Does the Sequence Matter: Interest Rates, Quantitative Easing or Forward Guidance?*

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We study the role of unconventional monetary policies during a pandemic, focusing on the implementation sequencing of policies when there is a social containment period. Using the Bank of Canada's main projection model (ToTEM), we compare the efficacy of a suite of extended monetary policies (EMPs), finding that the immediate implementation of forward guidance and quantitative easing, followed by credit easing when containment measures are lifted, delivers the best outcome. We also quantify the fiscal response needed to offset the gap in gross domestic product created by the effective lower bound, given operational limitations in scaling up EMPs.

JEL Codes: E3, E4, E5, E52, E58.

1. Introduction

The sharp impact of the global COVID-19 pandemic led to policymakers across the world taking strong accommodative measures to support their economies. Central banks in advanced economies eased monetary conditions through conventional monetary policy as well as through various other tools. The Bank of Canada, for example, cut the overnight rate from 175 to 25 basis points (bps)

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in March 2020. The Bank's immediate policy response also included various measures aimed at improving market functioning.[1] In parallel, the federal and provincial governments also rapidly provided extraordinary fiscal support during the pandemic.

Despite the rapid fiscal and monetary policy responses, plausible economic projections for Canada at the peak of the crisis (April 2020) suggested that real gross domestic product (GDP) could remain below prepandemic levels for a prolonged period.[2] While the government's fiscal stimulus and the Bank's liquidity provision offered important support, the measures were not sufficient to fully make up for the drop in activity given the pandemic's widespread economic impacts. However, implementing additional accommodative monetary policy by continuing to lower policy rates was not feasible because it would have resulted in negative interest rates. To support the recovery, the Bank implemented extended monetary policy (EMP) tools, in particular, forward guidance, credit easing, and quantitative easing.[3]

The rapid evolution of the COVID-19 pandemic and the swift response from central banks highlighted an important gap in the literature. Observers and market participants generally judge that aggressive policies helped prevent a worst-case economic collapse, but little is known about the transmission, impact, and relative gains from such policies. For instance, how large are the benefits from implementing EMPs at the effective lower bound (ELB)? Which EMP sequence works best to reduce the output and inflation

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[1] Examples include the Commercial Paper Purchase Program, the Provincial Money Market Purchase program, and the Standing Term Liquidity Facility. The secondary market purchases of Government of Canada securities (Government of Canada Bond Purchase Program) announced on March 27, 2020, also initially aimed at ensuring liquidity. As market functioning normalized, the program's objective shifted toward more traditional quantitative easing, as announced by the Bank in July (Macklem et al. 2020). In this paper, we use the term "quantitative easing" (QE) for such large-scale asset purchase programs aimed principally at bringing down longer-term yields.

[2] See, for instance, the Bank's central scenario presented in the July 2020 Monetary Policy Report (Macklem et al. 2020).

[3] Often referred to as unconventional monetary policies, tools such as negative interest rates, large-scale asset purchases, quantitative easing, credit easing, and forward guidance have become part of central banks' regular toolkits and in some cases remain in place for extended periods. The unconventional has become conventional, which is why we refer to them as extended monetary tools.

fallout? The context of the pandemic also raises questions on the optimal implementation of such tools; for instance, is it advantageous to delay their use until the recovery takes hold to provide continued easing and avoid a preemptive increase in long-term rates?[4] Rigorous assessments of policy tools and implementation options are important to inform policymakers to help shape the best possible policy response.

