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Longer-term structural transitions and short-term macroeconomic adjustment: quantitative implications for the global financial system

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Abstract

This paper provides quantitative modelling of the effect of three longer-term global transitions: the global demographic transition involving a marked reduction in population growth; a long-term slowdown in productivity growth which may continue, or may conceivably be reversed; and the disruption in the global economy due to increasing climate shocks and the implementation of climate policies that will be needed to reach net-zero emissions by 2050. We study the global investment needs to which these transitions will lead. We demonstrate that these investment needs will be both asymmetric across countries and over time. This asymmetry will lead to potentially large changes in trade flows and significant financial capital flows across national borders, and also to substantial real exchange changes and interest rate movements. The resulting large movements in international capital flows will have significant implications for the global financial system, which we demonstrate at the country and regional level.

Keywords: global demographic transition, global productivity, climate transition risk, climate physical risk, international capital flows, real exchange rates, real interest rates

JEL classification: E52, E61, E62, E65, F31, F32, F41, F42, F62.

I. Introduction and summary

The global economy is undergoing three longer-term transitions. The first is a global demographic transition which is already well under way. The second is a long-term slowdown in productivity growth which may continue (or reverse if artificial intelligence optimists prove correct). The third is the disruption in the global economy due to increasing climate shocks and the implementation of climate policies that will be needed to reach net-zero emissions by 2050. In particular, the investment needs at the worldwide level to transform global energy systems over the next 30 years are enormous.

Against this background, global policy-makers need to respond to many short-term shocks. The policy-maker responses include: dealing with a surge in global inflation through tighter monetary policy; financing the costs of build-back-better while the Covid-19 epidemic evolves; finding the investment involved in post-war reconstruction once peace is reached in Ukraine; and paying for more significant global defence expenditures due to the war in Europe and given the emergence of an increasingly assertive China.

These significant global macroeconomic developments are likely to present challenges just as substantial as those faced at the Bretton Woods Conference in 1944. National macroeconomic policy-makers and policy-makers in international financial institutions, including the International Monetary Fund (IMF) and the World Bank, will

need to rise to these challenges. Whatever happens, the nature of these global developments will likely lead to considerable capital flows across national borders and between advanced and emerging countries. And there will also be significant increases in the necessary lending to emerging market economies and the world's poorest economies. These will all need to be managed. It is crucial for all countries that policy-makers do what is necessary. Our concern in this paper is to analyse the nature and magnitude of these longer-term transitions and their implications for the international financial system. While focusing on the longer-term global trends, we turn, at the end of the paper, to consider the additional issues raised by the shorter-term shocks.

Our primary purpose is to demonstrate that the longer-term transitions will likely be both asymmetric across countries and over time. We aim to show that this asymmetry will lead to potentially large changes in trade flows and significant financial capital flows across national borders. These effects will also lead to substantial real exchange and interest rate changes. The resulting large movements in international capital flows will have significant implications for the global financial system.

In practice, separating the study of longer-term transitions from what happens during the shorter term is impossible. The two sets of things will necessarily be interconnected. In particular, the longer-term adjustments will sometimes cause movements in the opposite direction to what is happening in the shorter term. An example is how the energy shortages caused by the war in Ukraine are in danger of slowing the moves towards zero emissions of greenhouse gases in the short term. Nevertheless, the substitution from fossil fuels will be accelerated over time due to the high price of fossil fuel energy in the short term and the greater awareness of the geopolitical risks associated with reliance on external energy sources, especially fossil fuels.

We aim to describe, intuitively and quantitatively, the effects over two somewhat different time periods, namely for a shorter-term period of 5–10 years and a much longer-term period, stretching well beyond a single decade to 2050 and beyond. In particular, we show that it is essential to understand the long-term trends and quantify their significance if one is to be able to understand the shorter-term effects of these long-term trends. We provide numerical calculations based on simulations to assist with the necessary quantitative understanding. These calculations are—in turn—necessary as a guide for our intuition.

Exploring the longer-term context of current disruptions in the global economy indicates the likely demands placed on international financial institutions, including the IMF and the World Bank, looking forward 5 or 10 years and looking much further into the future.

An essential feature of our approach is highlighting the link between international financial flows, physical capital accumulation, and the investment implications of the transitions we identify. The international flow of financial capital from regions with excess savings relative to investment opportunities to areas where opportunities emerge will imply corresponding changes in trade flows, real exchange rates, and global real interest rates. The G-Cubed multi-country model we use in this study makes it possible to study the need for and implications of these substantial movements of international financial capital.

In particular, our approach does not simply focus on international capital movements emerging as a result of arbitrage, consequent upon interest-rate movements brought about by national central banks and the exchange rate adjustments that such interest-rate movements necessarily cause. These arbitrage movements will necessarily form part of our analysis. However, going beyond this, the new insights provided by our approach emerge from studying international capital movements as a consequence of the processes of capital accumulation in the countries that make up the world economic system. These accumulation processes are driven by population growth and productivity growth. They are also caused by the significant structural changes due to the move towards restructuring the global energy system and the increasingly important shock to the global climate.

In sum, we demonstrate the importance of integrating an analysis of the global financial system, including international capital flows, with an analysis of the longer-term growth trajectory of the countries that make up the global economy.

II. The G-Cubed framework

In what follows, we draw on several recent papers that apply the G-Cubed global macroeconomic model to study global macroeconomic developments. This model has been developed by Warwick McKibbin, Peter Wilcoxen, and colleagues over the past 30 years and is now in use at both the IMF and several major central banks. We use the results of the research described in those papers to present some ballpark numbers about the transitions we identified in the paper's introduction.

An overview of the G-Cubed model can be found in McKibbin and Wilcoxen (1999, 2013), with a more recent update in Liu *et al.* (2020), where further descriptions of the model's structure are provided. Some applications to

study policy issues can be found in McKibbin and Vines (2000) and McKibbin and Stoeckel (2018). Many versions of the G-Cubed model have different sectoral coverages and country coverage. The methodology is standard across models, but, the disaggregation of countries and sectors are chosen to reflect the question being addressed. The Appendix outlines the different versions used in this paper.

In summary, the G-Cubed model is a hybrid of a dynamic stochastic general equilibrium (DSGE) model (of the kind used by central banks) and a computable general equilibrium (CGE) model (of the type often applied to study tax policy and trade policy). The G-Cubed modelling framework has several important features.

(a) G-Cubed is an annual model that depicts macroeconomic and sectoral dynamics for the world economy, disaggregated into many countries and regions.
(b) G-Cubed is based on the intertemporal decisions about saving and investment, which determine the effects of investment on economic growth. The model depicts inter-industry linkages, international trade, and capital flows.
(c) G-Cubed incorporates consumers who seek to maximize the expected value of discounted utility obtained by consuming commodities and consumers who are liquidity-constrained.
(d) The accumulation of physical capital in each sector is determined by the owners of productive firms seeking to drive the marginal product of capital towards the relevant (risk-adjusted) real interest rate. But there are important, sector-specific adjustment costs to accumulating physical capital. These are assumed to be quadratic and are empirically calibrated. Some firms have backward-looking expectations of the marginal product of capital. In contrast, other firms have forward-looking expectations that are assumed to be consistent with the economy's behaviour, as depicted by this model.
(e) G-Cubed captures frictions in labour markets. There is full employment of labour in the long run, but there can be unemployment, or excess demand for labour due to nominal wage stickiness, in the short run. Labour is mobile across sectors but not across countries. Nominal wages adjust sluggishly in a manner that is partly forward-looking and backward-looking.
(f) The model depicts trade between countries, across production networks of intermediate and final goods, in a way that adds up across all countries worldwide.
(g) Exchange rates are determined in such a way as to satisfy uncovered interest parity across short-term financial asset holding in all countries after allowing for country-specific risk premia. The uncovered interest rate parity assumption and the assumption of rational expectations in the currency markets imply that several factors determine the current exchange rate between a country and the US. These factors include the expected future path of interest differentials relative to the US, the country risk premium relative to the US, and the long-run equilibrium exchange rate determined by long-run asset stock equilibrium.

An Appendix to this paper outlines the significant features of the model in more detail.

III. How to analyse the three transitions that we are studying

We explore the likely dynamics of adjustment of the world economy under the ongoing demographic transition, the slowing (or acceleration) of productivity growth, and climate shocks and climate policies needed to reach net-zero emissions by 2050.

As the Appendix to this paper makes clear, the G-Cubed model enables an analysis consistent with our understanding of the Ramsey model of economic growth.[1] Because of this, we can offer consistency between the empirical results we present and an underlying theoretical analysis of the global growth process, which is not often present in modelling exercises like the one we present.

The intuition from a standard Ramsey growth model suggests that all three of these transitions will likely lead to lower capital accumulation and a lower long-term global growth rate (unless there is a reversal of the productivity slowdown). The climate policy scenarios depend on whether investment increases or decreases as a result of the policies.[2] That same intuition suggests that these transitions will imply a low long-term interest rate, r*, in the

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[1] As we make clear in the Appendix, there are significant and important qualifications to that statement, for reasons which the structure of the G-Cubed model makes clear. More documentation of the G-Cubed model can be founds at https://www.gcubed.com.
[2] In the standard Ramsey model there are no adjustment costs in capital accumululation. In the G-Cubed model the assumption of adjustment costs in each sector implies that investment in small renewable sectors cannot increase fast enough to offset the decline in investment in the large fossil fuel sectors. Thus without particular policies that offset these adjustment costs, total investment usually falls in a climate policy scenario analysed using the G-Cubed model.

world economy.[3] However, it may be that an acceleration in productivity growth occurs. This acceleration in productivity could be due to the technological innovation stimulated by the Covid-19 pandemic, new technological developments emerging as part of the energy transition, or the adoption of artificial intelligence. Such an acceleration in productivity growth in some sectors or countries would increase potential growth and put upward pressure on r* in some countries.

