The role of monetary policy during a low-carbon transition

September 2020

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This research was undertaken by Vivid Economics in partnership with researchers at the Australian National University. The authors of this work were Rosetta Dollman, Giulio Vannicelli, Pablo Anton Arnal, Jason Eis, Warwick McKibbin and Weifeng Liu. We would also like to thank Roshen Fernando for his valuable contribution.

The research has been funded by the International Network for Sustainable Financial Policy Insights, Research and Exchange (INSPIRE). INSPIRE is a global research stakeholder of the Network for Greening the Financial System (NGFS); it is philanthropically funded through the ClimateWorks Foundation and co-hosted by ClimateWorks and the Grantham Research Institute on Climate Change and the Environment at the London School of Economics.
Executive Summary

The Paris agreement reflects a commitment ratified by 189 countries to limit global temperature increases to well below 2°C. This commitment for a global transition to a low-carbon economy could exacerbate economic and financial risks in the near term, particularly if the transition is disorderly. Policymakers must therefore seek to take actions that mitigate these risks. While the majority of research on transition risk to date has related to concerns around financial stability, less attention has been paid to the monetary policy implications of the transition.

This work assesses the potential monetary policy actions that can be taken to facilitate the transition to a low-carbon economy and limit global temperature increases to 2°C. The low-carbon transition has key implications for monetary policy; this can manifest itself as both a negative demand and supply shock. While the monetary policy response to a demand shock is clear, central banks face a trade-off when responding to a negative supply shock, as this can lead to higher inflation and lower output growth. Predicting monetary policy responses are further complicated by the evolving remits of central banks. While most central banks have adopted inflation targeting, in recent years, a growing emphasis has been placed on other macroeconomic indicators such as output, employment or nominal income. In addition, the variation in responses to past supply shocks, in part due to a different interpretation of the shock, makes the policy responses more uncertain. We therefore consider the impacts under various monetary policy responses to reflect the flexibility of central bank actions.

This study models the macroeconomic impacts and monetary policy implications of a 2°C scenario via a carbon tax shock. We begin by considering the impacts across regions and sectors under a Henderson-McKibbin-Taylor (HMT) rule. We then estimate the effects when central banks follow alternative rules, by either placing more weight on inflation or output growth. Finally we explore the monetary policy implications of a carbon tax implemented alongside a government spending shock to low-carbon infrastructure which boosts productivity.

We find that the transition to a low-carbon economy will need to be accompanied by greater monetary expansion in the long term. In the near term, a carbon tax is associated with higher inflation via higher energy costs and a negative output gap due to the abrupt restriction on fossil-fuel based energy production. Central banks respond in the near term by raising nominal interest rates but ease in the medium- to long-term as the impact on growth offsets that on inflation. Interest rates remain much lower than baseline in the long term, suggesting that the high adjustment costs associated with the transition will lead to a reduction in the neutral interest rate. As expected, the impact on inflation is lower under an inflation-targeting regime, and the impact on output less negative under an output-targeting regime.

This research highlights a number of implications for policy in facilitating the transition. First, central banks should consider the trade-off in raising interest rates following a temporary supply shock if they will likely need to ease rates in the future (in other words, there is a case to ‘look through’ the inflation increase). If there appears to be little risk of price rises feeding into inflation expectations, a monetary rule that places more weight on output might be appropriate for a temporary supply shock. In addition, there is a potential role for monetary and fiscal policy coordination. In particular, government spending on low-carbon infrastructure could assist in limiting the near-term negative impact on growth and facilitate a longer-term increase in productivity. However, given the large productivity improvements required to offset the negative impact of the shock, independent improvement in low-carbon technologies would likely also be needed.
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1 Introduction

The Paris Agreement is a commitment to combat climate change adopted at the 21st Conference of Parties (COP21) in December 2015. This includes a commitment to limit global temperature increases to well below 2°C above pre-industrial levels, and to pursue efforts to limit temperature increases even further to 1.5°C. Given the agreement has now been ratified by 189 countries, this suggests that sweeping reforms will be needed to achieve emissions targets consistent with the target temperature increases.