To our knowledge, our research is the first to use a theoretical model setup to study the optimal sequencing of EMPs during the pandemic. An emerging literature investigates the efficacy of EMPs to address the shortfall of the pandemic (Acurio Vásconez, Damette, and Shanafelt 2023)[5] but remains limited, especially using estimated quantitative models.[6] Existing work also largely focuses on QE (e.g., Costa Junior, Garcia-Cintado, and Junior 2021; Akkaya et al. 2023) and thereby does not take into account the more comprehensive suite of measures that now feature prominently in central bank toolkits.[7] We address this gap by assessing different EMP tools and their implementation, specifically regarding how to best sequence such tools. We use the Bank's projection model, the Terms-of-Trade Economic Model (ToTEM), to explore the effectiveness of EMPs in pandemic scenarios where the ELB constrains the policy interest rate.[8] We assess different combinations of EMP tools by their ability to help maintain demand near the economy's productive potential and inflation near the 2 percent inflation target. Our approach allows

[4]This argument may be further motivated by the fact that some tools aimed at reducing longer-term yields, including forward guidance and quantitative easing, may have had limited impact immediately following the shock because the yield curve was already flat.

[5]Dominguez and Foschi (2024) also estimate the impact of the whatever-it-takes approach by central banks during the pandemic using a narrative approach.

[6]See, for instance, Rebucci, Hartley, and Jiménez (2020) for a cross-country analysis of financial market impacts and Vissing-Jorgensen (2021) for the United States. Chung et al. (2019), while not assessing the policy response to a pandemic specifically, assess the power of the U.S. Federal Reserve Bank's monetary policy toolkit in the 2020 environment, in response to a hypothetical large shock. Arora, Gungor et al. (2020) study the effect of the Bank's announcement of the Bankers' Acceptance Purchase Facility.

[7]A few papers use a shadow rate approach to account for the combined effect of conventional and extended monetary policy tools (e.g., De Rezende and Ristiniemi 2023).

[8]See Dorich et al. (2013) and Corrigan et al. (2021).

to model the distinct transmission channels of the policies, including quantitative easing, credit easing, and forward guidance.

Our analysis moreover contributes to a small literature that considers the importance of the sequencing and coordination of EMP tools. Potter and Smets (2019) survey the experience of policymakers using EMPs following the Global Financial Crisis, finding that the coordination of EMPs is considered an important factor for their efficacy although the sequencing at the time was largely dictated by the unfolding events. As Potter and Smets (2019) point out, the sequencing of EMPs had barely been addressed in the literature and was not well understood. This remains largely the case although there is some recent work on both the empirics and theory. On the former, Rostagno et al. (2021) estimate a Bayesian vector autoregression (VAR) to quantify the contribution of different tools and discuss the instrument mix. Hayashi and Koeda (2019) use an estimated structural vector autoregression (SVAR) to discuss the timing of an exit strategy from quantitative easing. Related to Potter and Smets (2019), Bernanke (2020) reviews the current wisdom regarding the use of EMPs using the Federal Reserve's FRB/US model to assess the appropriate policy mix to implement monetary policy. On the theory, our work is closely related to Sims and Wu (2020, 2021). Sims and Wu (2021) present a dynamic stochastic general equilibrium (DSGE) model with financial frictions and a whole suite of EMPs in order to study their interactions and unwinding.[9] Our work applies a similar framework, and applies it to studying the effectiveness of EMPs during the COVID-19 pandemic, where containment limits the transmission of certain channels of EMPs.

Finally, while the existing literature provides some initial assessment of policies in the United States, our work provides new insights on the mechanisms and efficacy of EMPs in small open economies such as Canada. Research remains limited (Diez de los Rios and Shamloo 2017; Akkaya et al. 2023) but crucially matters for policy implementation, as the relative importance of channels—such as that of the exchange rate channel—differs from that in large and more closed economies.

In this paper, we consider three types of EMPs: (i) *credit easing* as the purchase of short- and long-term corporate debt to compress

[9] See also Blattner and Swarbrick (2021), who assess the role of asset purchases and long-term refinance operations in a monetary union.

the spread of different risky assets; (ii) *forward guidance* as the commitment to keep the overnight interest rate at the ELB until the quarter-over-quarter inflation rate reaches the 2 percent target; and (iii) *quantitative easing* as the purchase of long-term government debt to lower long-term interest rates and control the yield curve.[10] Extended monetary policies alone cannot remove the adverse economic effects of the crisis (this finding is similar to Acurio Vásconez, Damette, and Shanafelt 2023). We thus also discuss implementation considerations, such as estimating the fiscal gap left after we implement the suite of EMPs and whether it is possible for the Bank to scale up EMPs to reduce the need for the government to provide fiscal stimulus.