There have been transitions in the world economy in the recent past, like the ones we study here. The experience of these transitions implies that there will likely be a reduction in the level of investment in some countries and an increase in investment, at least relatively, in other countries. That will, in turn, require current account deficits in the countries with higher investment, where this investment will be more than saving. Conversely, current account surpluses will emerge in other countries in which saving exceeds investment. These deficits and surpluses will, in turn, require real exchange rate changes to ensure longer-term sustainability in each of the two different kinds of countries.

As we show, these changes are likely to significantly affect the global financial system over a period stretching out many decades. We attempt to track the possible developments numerically. And we provide many figures to enable the reader to obtain an intuitive grasp of the adjustment process.

The Appendix to this paper makes clear that the G-Cubed model is a good vehicle for analysing these current account deficits and surpluses and the associated movements in real exchange rates.

For reasons that will become apparent, our simulations with this model stretch over a very long time. We run the model over more than 100 years (with the model solution out to 2150 to ensure convergence). There are two reasons for this. First, the shocks we study are assumed to last a very long time, as seen from the demographic assumptions described in Figures 1 and 2 and the productivity profile depicted in Figure 10. The expectations of future adjustment are a crucial driver of short-term investment and consumption decisions. Second, the convergence process in the G-Cubed model is prolonged. Essentially this slow convergence is because of the adjustment costs to physical capital accumulation, which are assumed in the model. Adjustment costs mean that even though financial capital can move to equate financial rates of return quickly, these financial movements take a long time to translate into changes in physical capital in sectors of the economy in these countries. The financial flows responding to differential rates on return in physical capital is a slow and gradual process.

The changes following these long-lasting shocks will clearly last well beyond 2050, which is the last year for which we display results for the simulations we study. That explains why some of the figures contain pictures of economic variables that look as if they might be exploding. They do not explode. But for some of these variables, they only settle down and move towards long-run equilibrium well into the twenty-second century.
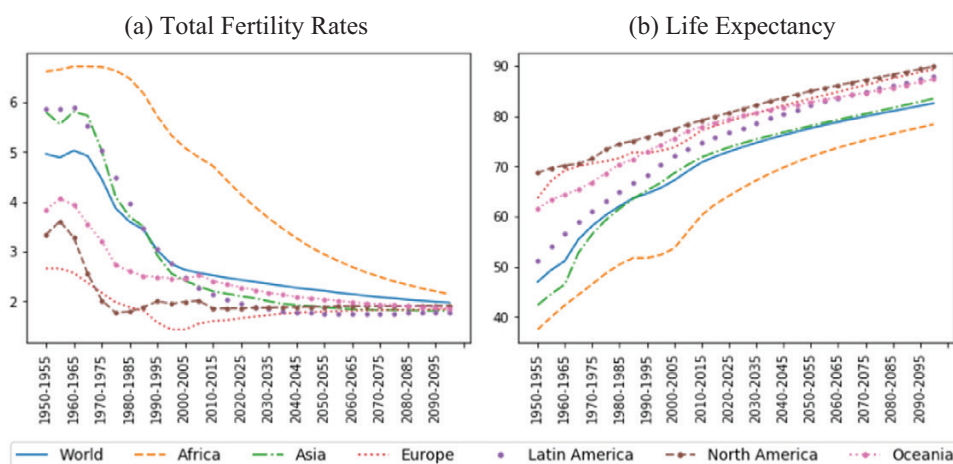

Figure 1: Demographic trends 1950–2100. *Source*: Liu and McKibbin (2021).

[3] This is even available from the much simpler Solow growth model. In that model a lower rate of population growth and a lower rate of productivity growth will increase the level of capital-per-effective-worker in the long-run equilibrium. That will in turn reduce the marginal productivity of capital in the long run and so reduce the long-run value of the real rate of interest.
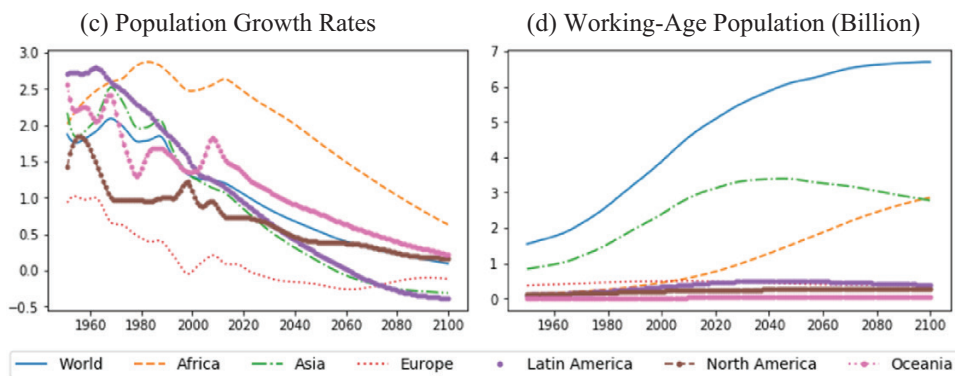
Figure 2: Demographic trends 1950–2100. *Source*: Liu and McKibbin (2021).

IV. Results

We now describe our exercises and present the research results underlying the paper.

(i) The demographic transition

Figures 1a and 1b contain data collected by the United Nations for the global economy from 1950 to 2100, which both describe the historical experience and present a future projection of fertility rates and life expectancy, using what is described as a 'medium fertility' assumption. A more detailed presentation of this data and its sources can be found in Liu and McKibbin (2021 and 2022). Although the model is disaggregated by country and produces results for individual countries, we aggregate these results into regional groupings for purposes of presentation. It is clear from these figures that the projected ageing of the worldwide population is due to both declining fertility rates and rising longevity rates. The composition is important as the two demographic factors have very different macroeconomic implications.

Figure 2a shows how these factors translate into changes in population growth rates and the level of the working-age populations across the seven regions studied. Several important patterns stand out from these figures. First, population growth rates are falling globally and are projected to continue declining until 2100. Second, while the pattern of decline is almost universal, the size of population growth rates varies widely across regions. Africa has a much higher population growth rate than Europe, and this differential continues through the remainder of the present century. These different growth rates have important implications for the level of labour supply, as shown in Figure 2b. Much of the future growth in global labour supply is projected to occur in Asia and Africa, which has important implications for the distribution of returns to capital across the globe.

The following analysis summarizes the consequences for the world economy of the continuing demographic transition we have just described. Here we deliberately focus on the implications for capital flows and thus for the international financial system. We draw on Liu and McKibbin (2021, 2022), where fuller details may be found.

Liu and McKibbin (2021, 2022) follow the theoretical approach of Blanchard (1985), Faruqee (2003), Yaari (1965), and Weil (1989) as a way of modelling this demographic transition. This approach enables them to approximate an overlapping-generations idea within a macroeconomic framework.[4] This model of individual cohorts of workers is then embedded in the G-Cubed model. They track the age distribution of the labour supply in each country and calculate the effective labour supply of each annual cohort of workers in each country, assuming that the age earning profile reflects the productivity levels of each worker at each period of a worker's life. They then aggregate the number of each annual cohort alive in each period to calculate the total effective labour supply in each country. This adjustment changes the potential labour supply projections in Figure 2b because it adjusts for each year's effective productivity of each cohort of workers in an economy. This calculation is applied to the United Nations projection of the number of workers under a medium fertility scenario. This demographic scenario is then compared to a world in which population growth rates are steady, with zero population growth in all countries.

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[4] This approach approximates an overlapping-generations set-up by supposing that those in work exponentially decay into retirement and that those in retirement also die by means of an exponential-decay process.

The difference in outcomes reflects the impact of demographic change over time and relative to a baseline without demographic change.[5]

Figure 3 contains the implications for GDP of incorporating demographic change with and without the adjustment for individual cohorts. This figure compares the level of GDP in each region in 2015 (actual data) with two alternative projected GDP levels in 2050. The bars labelled 2050_base only account for the baseline labour supply projections by 2050. The bar labelled 2040_demo contains the results when the effective labour supply (allowing for age-specific cohorts) in 2050 is used in the projections instead. The United States and Europe will continue to be large economies in 2050, but their share of the world economy will be significantly reduced by the growth of emerging-market economies. The role of the age distribution of workers is evident in Figure 3. Economies that continue to experience strong labour supply growth, such as India, Latin America, Africa, the Middle East, and North Africa, will have larger effective labour forces by 2050. In contrast, the ageing workforces in Europe and Japan reduce the effective labour supply in these economies.

To clarify the steps, we first run a baseline of the model from 2015 with population growth assumed to be at zero. We then run a simulation incorporating the annual labour supply projections in the UN data adjusted by the cohort composition. The figures compare the variables in a simulation with the demographic change in the labour supply projections relative to a baseline in which the population growth rate is assumed to be at zero.

Figure 4 shows the changes in investment and GDP, which the G-Cubed model suggests will occur over time and relative to a baseline without demographic change due to the demographic transitions described above. Investment rises in regions with significant increases in effective labour supply and shrinks in the other regions. The growth in the marginal product of capital in the growing economies causes capital to flow from more ageing to less ageing countries.