This research considers the macroeconomic impacts and monetary policy implications of a transition to a 2°C world. The transition to a low-carbon economy may present economic and financial risks in the near term, particularly if the transition is disorderly. While the majority of central bank research on transition risk to date has related to concerns around financial stability, less attention has been paid to the monetary policy implications of the transition. This study investigates the impact on monetary policy under a 2°C scenario using the multi-region, multi-sector model of the global economy G-Cubed (version GGG20j_v152), developed by McKibbin and Wilcoxen (2013). To simulate this scenario, we model a carbon tax which leads to emissions pathways out to 2050 consistent with 2°C scenarios published by the IPCC. We then explore the impacts on output growth and inflation across regions, and ultimately how this influences central bank actions.

The rest of the report is structured as follows. Chapter 2 gives an overview of how monetary policy strategies have evolved over time, the current remits of central banks and considers responses to past supply shocks. Chapter 3 outlines the modelling approach, including the baseline emission and GDP projections, and the structure of the scenarios. Chapter 4 discusses the macroeconomic impacts and monetary policy implications from modelling a carbon tax, assuming central banks follow a Henderson-McKibbin-Taylor (HMT) rule. It then considers the impacts of a carbon tax under alternative monetary policy rules and alongside fiscal policy efforts to reduce emissions. Chapter 5 reports the main conclusions.
2 Monetary Policy

2.1 Historical approaches

Large and rapid changes in inflation are costly. Firms incur costs from frequently updating prices, rewriting contracts and higher uncertainty regarding future prices. In addition, governments face costs in redefining tax brackets, savers experience a decrease in purchasing power, and in the most extreme case of hyperinflation, there is a loss of confidence in the currency and the central bank. As a result, one of the key functions of monetary authorities is to maintain price stability.

A number of strategies for maintaining price stability have been explored in the past. These include tying the value of a monetary unit to a fixed quantity of gold (the gold standard), fixed exchange rates and money supply targeting (Federal Reserve, 2018). However, unstable economic relationships (for example, between inflation and money growth) or external factors (such as new gold discoveries) led to unstable prices even when these anchors were maintained. Therefore, monetary authorities gradually adopted an approach of direct inflation targeting from the 1990s. More recently, central banks have been moving towards ‘flexible inflation targeting,’ where there is discretion over meeting the inflation target, often because there is also weight being placed on other macroeconomic indicators, such as output growth or unemployment.

2.2 Monetary policy remits across countries

Monetary policy remits vary across countries, with some favouring the primacy of inflation targeting, some opting for equal weight on inflation and employment objectives, and others which continue to employ an exchange rate target. The European Central Bank’s (ECB) primary objective is stable inflation, with full employment and balanced economic growth mentioned as secondary objectives (European Central Bank, 2019). Price stability is also the foremost objective for the Reserve Bank of India, the Bank of Japan and the Bank of Russia (Reserve Bank of India, 2019; Bank of Japan, 2019; Bank of Russia, 2020). The main aim of China’s monetary policy is to maintain the stability of the currency’s value, but an inflation target is also included (Gang, 2019). The primary objectives of Australia’s monetary authorities are price stability and full employment (Reserve Bank of Australia, 2019). The Bank of England has both inflation and output targets, although the former appears to have primacy (HM Treasury, 2018).

In the United States, monetary policy has an explicit dual mandate, focusing equally on the objectives of maintaining price stability and maximum employment (Federal Reserve, 2019). Up until August 2020, the mandate included objectives for inflation (2%) and employment. However, the Federal Reserve has now adjusted its mandate to reflect an average rather than a specific inflation target. It now states that it aims to ‘achieve inflation that averages 2% over time, and therefore judges that, following periods when inflation has been running persistently below 2%, appropriate monetary policy will likely aim to achieve inflation moderately above 2% for some time.’ Given this adjustment, which appears to be aimed at facilitating a correction in the price level following a period of subdued or elevated inflation, it could be argued that such a strategy is now more in line with a price-level targeting regime or even a nominal income level targeting regime given the continued strong emphasis on employment in the mandate.

