207007001318.

— — — (2009), 'Climate Change Scenarios and Long Term Projections', *Climatic Change*, 97, 23–47. https://doi.org/10.1007/s10584-009-9621-3.

Matsuyama, K. (2008), 'Structural Change', in S. N. Durlauf, and L. E. Blume (eds), *The New Palgrave Dictionary of Economics,* 2nd edn, Palgrave Macmillan, 10.1057/9780230226203.1621.

Ngai, L. R., and Pissarides, C. A. (2007), 'Structural Change in a Multisector Model of Growth', *The American Economic Review*, 97, 429–43, http://www.jstor. org/stable/30034402.

Rodrik, D., McMillan, M., and Sepúlveda, C. (2016), *Structural Change, Fundamentals, and Growth*, Washington DC: IFPRI, https://drodrik.scholar.harvard.edu/files/dani-rodrik/files/structural_change_fundamentals_and_growth.pdf.

Rybczynski, T. M. (1955), 'Factor Proportions and Comparative Advantage', *Journal of Political Economy*, 63, 559–66.

Stegman, A., and McKibbin, W. (2013), 'Long Term Projections of the World Economy—A Review', CAMA Working Paper Series Paper 14/2013, https://papers.ssrn. com/sol3/papers.cfm?abstract_id=2239520, 10.2139/ssrn.2239520.

Taylor, J. B. (1993), 'Discretion versus Policy Rules in Practice', *Carnegie–Rochester Conference Series on Public Policy*, 39, 195–214, https://www.sciencedirect.com/science/article/pii/016722319390009L.

Timmer, M., de Vries, G. J., and Vries, K. (2015), 'Patterns of Structural Change in Developing Countries', in *Routledge Handbook of Industry and Development*, Routledge, 65–83, https://www.taylorfrancis.com/chapters/edit/10.4324/9780203387061-4/patterns-structural-change-developing-countries-marcel-timmer-gaaitzen-de-vries-klaas-de-vries

Van Neuss, L. (2019), 'The Drivers of Structural Change', *Journal of Economic Surveys*, 33, 309–49. https://doi.org/10.1111/joes.12266.