Figure 5 shows the change in trade balances due to the demographic transition. A trade deficit reflects the inflow of capital, which appreciates the real exchange rate and worsens the trade balance (and current account). This change in the trade balance is a reflection of the capital inflow. These changes are shown to be very substantial. This capital flow pattern can be beneficial for young economies enabling them to finance productive investment (India and Africa) and, at the same time, favourable for ageing economies in allowing them to receive higher rates of return on capital than would be available in autarky situations. As well as the adjustment scale, the change over time is significant. Countries that attract foreign capital in the earlier years of the demographic adjustment experience an exchange rate appreciation as the capital flows into these countries. These countries eventually experience real exchange rate depreciations as they need to export more than they import as the returns on investments are
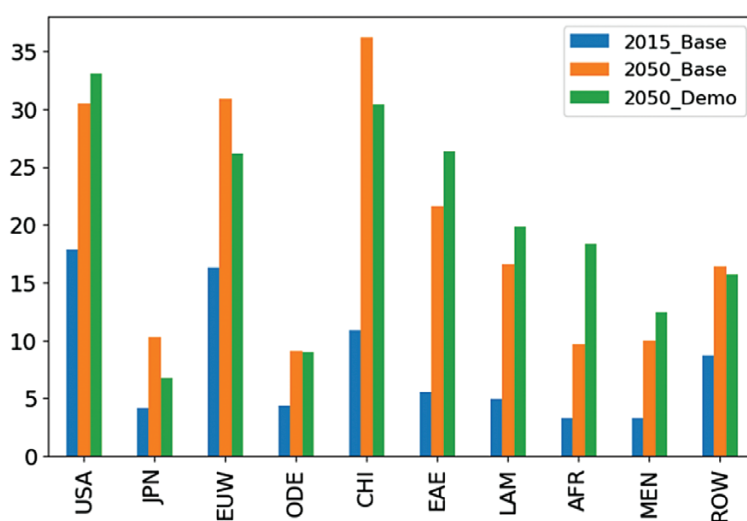

Figure 3: Global GDP projections. *Source*: Liu and McKibbin (2021).

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[5] An alternative approach would be to assume that population growth rates remain at the initial levels rather than falling over time consistent with the projections. The technical problem this causes is that the model is assumed to reach a steady state with productivity growth at 1.4 per cent per year and zero population growth. Changing the assumptions of continuous high population growth would lead to a different steady state and there would essentially be two different models. Liu and McKibbin (2021) prefer to have the same steady state but only change the transition path.

repatriated to foreign lenders. There is also a longer-run depreciation caused by the assumption of Armington trade elasticities where goods are country- and sector-specific; thus, a doubling of African production will tend to reduce the relative price of African goods in the long run.[6]

Figure 6 shows that the projected demographic scenarios will likely reduce the real interest rate in ageing economies (reflecting the falling return on capital). However, this reduction is substantially offset globally due to an increase in the real interest rate in young economies such as emerging Asia and Africa. These growing economies are likely to attract significant capital from the world market. Although financial capital flows quickly in response to financial arbitrage, physical capital relocation takes many years. It takes many decades for the real interest to equilibrate across regions eventually. During this long transition, real exchange rates will need to adjust gradually to offset differences in real interest rates across countries after allowing for (exogenous) country-specific risk premia.

The fact that demographic change in different economies is likely to produce both upward and downward pressure on real interest rates suggests that the studies of demographic change in closed economies are likely to miss spillover effects on capital flows, exchange rates, and so on international trade flows.

By contrast, the spillover impacts on GDP are likely smaller because the effects of capital flows on investment and trade balances go in opposite directions. Nevertheless, the results of demographic change significantly affect domestic GDP through their impact on the domestic effective labour supply. Thus asymmetric demographic change is likely to substantially change the relative size of the world's economies in the world economy's landscape. In particular, under the assumptions made in this paper (particularly that private capital can flow to areas with a greater
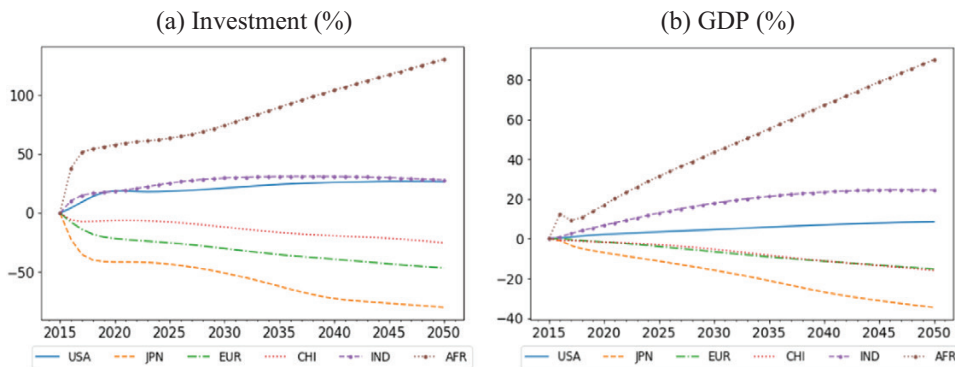

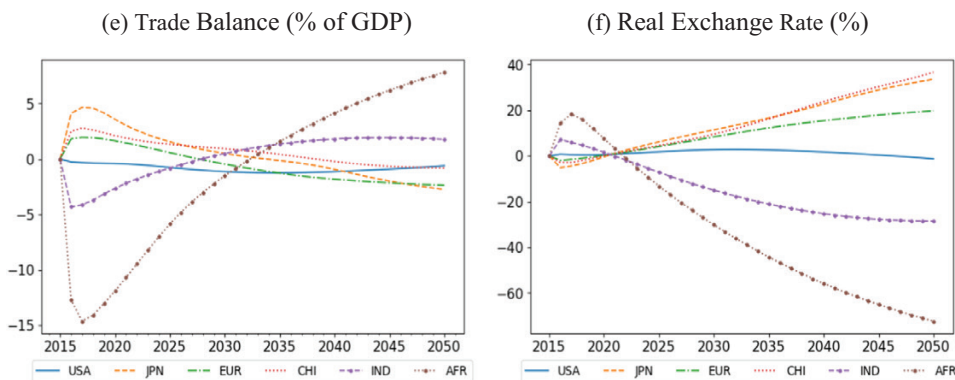**Figure 4:** Impacts of global demographic change. *Source*: Liu and McKibbin (2021).

Figure 5: Impacts of global demographic change. *Source*: Liu and McKibbin (2021).

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[6] Figure 4 shows investment continuing to diverge for Africa, and so GDP continuing to diverge, even though the period of results is 35 years. But as noted above, the relative changes in the demographic position of the regions which we are studying take until 2100 to work themselves out. So the shock continues until decades beyond the timescale of the results shown in Figure 4. Furthermore, as noted above at the end of section III, the processes of adjustment to shocks in the G-Cubed model take a long period of time to play out because the induced changes in physical investment occur only gradually. Figure 5 has real exchange rates and trade balances converging for most countries by 2050, but for Africa and China and Japan this convergence will happen at a time well beyond 2050. The reasons for this are the same as the reasons why both investment and GDP take so long to settle down.
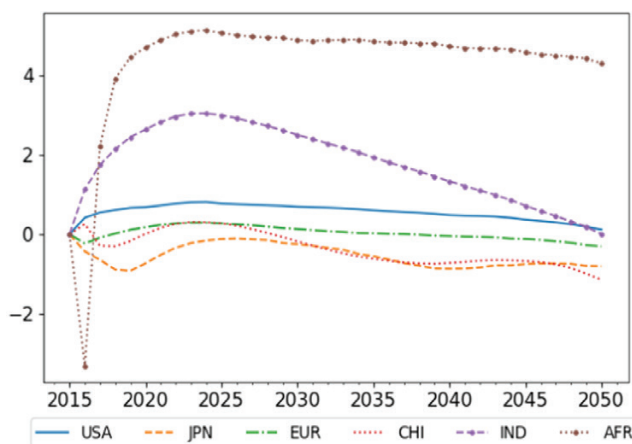
(d) Real Interest Rate (Percentage Point)

Figure 6: Impacts of global demographic change. *Source*: Liu and McKibbin (2021).

return), emerging Asia and Africa appear likely to enjoy significantly higher economic growth due to the shifting demographics.

The results also show that international capital flows can significantly reduce the significant consumption contractions that would otherwise occur in ageing countries. Consumption responds much more smoothly than production because capital can move around the world to earn higher rates of return in response to demographic shocks in ageing counties, avoiding significant income declines.

(ii) Possible global paths for productivity

McKibbin and Triggs (2020) apply a six-sector 24-region version of the G-Cubed model (detailed in McKibbin and Triggs, 2018) to explore the consequences for the world economy of four possible paths for future productivity growth. The country codes are contained in the Appendix.

The four possible paths are as follows:

  (i) a future of lower productivity growth in all advanced countries (0.5 per cent per year);
 (ii) an upcoming surge in productivity growth in all countries;
(iii) a surge in productivity growth favouring countries that have invested in technology;
(iv) a surge in productivity growth favouring sectors that have invested in technology.

McKibbin and Triggs first create a baseline for the model. The critical inputs for this are the economy's evolution up to 2016 and subsequent projections from 2016 onwards for baseline labour force growth and productivity growth (defined as labour augmenting technical change) by sector and country. The labour force growth is from the United Nations Population Projections (2017). The productivity projections in the baseline are generated following the approach of Barro (1991) and updated in Barro (2015).[7]

The exogenous sectoral labour productivity growth rate and the economy-wide growth in labour supply are each country's exogenous drivers of sector growth. The change in the capital stock in each sector in each region is determined endogenously within the model. Given assumptions about monetary policy rules, fiscal rules, and other institutional rigidities in the model (including labour markets), the authors solve a path for the world economy from 2016 to 2100. They then explore each of the scenarios on productivity by rolling the model forward to 2019 and beginning the shocks as surprise events, all commencing in 2019.

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  [7] Over long periods of time, Barro estimates that the average catch-up rate of individual countries to the world-wide productivity frontier is 2 per cent per year. We assume each sector in the US has labour productivity growth of 1.4 per cent per year. We use the Groningen Growth and Development 10 sector database, as outlined in Timmer *et al.* (2015), to estimate the initial level of productivity in each sector of each region in the model in 2010. Given this initial productivity, we then take the ratio of this productivity to the equivalent sector in the United States, which we assume is the frontier. Given this initial gap in sectoral productivity, we then use the Barro catch-up model to generate long-term projections of the productivity growth rate of each sector within each country. In the cases where we expect that regions will catch up more quickly to the frontier due to economic reforms (e.g. China) or more slowly to the frontier due to institutional rigidities (e.g. Russia), we vary the catch-up rate over time.