Our research provides several insights that are relevant to monetary policy in response to a shock as disruptive as COVID-19. First, the EMP sequence that delivers the best macroeconomic outcome in ToTEM begins with a combination of state-contingent forward guidance and a quantitative easing program, followed by credit easing.[11] Even though the labor supply and domestic demand do not respond to monetary policy stimulus during the containment period, quantitative easing can raise inflation through the exchange rate channel and higher inflation expectations. Second, model simulations suggest that immediately implementing the EMP tools simultaneously is a powerful option, with the tools complementing each other as they work through different channels. Forward guidance helps to reduce uncertainty about the monetary policy reaction function, credit easing restores transmission channels by lowering the spread on risky bonds faced by firms, and quantitative easing lowers long-term rates and anchors the yield curve. Third, such front-loaded implementation of all EMPs could make up about 35 percent of the GDP

[10]These measures are some of those listed by the Bank of Canada as possible additional tools in its monetary policy toolkit (Bank of Canada 2015, 2020b). The EMP toolkit, published in 2015, also includes negative interest rates. The technical ELB that reflects a switch-to-cash rate is estimated to be approximately –50 bps (Witmer and Yang 2016). However, Lane (2020) states this policy comes with important costs, and the Bank considered its ELB to be +25 bps (Bank of Canada 2020a).

[11]Due to model limitations, the efficacy of some policy tools may be understated. In particular, credit easing can play important roles in restoring financial intermediation and reducing default risk, which are not captured in ToTEM III.

decline and about 45 percent of the inflation decline created by the ELB under a moderate scenario of the crisis and subsequent recovery. Finally, EMPs alone cannot fully mitigate the effects of the ELB in the severe pandemic scenario. Thus, a large complementary fiscal package would be required to fully offset the impact on output and inflation.

The paper is organized as follows: Section 2 discusses the EMP options and the calibration of their effects. Section 3 describes two underlying macroeconomic scenarios: a moderate scenario of the crisis and recovery and a severe and much more persistent scenario. This is followed by an evaluation of six different EMP sequencing options in Section 4. Section 5 discusses implementation issues and the role for fiscal policy. Section 6 provides a retrospective review of model's forecast performance. Lastly, we present our conclusions and discuss some avenues for future work in Section 7.

2. The Suite of Monetary Policy Tools

We consider four categories of monetary policy tools in this paper.[12] The first is conventional interest rate policy which is subject to a lower bound (the ELB) of 25 bps. The constraint on the policy rate reflects the view that rates below this level would become less effective in providing stimulus as they start to impair market functioning. We thus rule out negative interest rate policy.

The second tool, and the first of the extended toolkit, is state-contingent forward guidance. Under this policy, we assume the central bank commits to holding interest rates low, conditional on the inflation outlook (e.g., until quarter-over-quarter inflation reaches 2 percent).[13]

[12] These correspond to the strategies outlined by the Bank of Canada in 2015 (Bank of Canada 2015).

[13] Forward guidance may be conditional on other economic variables or on inflation but with a different level target. The Bank of Canada indeed chose to condition forward guidance on economic variables: "The Governing Council will hold the policy interest rate at the effective lower bound until economic slack is absorbed so that the 2 percent inflation target is sustainably achieved." (Bank of Canada 2020a; Chu and Zhang 2022). Exploring time-dependent forward guidance is left for future work.