2.3 Monetary policy response to past supply shocks

A transition to a low-carbon economy can lead to both supply and demand shocks. Supply shocks can stem from the sharp restriction of fossil fuel energy resources required to meet global warming targets. This can lead to a large increase in energy prices and therefore place upward pressure on inflation. Demand shocks can also be induced by tighter climate policies as this can lead to a dislocation of high-carbon sectors and a large, sudden reduction in investment which weighs on growth (Batten et al., 2019). While the policy response to a demand shock is clear, following a supply shock, monetary authorities face a trade-off between upward inflationary pressure and slower growth.
It can be difficult to determine the appropriate monetary policy response to a supply shock given the difficulty in identifying the persistence of the shock. Given the long lags associated with monetary policy, a shock that is recognised to be temporary is unlikely to warrant a policy response. However, the response is less clear if the shock is more persistent, as the initial increase in price levels can lead to an adjustment in inflation expectations, which can fuel higher inflation in the future via an increase in wage bargaining and consumers bringing forward spending. In such a case, lowering interest rates to stimulate growth risks adding inflationary pressure. On the other hand, raising interest rates to reduce the inflationary effect may exacerbate the growth slowdown. The response to a permanent supply shock depends on the monetary authority’s goals, however, it is more likely that the interest rate will rise in the near term, given the emphasis most central banks place on price stability. In the long-run however, a permanent supply shock will lead to a reduction in the equilibrium interest rate, which suggests that policy rates will eventually need to align with a lower rate (Garganas, 2006). Next, we consider how central banks have responded to supply shocks in the past as this may provide insights as to how they will respond to a transition shock.

Monetary policy responses to supply shocks have varied over time. The 1970s oil price shocks provide a good example of the same monetary authority using different strategies to address negative supply shocks. The oil price rise that took place in 1973-74 in most industrialised countries was accompanied by increases in inflation and declines in output. The Federal Reserve responded to the shock initially by loosening monetary policy, in order to offset the negative effects of the shock on economic growth. In contrast, during the oil price rise of 1979-1980, the federal funds rate was significantly tightened in order to contain inflation (Garganas, 2006). Some argue that this monetary policy tightening was the main cause of the decline in real output following the supply shock and that had rates been held constant, a recession following the oil price shock could have been avoided (Bernanke et al., 1997). In contrast, Killian and Lewis (2010) claim there is no empirical support for monetary policy amplifying the negative effects of oil price shocks.

The impacts of more recent oil price spikes are said to have been more subdued compared to increases during the 1970s, allowing policymakers to respond less aggressively. Factors that may explain this shift include the enhanced credibility of monetary authorities in maintaining their long-term targets, the lower dependence on oil than during the 1970s, and increased globalisation which has weakened the power of trade unions, and in turn, dampened the second-round effects stemming from wage-price spirals (Garganas, 2006).

Monetary authorities can also interpret the underlying driver of the shock differently, as appeared to be the case with the 2014 oil price slump. The 2014 decrease in oil prices was driven by a slowdown in growth from major developing economies such as China, as well as an increase in oil supply from the United States and other OPEC countries. The Federal Reserve interpreted the oil slump as mainly a supply shock that would temporarily reduce headline inflation and increase GDP growth. Given the temporary nature of the shock, the Fed concluded that raising interest rates would still be the most appropriate setting for long term monetary policy, given the long period of low interest rates following the crisis. In contrast, the ECB interpreted the slump as principally a negative demand shock. The ECB therefore lowered interest rates to support demand growth, even though it was near the zero-lower-bound (Davies, 2014).

Given that predicting central bank responses to a supply shock is difficult, we consider the impact of a transition shock under a number of monetary rules. We begin by modelling monetary responses that are a reasonable approximation of recent historical actions. For the majority of regions, this is the Henderson-McKibbin-Taylor (HMT) rule, which places equal weight on inflation and output growth. However, for regions that still have some degree of exchange rate targeting, weight is also placed on the exchange rate. Given the difficulty in identifying economic shocks and the fact that central bank strategies change over time (in part due to the ‘flexible’ inflation targeting approach), we also examine the impacts under differing monetary rules, including more explicit inflation targeting and output targeting (see section 3.3.2 for more details).
3 Modelling Approach

3.1 Structure of G-cubed

We model the macroeconomic impacts of a 2°C scenario using the intertemporal general equilibrium model G-cubed, developed by McKibbin and Wilcoxen (1998). G-Cubed is a multi-region, multi-sector model of the global economy. The GGG20j_v152 version of the model includes a representation of both developing and developed economies (see Table 1 for region list), as well as the trade and financial links between countries. The model covers 20 sectors, including a breakdown of the electricity generation sector by technology type (see Table 2 for sector list).