[Figure 7](#) shows the results for investment for a selection of advanced economies when a surprise decline is expected in productivity growth in advanced economies of 0.5 per cent per year. The results are expressed as deviations from the baseline projections due to the productivity shock.

Advanced economies are experiencing a persistent negative productivity shock. The expected return on capital is lower for an extended period, thus reducing private investment. The consequences of the shock are front-loaded because the reduction in productivity is a decline in the growth rate over many years into the future. Thus the level of productivity in each future period is increasingly below the level expected before the shock was known. Some households and firms understand the persistence of the shocks. Investment falls in advanced economies. Investment rises in emerging economies because the capital being reallocated earns a higher rate of return than the advanced economies where expected returns have dropped. Financial capital flows from the advanced economies into the emerging economies that are still experiencing catch-up productivity growth to the frontier. This capital outflow causes a depreciation of the real exchange rate of advanced economies. The result is a sizeable current trade balance surplus in countries experiencing a productivity slowdown because capital is leaving these economies and migrating to regions where this slowdown has not occurred ([Figure 8](#)). The largest of these surpluses occurs in Japan (JPN). A key feature of the Japan story is not only the size of the demographic slowdown but also the fact that Japan is a net exporter of capital goods (which are produced by the durables goods sector). The decline in
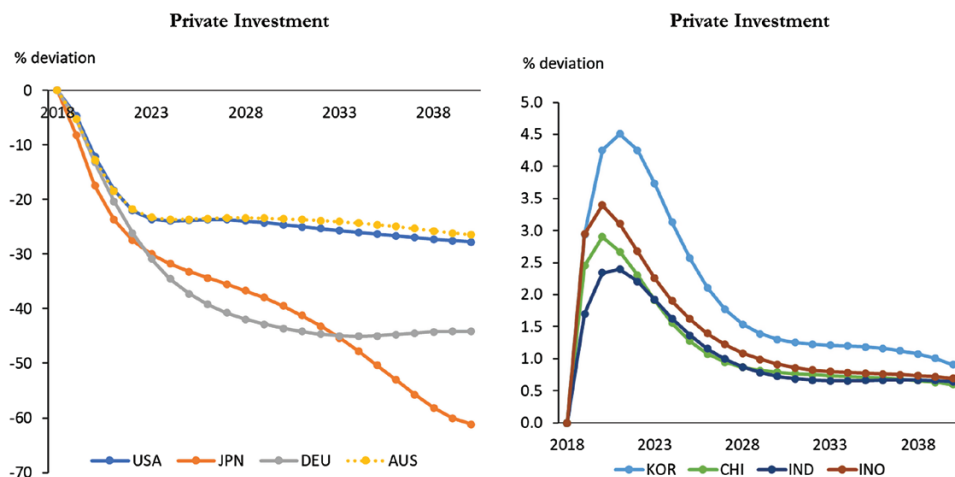

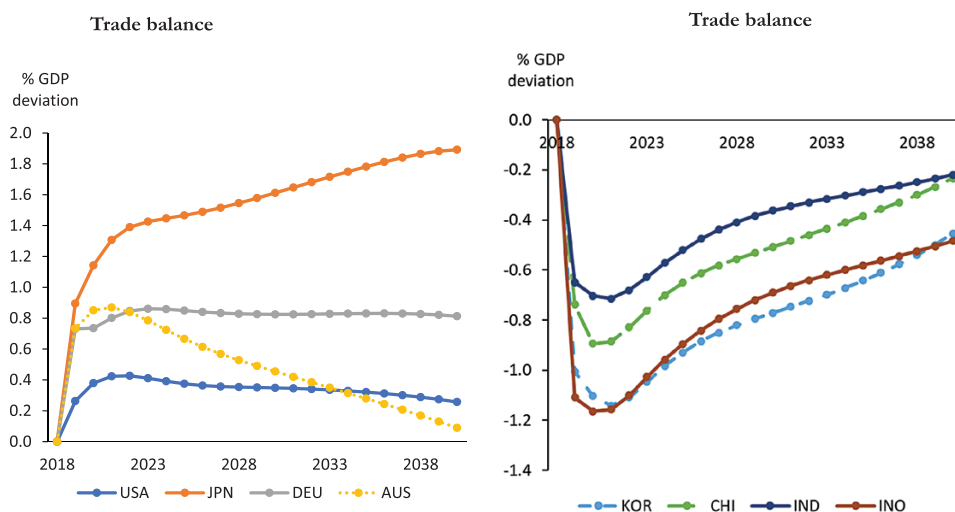**Figure 7:** A decline in productivity growth in advanced economies.

Figure 8: A decline in productivity growth in advanced economies. *Source*: McKibbin and Triggs (2020).

demand for capital goods across the advanced economies negatively impacts the return of capital in the Japanese durable goods sector because it experiences a drop in the demand for its output. The countries receiving the financial capital flows experience an appreciation of their real exchange rate (Figure 9) and a worsening trade balance (Figure 8).[8]

The following three scenarios consider the case where productivity takeoff is due to the uptake of artificial intelligence. The idea follows Nordhaus (2015) and Saniee *et al.* (2017), where productivity rises rapidly due to the penetration of technology improvements. This rapid takeoff in productivity is represented by Figure 10, which uses
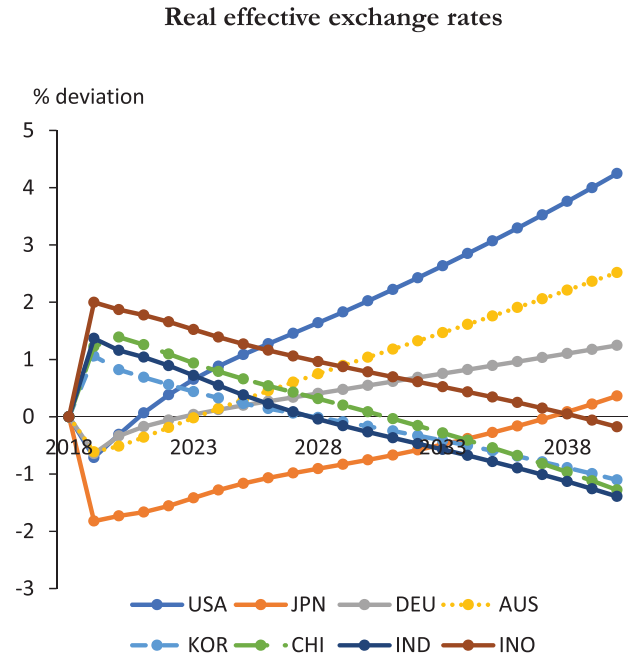
Real effective exchange rates

% deviation

Figure 9: A decline in productivity growth in advanced economies. *Source*: McKibbin and Triggs (2020).

% Deviation from the baseline

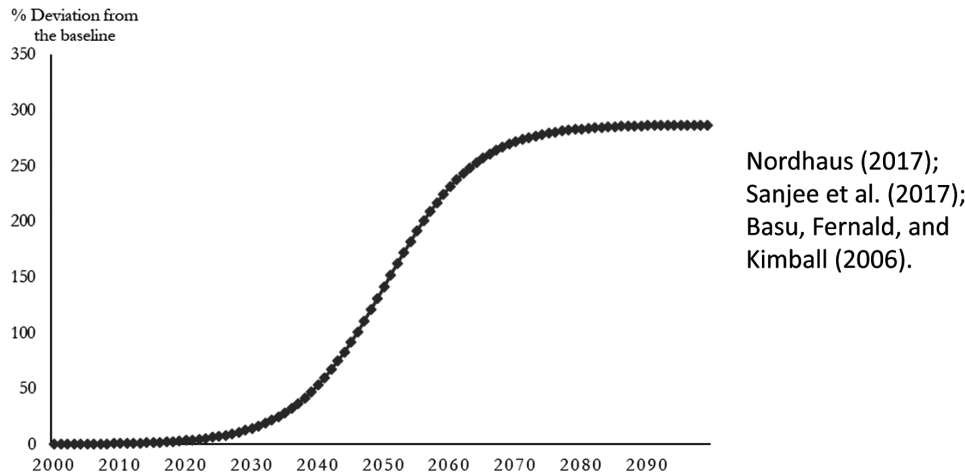Nordhaus (2017); Sanjee et al. (2017); Basu, Fernald, and Kimball (2006).

Figure 10: Stylized surge in productivity. *Source*: McKibbin and Triggs (2020).

⁸ It is clear from Figure 9 that exchange rates need to keep moving in periods of time long beyond those shown in the figure. That is because the capital flows which are created in this investigation, and the resulting trade imbalances, generate long-term changes in balance sheets and thus in interest payments. Exchange rates must move in the longer term to create the trade surpluses and deficits which offet these interest payments.

the takeoff projection in Saniee *et al.* but is stylized for the present experiment. The critical difference between what McKibbin and Triggs (2020) implement and the existing literature is that the G-Cubed model cannot be solved if productivity trends towards infinity. Thus, the authors model the takeoff until 2070 and gradually bring the productivity growth rate back to the steady state assumed in the baseline. The growth rate of productivity growth eventually stabilizes, but the level of productivity is higher than it otherwise would have been in the baseline. This stylized shock demonstrates the impacts in the early stage of takeoff. However, technical limitations prevent long-run singularity analysis in this model.

The following scenario is when this productivity surge occurs in all countries and sectors. The impact of the realization that future productivity will be high leads to an increase in the return to capital and an investment boom globally. The problem is that at the global level, savings need to rise to fund the investment, but consumers realize wealth will be higher and are reluctant to reduce consumption to finance the investment boom. Over time, as productivity begins to surge, real interest rates rise to encourage savings to fund a return on capital which is continuing to increase over the period, which we display in Figures 11 and 12.[9] The global surge in productivity eventually leads to a worldwide rise in r*. Although the shock is symmetric across countries, the impacts are not because of the economic structures of economies in the baseline. This asymmetry shows in the movements of the trade balance in Figure 12. Some countries are net exporters of capital goods (the durable goods sector in the model). An investment boom causes the demand for durable goods to surge. Countries with a comparative advantage in these goods, such as Germany(DEU) and Japan (JPN), experience a boom. Capital flows into Japan and Germany, which appreciates their exchange rates and worsens their trade account. Countries such as Australia (AUS) that provide raw materials into the durable goods sector, such as mining and energy, also experience a secondary increase in the demand for their exports. Capital flows there too, causing an investment boom, currency appreciation, and trade deficit.