The next tool is quantitative easing, which describes the central bank purchase of long-term government bonds, funded by increases in central bank reserves (or settlement balances in the case of the Bank of Canada). This bids up the price of the government securities, thereby lowering their yields. Through arbitrage and asset substitution, these reduced yields transmit to lower borrowing costs more broadly, increase asset prices, and depreciate the currency. To implement quantitative easing in ToTEM, we directly model yield curve control (YCC).[14] In other words, central bank asset purchases are conditional on a target for the long-term yield spread. Equivalent necessary purchases can then be backed out with simple estimates from the literature. In small open economies, quantitative easing has a more limited impact on long-term yields.[15] In order to quantify the purchases, we use the following estimate: $5 billion weekly purchases of five-year government bonds (i.e., $260 billion per year, or around 10 percent of GDP) reduce the five-year term premium by 30 bps in line with what was observed in Canada during the pandemic.[16]

[14]While YCC differs from QE in terms of communication and target metrics, the overall objective of both tools are the same. See, for example, the speech by then Deputy Governor Paul Beaudry in December 2010 (Beaudry 2020) in which he describes the Government of Canada Bond Purchase Program (GBPP) as lowering the rate of interest on government bonds. Under the GBPP, bonds were purchased across all maturities in order to flatten the yield curve (Arora et al. 2021).

[15]This is because quantitative easing is unlikely to affect the global term premium, given the high substitutability between domestic and foreign assets (see Kabaca 2016; Diez de los Rios and Shamloo 2017).

[16]This estimate is based on several considerations. First, international experience of small open economies suggests that purchases of 10 percent of GDP have been able to reduce 10-year yields by about 30 bps (an average of estimates in Joyce et al. 2011; Joyce, Tong, and Woods 2011; Breedon, Chadha, and Waters 2012; De Rezende, Kjellberg, and Tysklind 2015; Meaning and Warren 2015; and Diez de los Rios and Shamloo 2017 for Sweden, Switzerland, and the United Kingdom). Second, upon announcement on March 27, 2020 of the Government of Canada Bond Purchase Program in Canada, 10-year government yields declined about 15 bps within two days (Fontaine et al. 2021). Third, quantitative easing can be interpreted as an offset to government debt issuance. Laubach (2009) estimates 10 percent of GDP debt issuance increases the forward rate by 30 to 40 bps. Finally, the impact of quantitative easing is state-contingent in the sense that quantitative easing is less powerful in compressing long-term yields when the yield curve is already flat. Immediately following the COVID-19 shock, achieving a greater impact would be difficult given the already compressed term premium; we thus consider 30 bps to be the maximum. Note that while the

Corporate spreads at the five-year horizon are assumed to fall by 60 percent of the compression in government bond yields.[17]

The final tool is the credit easing policy which aims to restore the transmission channel by purchasing impaired assets. In this paper, we only consider purchases of short-term corporate debt (e.g., commercial paper or corporate bonds) with the aim to reduce spreads and improve liquidity.[18] There are two credit spreads in ToTEM that are subject to asset purchase programs: long- and short-term corporate spreads. The five-year, long-term corporate spread in ToTEM is constructed based on the weighted average of a basket of three- to seven-year Canadian investment-grade bonds. A degree of uncertainty surrounds the precise quantitative effects, but recent experience of similar purchase programs offers some benchmarks. The effect of a purchase program on credit spreads depends on how much of the spread results from heightened default risk versus a higher liquidity premium. Based on the assumption that 50 bps of the 150 bps spike at the start of the COVID-19 pandemic was due to higher default risk,[19] we estimate that $40 billion in purchases could lower the five-year corporate spread by up to 80 bps.[20]

Bank of Canada's large-scale program was initially implemented with $5 billion weekly purchases in March 2020, which we use here in the simulations, the Bank recalibrated the quantitative easing purchases in October 2020 toward long-term bonds. The recalibration reduced the amount to $4 billion a week, although it did not reduce its impact. Arora et al. (2021) estimate a fall of 18 bps on the five-year spread during a three-hour window when the program was announced; however, as the authors point out, this likely understates the overall effect, as this captures only the surprise element of the announcement. It is likely the program was anticipated by the markets and much of the squeeze in yields was already priced in.