Table 1 Regions in the G-cubed model

<table>
<thead>
<tr>
<th>Region</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Australia</td>
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<tr>
<td>China</td>
<td>China</td>
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<tr>
<td>India</td>
<td>India</td>
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<tr>
<td>Japan</td>
<td>Japan</td>
</tr>
<tr>
<td>OPEC</td>
<td>Oil-exporting developing countries: Ecuador, Nigeria, Angola, Congo, Iran, Venezuela, Algeria, Libya, Bahrain, Iraq, Israel, Jordan, Kuwait, Lebanon, Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen</td>
</tr>
<tr>
<td>ROECD</td>
<td>Rest of the OECD (Canada, New Zealand, Iceland, Liechtenstein)</td>
</tr>
<tr>
<td>ROW</td>
<td>Rest of the World</td>
</tr>
<tr>
<td>Russia</td>
<td>Russian Federation</td>
</tr>
<tr>
<td>Europe</td>
<td>Germany, France, Italy, Spain, Netherlands, Belgium, Bulgaria, Croatia, Czech Republic, Estonia, Cyprus, Lithuania, Latvia, Hungary, Malta, Poland, Romania, Slovenia, Slovakia, Luxembourg, Ireland, Greece, Austria, Portugal, Finland, United Kingdom, Norway, Sweden, Switzerland, Denmark</td>
</tr>
<tr>
<td>USA</td>
<td>United States</td>
</tr>
</tbody>
</table>

Table 2 Sectors in the G-Cubed Model

<table>
<thead>
<tr>
<th>Sector Name</th>
<th>Sector Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Electricity delivery</td>
<td></td>
</tr>
<tr>
<td>2 Gas utilities</td>
<td></td>
</tr>
<tr>
<td>3 Petroleum refining</td>
<td>Energy Sectors other than Generation</td>
</tr>
<tr>
<td>4 Coal mining</td>
<td></td>
</tr>
<tr>
<td>5 Crude oil extraction</td>
<td></td>
</tr>
<tr>
<td>6 Natural gas extraction</td>
<td></td>
</tr>
<tr>
<td>7 Other mining</td>
<td></td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th></th>
<th>Goods and Services</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Agriculture and forestry</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Durable manufacturing</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Nondurable manufacturing</td>
<td></td>
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<tr>
<td>11</td>
<td>Transportation</td>
<td></td>
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<tr>
<td>12</td>
<td>Services</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Coal generation</td>
<td></td>
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<tr>
<td>14</td>
<td>Natural gas generation</td>
<td></td>
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<tr>
<td>15</td>
<td>Petroleum generation</td>
<td></td>
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<tr>
<td>16</td>
<td>Nuclear generation</td>
<td></td>
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<tr>
<td>17</td>
<td>Wind generation</td>
<td></td>
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<tr>
<td>18</td>
<td>Solar generation</td>
<td></td>
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<tr>
<td>19</td>
<td>Hydroelectric generation</td>
<td></td>
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<tr>
<td>20</td>
<td>Other renewable generation</td>
<td></td>
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</tbody>
</table>

### 3.2 Baseline projections

We begin by generating a baseline or business-as-usual scenario based on projected labour force and productivity growth. We take the labour force growth from the United Nations Population Projections (2018). The productivity projections are generated following the approach of Barro (1991) and updated in Barro (2015). We use the Groningen Growth and Development database (2018) to estimate the initial level of productivity in each sector of each region in the model. See Liu et al. (2019) for more details on the productivity assumptions in the baseline scenario. Figures 1 and 2 illustrate the model’s baseline projections for GDP and energy-related CO₂ emissions from fossil fuel combustion. These show that the growth rate in both GDP and emissions is expected to be much higher for developing economies when compared with developed economies.

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Note that the model does not include CO₂ from industrial processes or non-CO₂ GHG emissions. In addition, the baseline emissions projections for rapidly growing economies are sensitive to assumptions about the penetration of renewables in energy systems and energy policies. Therefore, small changes in baseline assumptions can lead to differing deviation from baseline impacts in these economies.
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Figure 1  Baseline CO₂ emissions (Gt)

![Figure 1 Baseline CO₂ emissions (Gt)](image)

Source: Vivid Economics

Figure 2  Baseline GDP (USD billion)

![Figure 2 Baseline GDP (USD billion)](image)

Source: Vivid Economics

3.3 Scenarios

3.3.1 Carbon tax scenario

We model a carbon tax shock across regions to achieve emissions reductions that are broadly consistent with global warming of 2°C by 2100. The taxes applied simulate a reduction in energy-related CO₂ emissions of 70%-80% against baseline across all regions by 2050 (see Figure 3). In absolute terms, global emissions in this scenario fall by around 60% between 2020 and 2050, which is consistent with 2°C CO₂ emissions
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Pathways in the energy sector published by the IPCC. The taxes applied to achieve this emissions reduction are not uniform. Regions relying on fossil fuels sectors, such as OPEC, require a relatively large tax to achieve an emissions reduction of 70%-80% against baseline, while Europe requires a much lower tax, due to relatively well-established renewable energy sectors.