The next scenario is asymmetric. It assumes that the surge in productivity only occurs in countries with targeted investment in technology. These countries are assumed to be the United States (USA), Japan (JPN), Germany (DEU), France (FRA), the United Kingdom (GBR), China (CHI), and Korea (KOR).

Figure 13 shows the outcomes for investment and trade flows in this case. The productivity surge causes the return to capital to rise in the booming economies, and investment takes off.[10] This investment is partly financed by a capital outflow from countries not experiencing the productivity pay-off. Thus investment falls in economies not experiencing the boom. Some countries, such as Italy (ITA), are unfortunate because the exchange rate is the euro which experiences an appreciation due to the boom in France and Germany. A combination of capital flow out of Italy and an economic recession due to the exchange-rate appreciation causes investment to collapse in Italy. The
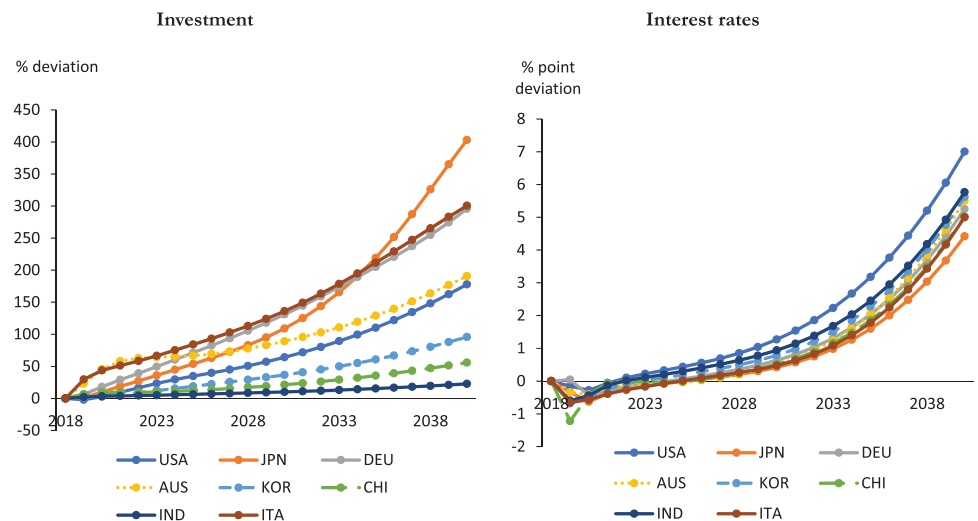
Figure 11: A global surge in productivity. *Source*: McKibbin and Triggs (2020).

[9] As Figure 10 shows the level of productivity is supposed to stop increasing by the last part of this century.

[10] In this case, too, it looks as if investment is exploding in some countries in particular Japan, and the trade balance there is getting worse and worse. But because the level of productivity will eventually stabilize, as shown in Figure 10, investment will eventually stabilize at some time in the future, long beyond the dates showing in the figure, and so will the trade balance.

countries losing capital experience a trade surplus in Figure 12. The countries experiencing the productivity boom experience a real exchange rate appreciation and trade deficits. The real exchange rate of Italy also depreciated, but this is achieved through domestic price deflation rather than the depreciation of the nominal exchange rate because of the Eurozone arrangements of a fixed nominal exchange rate within the zone.

Note that the trade balance adjustment is on the order of 5 per cent of GDP, a significant magnitude.

Figure 14 shows the impact on economic growth, which is what is expected. The productivity takeoff leads to stronger economic growth in takeoff economies but a slowdown outside these economies. Interestingly, the composition of trade matters for the spillovers across countries. Figure 14b shows the sectoral results for Australia. Even though Australia does not experience a productivity takeoff, it does benefit from positive spillover through the demand for energy and mining exports that feed into the investment boom in the takeoff economies.

The final scenario assumes that the asymmetry in takeoff is not by country but by sector. The assumption is that the services sectors experience the productivity takeoff in all countries, but no other sectors achieve the
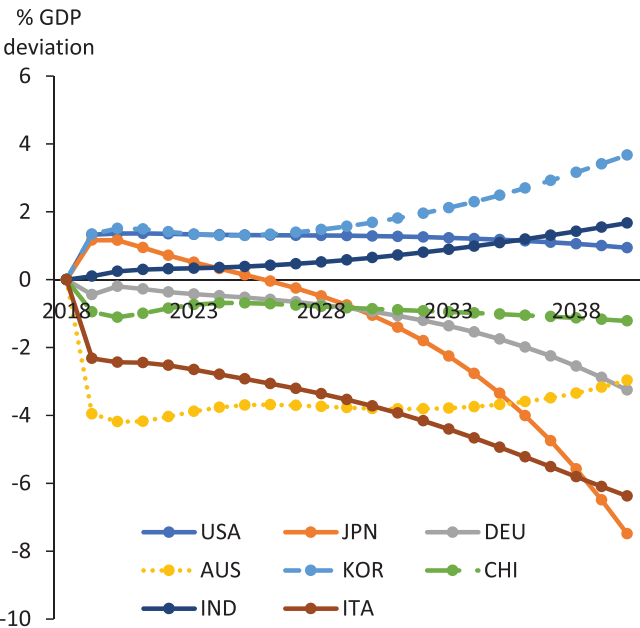

Figure 12: A global surge in productivity. *Source:* McKibbin and Triggs (2020).
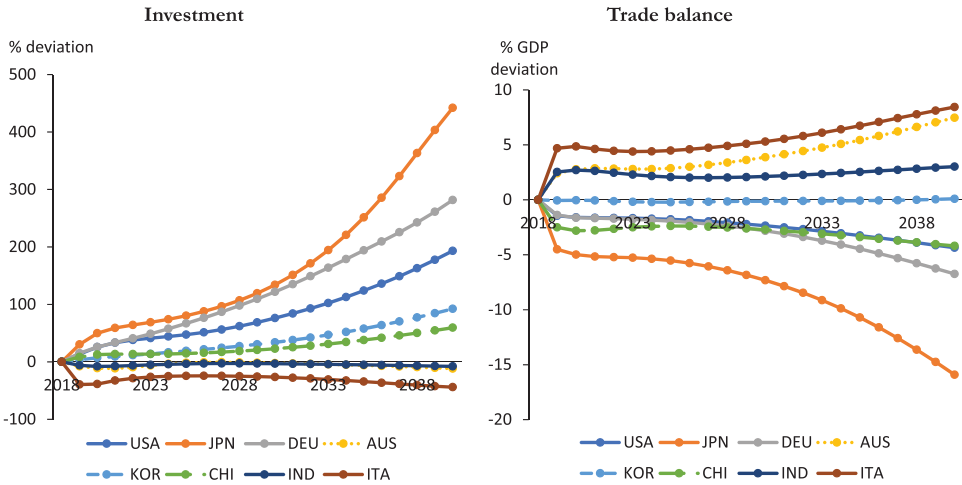

Figure 13: A productivity surge in only some countries. *Source:* McKibbin and Triggs (2020).

productivity boost. However, they experience positive spillovers through the demand for inputs into the booming sector and the rise in overall demand through higher incomes.

Figure 15 shows that economies with large service sectors experience higher economic growth. The critical feature, however, is that there is still an investment boom in the service sector, which increases the demand for capital goods to build the investment.[11] Thus countries that export durable goods (Japan and Germany) also benefit via demand for durable goods, and countries that export goods into the durable sectors (mining and energy in the case of Australia) also have second-round benefits. Thus capital will flow into economies depending on their comparative advantage in services and durable goods. Therefore the trade flows reflect this reallocation of global capital.

(iii) Climate transition paths to 2050

Several recent studies have used the G-Cubed model to explore the impacts of climate change.[12] In particular, they focus on the adjustment of the world economy to climate change shocks and the different policy mixes applied in
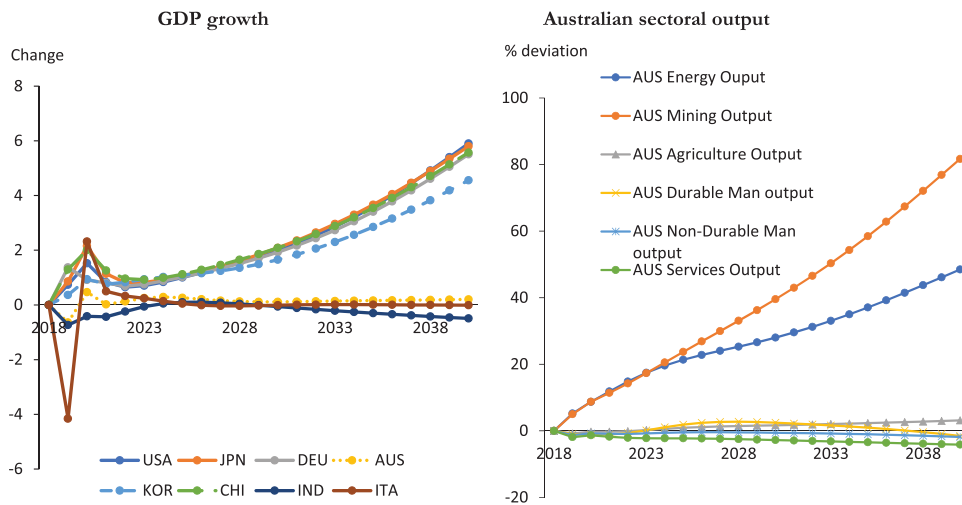
Figure 14: A productivity surge in only some countries. *Source*: McKibbin and Triggs (2020).
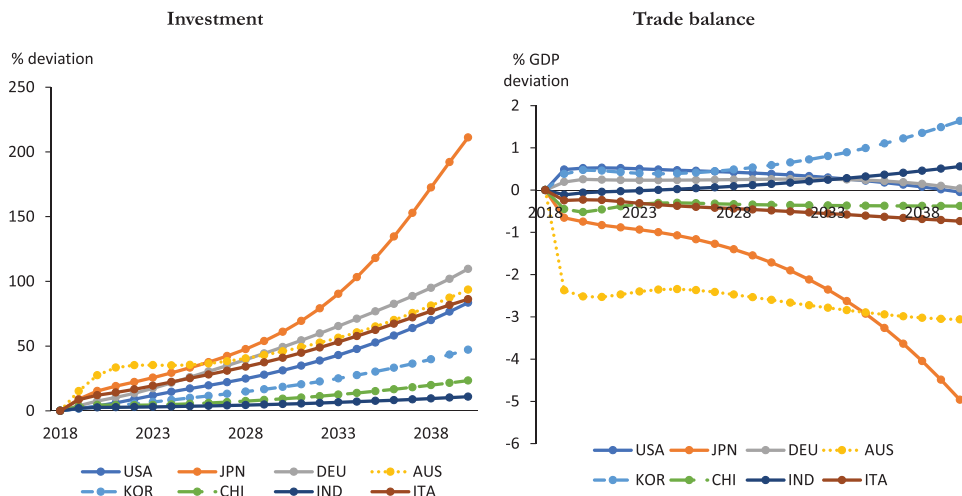
Figure 15: A productivity surge in service sectors. *Source*: McKibbin and Triggs (2020).