[17]Given the importance of terms-of-trade shocks in ToTEM, the exchange rate is a key channel for quantitative easing, in line with the literature on small open economies (Kabaca 2016; Fontaine, Suchanek, and Yang 2017; Drought, Perry, and Richardson 2018).

[18]In addition, funding for lending schemes can boost lending. This topic is left to be considered in future work.

[19]This rough estimation is based on the methodology in Leboeuf and Hyun (2018).

[20]For example, the Bank of Canada's Banker's Acceptance Purchase Facility is estimated to have compressed bankers' acceptance yields by 15 bps upon announcement and by up to 70 bps over the following weeks (Arora, Gungor et al. 2020). Moreover, the effect of a $30 billion sale of corporate bonds in a stress scenario is estimated to increase corporate spreads by about 90 bps

Short-term spreads in ToTEM correspond to short-term commercial paper. We assume that commercial paper purchases reduce the short-term (three-month) corporate spread by about 80 bps.[21] Based on the literature and the Bank's experience with its Commercial Paper Purchase Program, such a reduction in spread would require purchases of about $3 billion to $6 billion of commercial paper.[22]

3. Description of Scenarios

We conduct our analysis using ToTEM (version III), a large-scale New Keynesian DSGE model with rational expectations.[23] The simulation for EMP sequencing options is done in two steps. First, we use two scenarios of pandemic development, one moderate and one severe. In the second step, we introduce six different EMP sequence plans that can be implemented to stabilize the economy during the three years after the onset of the pandemic.

3.1 Short Description of the Terms-of-Trade Economic Model

ToTEM contains several key ingredients that are empirically relevant for explaining Canadian data. The model features more

(Arora, Bédard-Pagé et al. 2020). Evidence from recent corporate bond purchase programs at the European Central Bank (ECB) (European Central Bank 2016; Abidi and Miquel-Flores 2018; Santis et al. 2018; Zaghini 2019; Cecchetti 2020) and the Bank of England (Belsham, Rattan, and Maher 2017; Boneva, de Roure, and Morley 2018) suggests that purchasing 10 percent of outstanding corporate bonds can reduce the spread by 69 bps. This translates into up to 90 bps for $40 billion in Canada, or 13 percent of corporate bonds outstanding.

[21]The actual compression depends on the current spread. In the first quarter of 2020, the spread is reduced by around 80 bps, but it falls to about half of this by the first quarter of 2021.

[22]In Canada, since the announcement of the Commercial Paper Purchasing Program, spreads have dropped sharply, declining by around 80 bps on an average volume-weighted basis for Canadian corporate issuers. The decline happened amid a peak size of the program of $3 billion, or 5 percent of outstanding commercial paper ($62 billion in February 2020). The literature for the Bank of England (Bank of England 2019), Bank of Japan (Hirose and Ohyama 2010), and the United States (Adrian, Kimbrough, and Marchioni 2011; Duygan-Bump et al. 2013; Boyarchenko, Crump, and Kovner 2020) suggest a somewhat smaller impact of about 64 bps on average for purchases of 10 percent of outstanding commercial paper.

[23]For a detailed model overview, see Appendix B. For full information and description of ToTEM, see Dorich et al. (2013) and Corrigan et al. (2021).

disaggregation than in prominent DSGE models used in the literature, such as Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007). ToTEM includes producers of five distinct types of final products: core consumption goods, business investment goods, residential investment goods, government goods, and noncommodity export goods. ToTEM also contains a separate commodity-producing sector because of the importance of commodities in the Canadian economy.