Figure 3: CO₂ emissions reductions relative to baseline

Source: Vivid Economics

In the initial scenario, the majority of central banks are assumed to follow a Henderson-McKibbin-Taylor (HMT) rule. Under this rule, the interest rate is determined as a linear function of output growth and inflation, with equal weights on these two variables. There is also a weight placed on the value of the currency where exchange rate targeting has been practiced. The policy interest rate is defined in equation (1):

\[ i_t = \beta_1 i_{t-1} + \beta_2 (\pi_t - \pi^T_t) + \beta_3 (\Delta y_t - \Delta y^T_t) + \beta_4 (\Delta e_t - \Delta e^T_t) \]  

where \( i_t \) is the policy rate, \( \pi_t \) is actual inflation, \( \pi^T_t \) is the inflation target, \( \Delta y_t \) is output growth, \( \Delta y^T_t \) is growth in potential output, \( \Delta e_t \) is the change in the exchange rate and \( \Delta e^T_t \) is the target change in exchange rate. For the majority of regions, \( \beta_2 = \beta_3 = 1.5 \) and \( \beta_4 = 0 \). However, for China, \( \beta_4 = -1 \), and for Russia and ROW \( \beta_4 = -0.1 \), reflecting weight on the exchange rate in historical monetary policy actions.

3.3.2 Alternative monetary policy rules

We also explore the impact of a carbon tax shock under alternative monetary policy rules. We define an ‘inflation targeting’ rule as a case where the central bank still assigns weight to both inflation and output growth, however, a greater weight is placed on inflation (in equation (1), \( \beta_2 = 2 \) and \( \beta_3 = 1 \)). We define ‘output targeting’ as a case where central banks assign a greater weight to output growth than inflation (in equation (1), \( \beta_2 = 1 \) and \( \beta_3 = 2 \)). Following this rule, the central bank’s primary objective is to maintain an output gap of zero.  

Footnotes:

1 In particular, the ADVANCE_2020, Mod2C scenario modelled by AIM/CGE 2.0. This scenario reflects an unanticipated strengthening of ambition after 2020 and is in line with a long-term target of reaching 2°C with 50% likelihood.

2 The output gap is the difference between actual output growth and an estimate of potential output growth. When the output gap is positive (negative), there will be inflationary (deflationary) pressure as demand is higher (lower) than long-run supply.
3.3.3 Government spending shock to low-carbon infrastructure

There is an argument for monetary and fiscal policy coordination to facilitate the low-carbon transition. Given the asymmetric impacts on inflation and output growth associated with a negative supply shock, some studies argue that central banks should focus on restraining inflation when facing such shocks and other policies (either fiscal or structural) should seek to address the negative impact on growth (Garganas, 2006). In addition, some argue for a range of policies to achieve emissions reductions because while carbon pricing incentivises abatement, there are additional market failures that can prevent participants from reacting efficiently to the price signal (CPLC, 2017). For example, firms may not pursue low-carbon investments, such as energy efficiency improvements, due to a lack of information or systematic behavioural biases. In addition, if emerging low-carbon technologies rely on networks (for example, electric vehicles rely on charging infrastructure), these can be difficult to incentivise with carbon pricing alone given the high up-front costs in expanding the network. Therefore, government spending on research into low-carbon technologies or the building of low-carbon infrastructure could help to achieve further emissions reductions and limit the negative impact on growth.