[11] As above it looks as if investment is exploding in some countries, in particular Japan, and the trade balance is getting worse and worse. But because the level of productivity will eventually stabilize, as shown in Figure 10, investment will stabilize at some time in the future, long beyond the dates showing in the figure, and so will the trade balance.

[12] See Liu *et al.* (2020), McKibbin *et al.* (2020), Fernando *et al.* (2021), Bems *et al.* (2023), and Bertram *et al.* (2022).

the presence of those shocks. Physical risk is the impact of climate shocks on economic activity. These shocks include changes in trends of temperatures and the frequency of extreme climate events. Transition risk is the impact on economic activity of changes in climate policies designed to achieve a particular emissions and temperature outcome over time.

Fernando *et al.* (2021) explore the macroeconomic impacts of physical climate risk due to chronic climate change associated with global temperature increases and climate-related extreme shocks; the macroeconomic effects of climate policies designed to transition to net zero emissions by 2050 (transition risk); and the potential macroeconomic consequences of changes in risk premia in financial markets associated with increasing concern over climate events. The IMF *World Economic Outlook* in September 2020 applied the G-Cubed model to explore the transition risk related to various mixes of climate policies designed to achieve net zero by 2050. More recently, the International Monetary Fund global imbalances report (IMF, 2022) used the G-Cubed model to explore the impacts on current account balances of the climate policy package explored by Bang *et al.* (2020).

This section draws on the relevant parts of these studies to present some significant implications of potential movements in current account balances, investment, and long-term interest rates between now and 2050.

Fernando *et al.* (2021) used four widely used climate scenarios (representative concentration pathways, or RCP) and identified the physical damage functions due to chronic climate risks. The chronic climate risks include sea-level rise, crop yield changes, heat-induced impacts on labour, and increased incidence of diseases; and estimates of the future incidence of climate-related extreme events, including droughts, floods, heat waves, cold waves, storms, and wildfires, based on climate variable projections under the climate scenarios. Their study used physical damage functions to translate the scenarios about future temperature paths into shocks to labour productivity and total factor productivity in different sectors and countries over time. The study also explores 'transition risk', which captures the economic impacts of various climate policies on all economies over time to achieve net zero emissions by 2050. The only climate policy explored for transition risk was a carbon tax. However, in Bang *et al.* (2020), a more complex policy package was considered, including infrastructure investment, carbon pricing, and subsidies for renewable energy to explore the impacts of achieving net zero emissions by 2050. These studies show that the outcomes for trade, investment, and capital flows depend very significantly on detailed features of how the climate policies are structured.

First, consider the potential impacts of climate risk on the world economy between now and 2050. Rather than show all of the results from the original paper, we draw out just one scenario, the RCP 4.5 scenario. This scenario implies a global mean temperature increase of between 2.5 and 3 degrees C by 2100 relative to the pre-industrial level.

Figure 16 contains the physical risk and transition risk results for GDP and the change in private investment under the RCP 4.5 scenario for each region. The figure shows the differences relative to the baseline in 2021, when the shocks and the policies are announced, with the outcomes by 2050.

The transition risks shocks are the effects of changes due to policy, and it is clear that these have most of their impact as the policies are ramped up after 2050 when net zero emissions are achieved. Figure 16 shows that for the physical climate risk, the shocks in the earlier periods are small but gradually grow over time with significant GDP losses due to climate change shocks. The effects of climate shocks increase over time, reducing output per unit of input in various sectors. These climate shocks reduce the relative return to capital in different sectors, leading to a
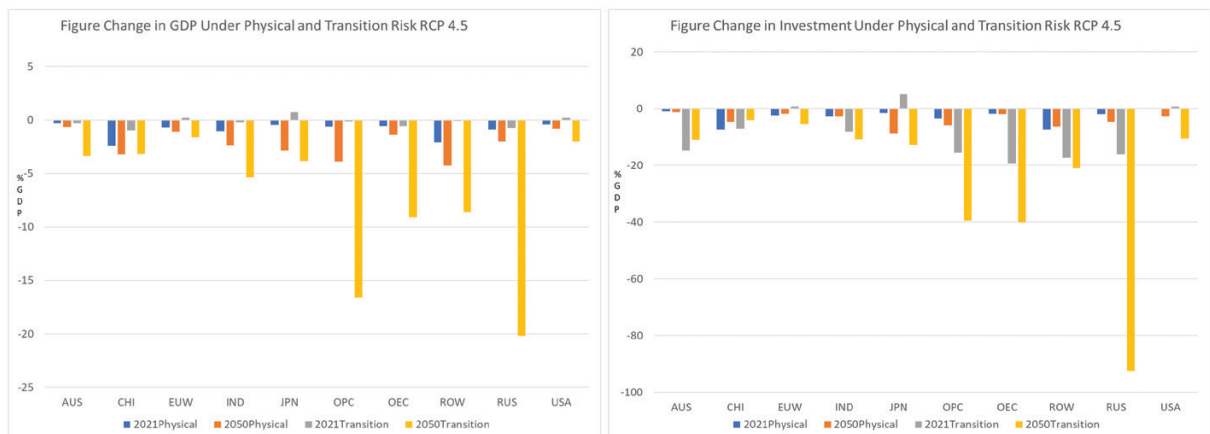

Figure 16: Physical and transition risks. *Source*: Fernando *et al.* (2021).

decline in private investment. The impacts are different across sectors, which is the original paper's focus. However, in this paper, we focus just on the overall macroeconomic results. Note that the impacts of net zero climate policies are significant for countries that are very fossil fuel intensive, for example, Russia, the rest of the OECD, which is primarily Canada and OPEC economies, and Australia.

Figure 17 shows the impacts of climate shocks and climate policies on movements in global capital. In the case of climate shocks (physical risk), heavily impacted countries will see capital outflows and less affected will see capital inflows. The most significant negative impact in the short term of climate shocks is on China, the country with the current account moving towards surplus as private capital moves out of China into less impacted economies worldwide. The transition risk has a far more substantial impact in the short run because the allocation of capital which was in place in 2021, is suddenly impacted by changes in the rates of return to different activities due to climate policy. These policies cause capital to flow out of fossil-fuel-intensive sectors and out of fossil-fuel-intensive economies such as Australia, OPEC, the rest of the OECD, and Russia. Capital will flow into less fossil fuel-dependent economies with substantial climate policies or considerable renewable energy or nuclear industries, such as Europe, Japan, and the USA. As capital flows out, the real exchange rates of these economies will depreciate, causing current account surpluses.

Figure 17 also shows changes in the 10-year real interest rates. The climate shocks and the particular climate policy we use cause the long-term real interest rate to fall substantially—between 50 and 150 basis points. The fall in the long-term real interest rate occurs because the collapse in investment due to the climate policies implemented through a carbon tax system alone tends to reduce the return to capital in large parts of the economy, which are fossil fuel dependent. But it doesn't lead to a sufficient increase in investment in the renewable-intensive parts of the economy. However, this result is not a general proposition, as IMF (2020) shows, focusing on a range of policies to achieve net zero by 2050 rather than just using carbon pricing. That report shows that by mixing carbon pricing with infrastructure investment and subsidies to renewables, it is possible to stabilize world GDP by 2050 at the original level in the baseline and to still achieve net zero emissions from the global energy system by that time. Note, however, that the distribution of GDP changes across countries varies. In particular, fossil-fuel-intensive economies will experience lower GDP, whereas other economies will experience higher GDP by 2050.

Figures 18 and 19 contain the results of the policy package expressed as the average change over the first decade of the policy. Each figure shows the impact of the components of the package, carbon tax, green subsidy, green infrastructure investment, and the combined outcome (indicated by the black dot) for each variable.

The carbon tax reduces GDP and investment and leads to capital outflows from carbon-intensive economies. However, the subsidies and infrastructure investment, which also reduce emissions, tend to increase private investment, particularly in zero-emission activities.

V. Conclusion

The analysis in this paper has considered the shorter-term adjustment to long-term transitions expected in future years and already under way in the global economy.

The scenarios that we have considered involve projections of future events which are highly uncertain. Nevertheless, they provide quantitative insights into the nature of longer-term transitions that the world is likely to
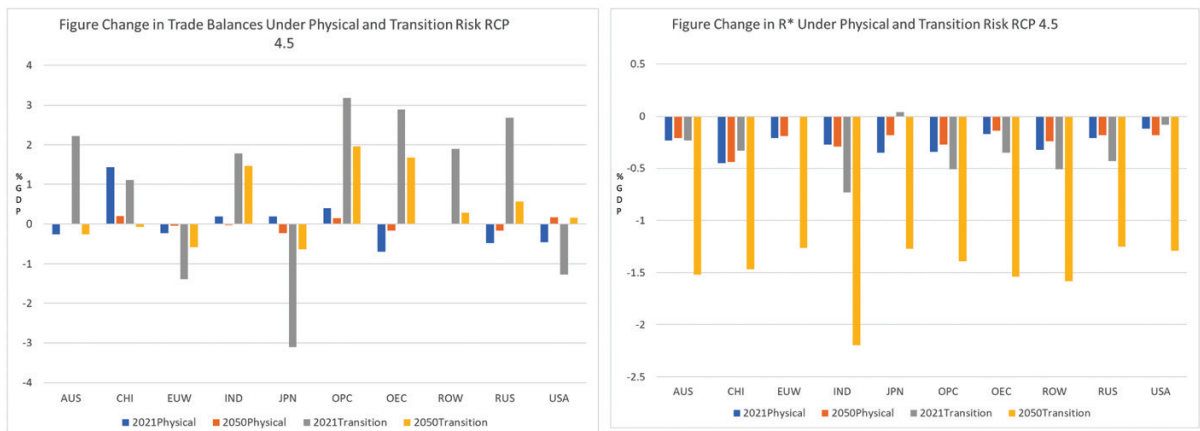
Figure 17: Physical and transition risks. *Source*: Fernando *et al.* (2021).
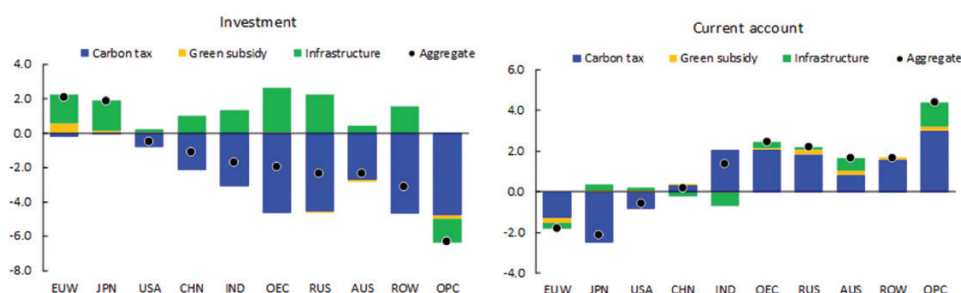
Figure 18: Impacts of a climate policy package: deviations from baseline (average over first decade). *Source*: Bems *et al.* (2023).
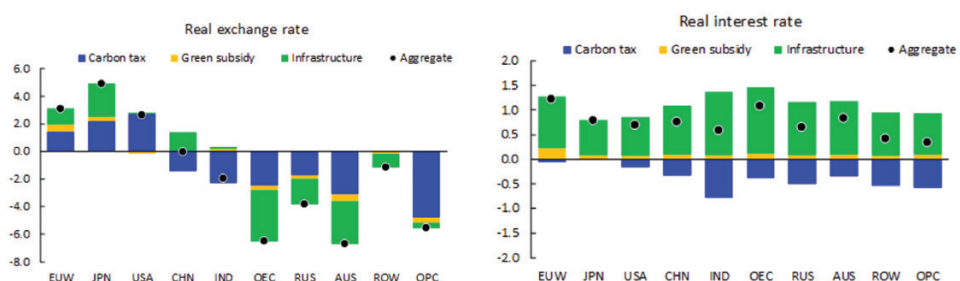

Figure 19: Impacts of a climate policy package: deviations from baseline (average over the first decade). *Source*: Bems *et al.* (2023).

undergo. Policy-makers must understand what is expected to happen and have strategies to respond. The purpose of this paper is to help them gain a relevant understanding and so formulate the necessary policies.

All of the adjustments we describe are happening at the same time as significant short-term macroeconomic shocks are disrupting the global economy. And so the overall outcomes in the global economy over the next few years will be the consequences of both the long-term transitions we have analysed in this paper and those short-term macroeconomic shocks.

For instance, the world is still dealing with an evolving global pandemic. In McKibbin and Vines (2020), we identified the substantial fiscal costs of dealing with this pandemic for emerging-market economies and the the world's poorest countries. Given that the pandemic has led to waves of infection from a rapidly evolving virus these costs have risen since that paper was written. Furthermore, the war in Ukraine has dramatically increased the need for financial support for emerging-market economies due to the rising prices of food, energy, and other raw materials, including fertilizer. To support the necessary adjustment, a substantial flow of global resources will need to flow to emerging market countries in the near term.

The rise in global inflation caused by these problems has led major central banks to embark on a rapid monetary tightening. However, this shifting in macroeconomic policy has not so far been accompanied by fiscal tightening. In addition, the geopolitical shifts caused by the Russian invasion of Ukraine and the rise of a more assertive China are likely to lead to increased defence expenditures and a further expansion of fiscal deficits in major economies. These short-term factors suggest that a period of rising real interest rates from fiscal spending may add to the rising real interest rate from monetary tightening. These higher real interest rates will, at least in the short term, increase pressure on countries with high external debt and large fiscal imbalances. These forces will likely offset some of the downward pressure on global real interest rates caused by the longer-term transitions we have studied in this paper.

It is worth emphasizing that the world's longer-term challenges are similar to those faced by John Maynard Keynes, Harry Dexter White, and others at the Bretton Woods Conference in 1944. The two tasks of ensuring global financial stability and ensuring macroeconomic adjustment in response to shocks were both tasks that were given to the International Monetary Fund at that conference. The task given to the World Bank was to make possible the international flows of funds that would be required for post-war reconstruction. Of course, the Marshall Plan was to play a role alongside the role played by these two international financial institutions (IFIs). The IFIs were not acting alone since the Marshall Plan injected substantial additional sums of money.

Now—without a Marshall Plan—private financial markets will need to play a key role, alongside the IFIs, in making possible the necessary movements of international capital. This paper shows that these capital movements

are likely to be very large. For example, differential productivity shocks are likely to lead to movements in trade and capital flows of many percentage points of GDP between economies. Preventing those capital flows, and thus preventing the significant movements in trade flows from occuring, is likely to reduce significantly the shared welfare gains that the productivity increases will make possible. Preventing adjustments in the international trading system will also make it more difficult for other countries to benefit from the positive productivity shocks because the successful reallocation of capital around the world, as depicted in this paper, is an essential part of the adjustment to these shocks.

Enabling foreign investment to come into places where productivity is improving may well require reforms of the policies of governments and the policies of international financial institutions. A number of these reforms have been described in other papers in this issue of the *Oxford Review of Economic Policy*. The purpose of the present paper has been to show that the flows of foreign investment triggered by the transitions we have studied are likely to be very large under plausible assumptions. So it is crucial that the reforms necessary to make those flows possible do take place.

Appendix

The G-Cubed model

There are many different versions of the G-Cubed model with different degrees of sectoral disaggregation and different country coverage. The models are developed with a particular question in mind. The theoretical basis of the models is the same. They draw on the G-Cubed model which has been developed by Warwick McKibbin and Peter Wilcoxen since 1991 (McKibbin and Wilcoxen, 1999). It is documented by McKibbin and Wilcoxen (2013) in chapter 17 of *Handbook of CGE Modeling* (North Holland); see also McKibbin and Vines (2000). The most detailed and up-to-date description of the model can be found in McKibbin and Triggs (2018) on the G20 model,

Table 1: Key components of the G-Cubed model

Region codes	Regions	Sectors
USA	United States	Energy
JPN	Japan	Mining
EUW	Western Europe	Agriculture
AUS	Australia	Durable Manufacturing
KOR	Korea	Non-Durable Manufacturing
OEC	Rest of Advanced Economies	Services
CHI	China	
IND	India	
INO	Indonesia	
PHL	Philippines	
VNM	Vietnam	
THA	Thailand	
MYS	Malaysia	
OAS	Other Asia (mainly South Asia excluding India)	
LAM	Latin America	
AFR	Sub-Sahara Africa	
MEN	Middle East and North Africa	
ROW	Rest of World	

Note: Table 1 sets out the key components of the version of the G-Cubed model used for the demographic modelling which is documented in Liu and McKibbin (2021).

Table 2: The G-Cubed (G20) model

USA	United States	Sectors
JPN	Japan	Energy
DEU	Germany	Mining
GBR	United Kingdom	Agriculture
FRA	France	Durable Manufacturing
ITA	Italy	Non-Durable Manufacturing
EUZ	Rest of Euro Zone	Services
CAN	Canada	
AUS	Australia	
OEC	Rest of Advanced Economies	
KOR	Korea	
TUR	Turkey	
CHN	China	
IND	India	
IDN	Indonesia	
OAS	Other Asia	
MEX	Mexico	
ARG	Argentina	
BRA	Brazil	
RUS	Russia	
SAU	Saudi Arabia	
ZAF	South Africa	
ROW	Rest of World	
OPC	Oil-exporting and the Middle East	

Note: Table 2 sets out the key components of the version of the G-Cubed G20 model documented in McKibbin and Triggs (2018).

and Jaumotte *et al.* (2021) on the G-Cubed climate model. G-Cubed models have been used for policy analysis and scenario planning by governments, international agencies, corporations, banks, and academic researchers.

The model is a 'hybrid' model, using that term in the way in which it was used in papers assembled in the 'Rebuilding Macroeconomic Theory Project' issue of the *Oxford Review of Economic Policy* (see Vines and Wills (2018), Blanchard (2018), and Wren-Lewis (2018)). The term 'hybrid' means that the model has both features of a microfounded DSGE model and features of a 'policy model' or 'structural economic model'. The model includes all of the features of a micro-founded DSGE model: there are optimizing agents who are subject to two important frictions. In this sense the model is like the Smets–Wouters (2007) model or the Christiano *et al.* (2005) model. At the core of the model is a Ramsay model of the growth process with three key features in which there are two major frictions.