We therefore consider a scenario where the carbon tax shock is accompanied by an increase in government spending towards low-carbon infrastructure projects. We report the macroeconomic impacts of this scenario and monetary policy implications where central banks follow an HMT rule. We assume that alongside the carbon tax, there is an increase in government spending for 20 years, starting at around 1% of GDP in 2020 and reducing to 0% by 2040. Spending occurs across a range of sectors to facilitate the development of low-carbon infrastructure. We also assume that the spending leads to improved productivity in low-carbon sectors. To estimate the productivity impacts we draw on the elasticity of GDP per worker with respect to infrastructure estimated by Calderon et al. (2011) and the process applied in McKibbin, Stoeckel and Lu (2014), although we assign the productivity improvements to sectors that are the focus of the policy (such as solar and wind power generation), rather than spreading the gains uniformly across the entire economy.
4 Results

4.1 Carbon tax under an HMT rule

The introduction of a carbon tax increases the cost of fossil fuel-based production, leading to a drop in GDP and a negative output gap across all regions (Figures 4 and 5). The United States and Europe experience the smallest decreases due to limited reliance on fossil fuels sectors and relatively well-established renewable energies sectors. OPEC sees the largest negative impact, reflecting its reliance on oil domestically and in generating national income through exports, combined with limited ability to substitute towards renewables. This results in a higher tax applied in the OPEC region relative to other regions. Australia and Russia also see relatively large decreases, although this reflects their dependence on fossil fuels for exports rather than for domestic supply. In China, a large negative gap emerges in 2020, reflecting a fall in investment and an increase in policy rates triggered by the exchange rate depreciation. As the monetary authorities loosen policy in the following year, targeting the change in exchange rate, real interest rates fall significantly and output rebounds in 2021 to close to baseline levels. In 2020, there is a slight increase in output growth for the United States, Europe and Japan, reflecting a higher term of trade and higher spending following a payout in fossil fuels dividends that would have otherwise been used for investment. Across all regions, the easing of interest rates facilitates a closing of the output gap by around 2040.

Figure 4 GDP, % difference under carbon tax relative to baseline

![Figure 4](image)

Source: Vivid Economics

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*The impact on GDP will not align exactly with the impact on output gap, as the measure of output growth in the monetary rule also includes intermediate consumption, which can differ substantially across countries.*
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**Figure 5  Output growth, ppt difference under carbon tax relative to baseline**

![Graph showing output growth under carbon tax relative to baseline for different regions](image)

Source: Vivid Economics

The introduction of the carbon tax leads to an increase in inflation across most regions (Figure 6). This is driven by an increase in energy costs while countries are still transitioning to lower-carbon technologies. OPEC sees the largest increase given the high taxes required to facilitate large emissions reductions. Australia also experiences a sizeable increase due to a large depreciation in the exchange rate. In China, inflation decreases in the near term, driven by a large fall in investment prices as investment falls sharply. Given investment is a large share of GDP in China, its sharp contraction following an expectation for slower global growth causes a drop in demand which initially lowers consumer prices. This is also exacerbated by a raising of policy rates in response to a depreciating exchange rate. The subsequent loosening of monetary policy and large reduction in real interest rates provides a boost to inflation in the years following the shock, which rebounds close to baseline levels.

**Figure 6  Inflation, ppt difference under carbon tax relative to baseline**

![Graph showing inflation under carbon tax relative to baseline for different regions](image)

Source: Vivid Economics
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Nominal interest rates increase in 2020, and then decrease to below baseline in all regions by 2030. In the near term, policy rates increase in response to high inflation in most regions and a weaker currency in China. Policy rates fall to lower than baseline levels from 2024 onwards in most regions and from 2030 onwards for all regions, as the negative impact of the shock on output growth begins to outweigh the positive impact on inflation (Figure 7).

Figure 7   Nominal interest rate, ppt difference under carbon tax relative to baseline

Source:  Vivid Economics

Real interest rates fall for the majority of regions following a carbon tax shock. The real interest rate is an indicator of how much expansionary/contractionary pressure the central bank is generating in the economy. Policy is expansionary for most regions following the shock, and in the long term, the real interest rate is persistently lower than baseline, implying that looser monetary policy is required to achieve central banks’ targets (in other words, the neutral interest rate has fallen). This is driven by the large adjustment costs incurred when transitioning from high-carbon sectors to lower-carbon sectors.

Figure 8   Real interest rate, ppt difference under carbon tax relative to baseline

Source:  Vivid Economics
As expected, the carbon tax has a positive impact on output for renewable energy generation sectors and a negative impact on sectors dependent on fossil fuels. Figure 9 shows the percentage increase in sector output for wind, solar, hydro and other renewable electricity generation in Europe. Of the fossil fuels sectors, the coal dependent sectors are hardest hit and disappear in many regions. In Europe, coal mining disappears before 2025 and coal-powered electricity generation has nearly ceased by 2050 (see Figure 10).