First, there is a process of capital accumulation in each sector of the economy, in each country, driven by an investment function in which investment depends on the value of Tobin's q, which depends on the ratio of the marginal product of capital (MPC) in that sector to the real interest rate. Investment is subject to adjustment costs, which means that capital accumulation only gradually drives the MPC into line with the real interest rate. This is the first of the major frictions in the model. As a result of this friction, investment leads to a gradual adjustment of the capital stock over time; investment responds to the value of Tobin's q, with 30 per cent of firms responding to a forward-looking q which evolves in a model-consistent manner with the remaining 70 per cent of firms having a backward-looking q.

Second, the behaviour of some consumers (30 per cent) is driven by the Euler equation central to a Ramsey growth model, in which consumption in any period responds both to the contemporaneous real interest rate and to a forward-looking expectation of future consumption (one which evolves in a model consistent manner). But the remaining 70 per cent of consumers are liquidity constrained.

Table 3: The G-Cubed (Climate) model

Region code	Region description	Sector name
AUS	Australia	Electricity delivery
CHI	China	Gas utilities
EUW	Europe	Petroleum refining
IND	India	Coal mining
JPN	Japan	Crude oil extraction
OPC	Oil-exporting developing countries	Natural gas extraction
OEC	Rest of the OECD	Other mining
ROW	Rest of the World	Agriculture and forestry
RUS	Russian Federation	Durable goods
USA	United States	Nondurables
		Transportation
		Services
		Coal generation
		Natural gas generation
		Petroleum generation
		Nuclear generation
		Wind generation
		Solar generation
		Hydroelectric generation
		Other generation

Note: Table 3 sets out the key components of a different version of the G-Cubed Model: the G-Cubed Climate Model.

Third, there is a wage-setting process in which nominal wages are driven by a Calvo–Rotemberg-style Philips curve (in which some workers are backward looking). Prices are set by profit-maximizing firms in each sector; these firms hire labour up to the point at which the marginal product of labour equals the real wage defined in terms of the output price level of that sector. As a result of these assumptions, nominal wages are sticky and adjust over time in a way which depends on labour-contracting assumptions, something which is allowed to differ from country to country. This gradual adjustment of wages is the second major friction in the model. Any excess supply of labour enters the unemployed pool of workers. Unemployment, or the presence of excess demand for labour, causes the nominal wage to adjust over time in a way which—taken in conjunction with the monetary rule and the behaviour of the nominal exchange rate—will ensure that the labour market clears in the long run. In the short run, unemployment can arise, or excess demand for labour can arise, both because of changes to aggregate demand and because of structural supply shocks to the economy.

Monetary policy is implemented by supposing that the nominal interest rate is set according to a Henderson–McKibbin–Taylor (HMT) rule.[13] In each country the rule adopted is programmed into the model in a way that is designed to approximate the actual monetary policy regime in that country. These monetary rules tie down the long-run inflation rates in each country as well as allowing for short-term adjustments of monetary policy, by means of interest rate changes, that are carried out so as to damp down fluctuations in the real economy.

The analytical structure of the model has the following features. As already noted, the model has two major frictions. One is in the process of capital accumulation (because of adjustment costs in the investment function), and the other is in the inflationary process (because of the overlapping nature of the wage-setting process). Taken together, these two major frictions in the model—the gradual adjustment of investment and the nominal rigidity in wage-setting—mean that the model has new-Keynesian features and does not behave, in the short run, like a real business cycle (RBC) model. But crucially, in the long run, the model does have the RBC-like properties of a

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[13] See Henderson and McKibbin (1993) and Taylor (1993).

Ramsey growth model. As the body of the paper makes clear, these longer-run properties are fundamental to the analysis which is described in the paper. It might be helpful to think of the model as having, at its core, an analytical structure of a DSGE kind, not unlike the Smets–Wouters model and in the Christiano *et al*. model,

Nevertheless, the model is a 'hybrid' one. It is much closer than most DSGE models to what Blanchard (2018) calls a policy model, or what Wren-Lewis (2018) calls a structural economic model. There are several aspects to this resemblance.

First, the model pays attention to the need to disaggregate output into a number of different sectors. Six different sectors are identified[14] and the model captures inter-industry linkages (in that some of the output of some industries serves as inputs into other industries). The relative prices of the outputs in these sectors move during simulation in a way which has an important implication for outcomes which we describe in this paper. This is because the prices of different kinds of good move in different ways. In particular, the model treats the price of energy and mining as determined in a flex-price manner. This is different from the determination of the prices of manufactured goods, and services, where nominal rigidity coming from wage setting is important. Because of the importance of these relative-price changes, there are many features of the model's behaviour which will be familiar to those who have experience with using computable general equilibrium (CGE) models.[15]

Second, being a global model, the G-Cubed model needs to capture the effects of international trade and of international capital flows. Trade balances are determined by properly modelled export functions and import functions for each country, which map consistently into the equations for imports and exports in other countries; changes in real exchange rates between countries have a significant and important influence on these trade flows between countries, as do changes in the level of economic activity in the countries concerned. The model supposes perfect international mobility of capital between countries, and the exchange rate is determined, *à la* Dornbusch, by the uncovered interest parity (UIP) condition, except for countries having pegged exchange rates and for those countries within the European Monetary Union. Nevertheless, there is explicit allowance for risk premia in these UIP equations.

Third, as already noted, the nominal interest rate in each country follows an HMT rule in most countries; in these countries the exchange rate floats. But in some countries, including those within the European Monetary Union and Saudi Arabia, exchange rates are fixed or pegged, and the interest rate is tied down by international conditions. Within EMU, all countries have an interest rate set by the European Central Bank, and the exchange rates between these countries are fixed within the European Monetary Union. For China the exchange rate has a managed float; although the central bank operates an HMT rule, there is an exchange rate term in this rule.

Fourth, the model shows appropriate respect for impediments to the smooth functioning of markets which go beyond the two major frictions already mentioned, but which are not easy to micro-found. These impediments include the liquidity constraints and backward-looking behaviour which we have already mentioned in all of investment behaviour, consumption behaviour, and wage setting. But in addition, serious attention is given to the importance of risk premia. All simulations of the model require assumptions to be made about (i) the country risk premium for each country relative to the US, (ii) the risk premium which consumers apply in calculating the present value of their accumulated wealth, and (iii) the equity risk premium for each of the six sectors in each country. But these assumptions about risk premia are deliberately treated as exogenous to the simulation in question.

Three further features of the model have an important influence on the results which we present.

First, the model completely accounts for stocks and flows of physical and financial assets. As a result, budget deficits accumulate into government debt, current account deficits accumulate into foreign debt, the surpluses of households cumulate into household wealth, and the deficits of firms in each of the six sectors cumulate into corporate debt and thereby determine the dividend payments and interest payments which the firms are able to make. The model imposes an intertemporal budget constraint on all countries, governments, households, and firms. This means that, in the long-run equilibrium of the model, to which all simulations must tend, the level of asset prices which emerges must be consistent with the long-run supply of assets, so that economic agents actually wish to hold the assets which are in existence. Thus in such a long-run equilibrium the current account of every country must stabilize; this has implications for the long-run real exchange rate. Furthermore, the interest rate on government fiscal positions must be consistent with private-sector agents wishing to hold the outstanding stock of government debt. And the stock of physical capital must have adjusted in all sectors so that the value of Tobin's q in each sector is equal to or very close to unity, after allowing for effects of corporate tax rates. However, the adjustment towards

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[14] The sectors are energy, mining, agriculture, durable manufacturing, non-durable manufacturing, and services.
[15] Allowing for changes in the relative prices of the goods produced in these six sectors has been absolutely fundamental in modelling the baseline simulations in the studies described in this paper, essentially because of movements in the prices of the energy and mining sectors.

the long-run equilibrium in each economy can be very slow indeed, in which some adjustment of some processes, including especially that to do with capital, take the best part of a century.

Second, the model incorporates heterogeneous households and firms. Firms are modelled separately within each sector. And, as already noted, within each country the model assumes two types of consumers, and two types of firms within each sector. One group of consumers and firms bases its decisions on forward-looking model-consistent expectations. The other group follows simple rules of thumb which are only optimal in the long run.

Third, rigidities prevent the economy from moving quickly from one equilibrium to another, but such adjustment does take place over the longer term. These rigidities include the costs of adjusting capital in firms and the nominal stickiness caused by wage rigidities. The former kinds of costs mean that physical capital is sector-specific in the short run. But in the longer term physical capital moves between sectors, and between countries, so as to equalize risk-adjusted rates of return around the world.[16] As the paper shows, this process of international reallocation of capital is a profoundly important part of the adjustment process, in response to the policy changes which we investigate.

Finally, the adjustment path in the model is also affected by a lack of complete foresight in the formation of expectations, and by monetary and fiscal authorities following particular monetary and fiscal rules in response to the rigidities in the economy. Short-term adjustment to economic shocks can be very different from the long-run equilibrium outcomes. The focus on short-run rigidities is essential for assessing the financial impacts following in the first 5 years or so after a major shock—the kind of time period on which some of our discussions will focus. The extremely long time which the model takes to move towards its long-run equilibrium after any shock is applied to it means that this short-run behaviour has very long-lasting implications. Nevertheless, the nature of the long-run equilibrium casts a shadow over short-term outcomes, through the implications for the investment needed in the short term in order to reach the long-run equilibrium position.

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[16] Such 'movement' of capital happens because in sectors in which Tobin's q is above unity, net investment is positive and the stock of physical capital accumulates, whereas in sectors where Tobin's q is below unity, depreciation leads the stock of physical capital to decumulate.

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