Figure 9  Renewable energy sector output in Europe, ppt difference under carbon tax relative to baseline

![Graph showing renewable energy sector output in Europe](image1)

Source: Vivid Economics

Figure 10  Other energy sector output in Europe, ppt difference under carbon tax relative to baseline

![Graph showing other energy sector output in Europe](image2)

Source: Vivid Economics

In the goods & services sectors, the majority see a decrease in output relative to baseline. The services sector sees an increase in output compared to baseline, reflecting substitution from the more carbon-intensive goods sectors, which experience a decrease in output. Labour also moves out of the contracting carbon-intensive sectors into low-carbon sectors and real wages fall across the economy, positively impacting the services sector. There is a large decrease in output for durable manufacturing in the near term, reflecting the fall in potential output and therefore a sharp drop in investment spending (which is
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largely on durable goods). Over time, the impact on durable manufacturing is dampened, as lower interest rates make it less expensive to invest in durable goods (see Figure 11).

Figure 11 Goods & services sector output in Europe, ppt difference under carbon tax relative to baseline

![Figure 11 Goods & services sector output in Europe, ppt difference under carbon tax relative to baseline](image)

Source: Vivid Economics

4.2 Alternative monetary rules

We test the impact of the carbon tax under two additional monetary rules outlined in section 3.3.2. Figures 12 and 13 illustrate the impacts on inflation and output growth for Australia. This shows that there is lower inflation under inflation targeting, at around half the impact compared with the HMT rule in 2020, but a more negative impact on output growth, which is around a third larger compared with HMT in the same year. Under output targeting, the negative impact on output growth is around half that following an HMT rule in 2020 (although the gap is smaller when comparing the trough of output growth under each rule). In addition, the change in inflation is nearly twice as high under output targeting compared with HMT in 2020. Looking over the longer term, under output targeting, moving inflation back to baseline levels takes more than ten years longer than under inflation targeting, whereas output growth moves back towards baseline at a similar pace under each rule.
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Figure 12  Inflation in Australia, ppt difference under carbon tax relative to baseline

![Graph showing inflation in Australia under different carbon tax scenarios.](image)

Source: Vivid Economics

Figure 13  Output growth in Australia, ppt difference under carbon tax relative to baseline

![Graph showing output growth in Australia under different carbon tax scenarios.](image)

Source: Vivid Economics

4.3  Government spending shock to low-carbon infrastructure

Modelling a carbon tax alongside a fiscal policy shock to low-carbon infrastructure provides insights into how coordinated policy action could encourage further abatement and limit the negative impact on output growth. This scenario leads to a higher level of abatement compared with a carbon tax alone as the spending facilitates a larger uptake of low-carbon technologies. As a result, emissions reductions across regions are estimated to be 80%-90% lower than baseline in 2050 (compared with 70%-80% in the scenario with no government spending boost). The increase in government spending and productivity in low-carbon sectors also limits the negative impact on growth (or in some cases, results in a positive impact). While higher government spending stimulates growth in the short term, higher productivity has a persistently positive impact. However, growth is slightly lower in the medium term when compared to the scenario considered in 4.1 as the level of government spending moves back towards baseline levels. Figure 14 shows that Europe
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sees a positive overall impact on GDP in 2050, and the USA and Japan only see a very small negative impact, as the spending boost is enough to offset (or mostly offset) the negative impact of the tax in regions with well-established renewable energy sectors. For most other regions, the increase in government spending reduces the negative impact of the tax, although it is not enough to completely offset the effects. The OPEC countries actually see a larger negative impact on GDP compared to the scenario with a carbon tax only, driven by higher interest rates leading to a larger decrease in investment.

Figure 14  GDP, ppt difference under coordinated policy response relative to baseline

Source:  Vivid Economics

Figure 15  Output growth, ppt difference under coordinated policy response relative to baseline

Source:  Vivid Economics
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Compared to the scenario with no spending boost, the outcome for nominal interest rates is generally lower in the near term but higher further out, reflecting the net impact of the government spending and productivity shocks (Figure 16). Higher government spending places upward pressure on both inflation and output in the short run but these impacts dissipate in the medium run as government spending increases are phased out. Higher productivity places downward pressure on inflation and upward pressure on output in the short run, with the net impact yielding lower nominal interest rates in the near term for most regions (compared to the scenario in 4.1). However, as the impact on inflation wanes in the medium term, output growth dominates, resulting in higher nominal interest rates. In the medium term, the net effect of the government spending and productivity shocks is therefore positive.

Figure 16  Nominal interest rates, ppt difference under coordinated policy response relative to baseline

![Nominal interest rates, ppt difference under coordinated policy response relative to baseline](chart)

Source: Vivid Economics

In the long term, policy rates under the government spending shock scenario are still higher compared to those under a carbon tax alone, although these are still much lower than baseline in 2050. Policy rates are higher in the long-term, even after the government spending shock has dissipated as there is a persistently positive impact on the productivity of low-carbon sectors which means that less expansionary pressure is needed to meet the central banks’ goals. However, given rates are still well below baseline, this does highlight that the positive impact on productivity facilitated by a government spending shock of the magnitude we consider, is insufficient to offset the negative impacts of the carbon tax.
5 Conclusion

This study finds that a carbon tax shock consistent with limiting global warming to 2°C provokes significant monetary policy action. In the near term, policy rates rise in response to higher inflation outweighing the negative impact on output growth. In the medium to long term, central banks reduce policy rates to below baseline levels, illustrating that when countries are unable to sufficiently transition away from fossil fuels, the large negative supply shock leads to a reduction in the neutral interest rate. Central banks could follow more flexible rules, placing more weight on inflation or output growth, which would lead to more favourable outcomes for the target variable in question in the near term. In addition, implementing a carbon tax alongside a government spending shock to low-carbon infrastructure can limit the negative impact on output growth in the near term and to some extent in the long-term due persistent productivity improvements.

The model results highlight a number of policy implications. First, central banks should consider the trade-off in raising policy rates following a climate policy shock given rates will likely need to decrease once the large impact on inflation has dissipated. In other words, central banks could ‘look through’ the temporary inflation increase.5 The counter argument is that price rises could feed into inflation expectations if persistent. However, recent energy price shocks suggest that inflation expectations have been fairly well anchored since the introduction of inflation targeting, and perhaps also due to other structural economic changes such as increased globalisation and a reduction in the power of trade unions. A monetary rule that places more weight on output might therefore be more appropriate for a temporary supply shock. Second, to facilitate the transition to a low-carbon economy, there is a potential role for monetary and fiscal policy coordination. The case for this is strengthened by the fact that governments will likely need to provide funding for low-carbon investments during the transition to address market failures. However, while complementary policies such as government-funded infrastructure can help to reduce the negative impact in the near term, the productivity improvements required to completely offset the impact of the carbon tax shock will likely need to be driven by an independent improvement in technology.

Future areas of research could explicitly model the ‘optimal’ response to a climate policy shock, with reference to other monetary rules such as nominal income targeting. The optimal monetary policy response could be determined by the monetary rule that minimises welfare losses. The HMT, inflation targeting and output targeting rules could be explored alongside nominal income level targeting (which appears to be consistent with the Federal Reserve’s revised strategy). Nominal income targeting has some desirable properties. The underlying target metrics tend to be easier to measure compared with other rules and central banks can simultaneously target a measure of output and the price level. In addition, if the level of nominal income is targeted rather than the growth rate, the policy response leads to a correction following a sustained period of low (or high) inflation (or output). The impact of employing such a rule would be useful to consider if the climate policy shock could lead to a sustained impact on prices or output.

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5 This is already common practice when responding to temporary shocks, as central banks often track measures of underlying inflation, which exclude volatile components such as energy prices, to gauge whether the impact on inflation is likely to be persistent. If an increase in inflation is deemed to be driven by a volatile component, central banks will often look through the impact when determining the appropriate path for policy.
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Company profile

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We are a premier consultant in the policy-commerce interface and resource- and environment-intensive sectors, where we advise on the most critical and complex policy and commercial questions facing clients around the world. The success we bring to our clients reflects a strong partnership culture, solid foundation of skills and analytical assets, and close cooperation with a large network of contacts across key organisations.

Contact us

Vivid Economics Limited
163 Eversholt Street
London NW1 1BU
United Kingdom

T: +44 (0)844 8000 254
enquiries@vivideconomics.com