The standard New Keynesian model has no role for quantitative easing. The household side of ToTEM is defined in a similar spirit to André, López-Salido, and Nelson (2004) and Chen, Cúrdia, and Ferrero (2012), introducing a particular type of asset market segmentation. This allows for the long-term interest rate to affect aggregate demand distinct from the expected path of short-term rates. A fraction of restricted households can trade only in long-term bonds.[24] A fraction of the remaining households is unrestricted because they trade in both short- and long-term bonds. The final fraction is current-income households that neither borrow nor save but live hand-to-mouth.

The asset market segmentation in ToTEM allows aggregate household spending to depend on both short- and long-term interest rates. In ToTEM, conventional monetary policy is governed by a Taylor rule with interest rate smoothing that reacts to both the expected year-over-year inflation four quarters ahead and the output gap. To match the data, the model contains 33 structural shocks.

Importantly, ToTEM includes features that make it less susceptible to the forward guidance puzzle which describes the fact that standard New Keynesian models exhibit excessively large reactions to anticipated monetary policy shocks. The model allows for rule-of-thumb (RoT) price setters (as in Galí and Gertler 1999) and habit persistence in consumption. In particular, price setting will take place as follows. With probability θ each period, firms will increase their prices in line with the inflation target. Of the remaining $1-\theta$ firms, a share $1-\omega$ will optimize their price to maximize expected discounted profits while the remaining ω will follow the rule:

$$p_t^i = p_{t-1}^i + \gamma \pi_{t-1} + (1-\gamma)\bar{\pi} + \Theta \hat{\mu}_t, \tag{1}$$

[24] These households could be motivated by a preferred habitat. See Vayanos and Vila (2009) for details.

where p_t denotes the log price of firm i, π_t period t aggregate inflation, $\bar{\pi}$ the inflation target, and $\hat{\mu}_t$ the deviation of the markup from steady state. The share of RoT price setters in the Canadian economy is estimated to be a relatively high 54 percent.[25] By limiting the role of inflation expectations on current price setting, this feature significantly dampens the responses of output and inflation to anticipated future monetary policy shocks. As a result, ToTEM is well suited to analysis involving forward guidance.[26]

3.2 Step 1: Identifying Two Scenarios Driven by the Global COVID-19 Pandemic

We begin by creating an environment featuring a deep downturn. This downturn results from a global pandemic shock hitting the Canadian economy. To provide a context, we rely on the Bank's scenario analysis in April 2020, as published in its Monetary Policy Report (Poloz et al. 2020). This analysis allows us to concretely mimic the range of outcomes that policymakers considered plausible at the time and based on the information available when they decided whether to implement EMP tools.[27] The COVID-19 shock is characterized by a significant global and domestic demand contraction, decline of oil prices, and sharp decline of the labor supply. The two alternative environments we consider serve as the starting point for analyzing the impact of the EMP sequencing:[28]

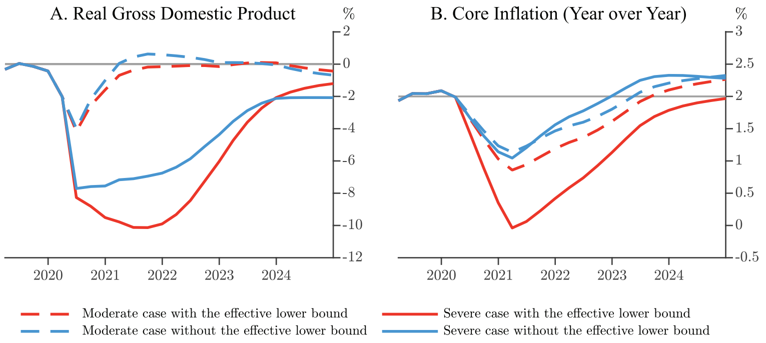
[25]This is the estimated share of RoT price setters specifically in the consumption goods sector; see Corrigan et al. (2021).

[26]This is further demonstrated in Dorich et al. (2018).

[27]The chosen economic scenarios were considered among the range of possible outcomes at the Bank of Canada when the COVID-19 crisis struck. The first scenario corresponds approximately to a profile in the middle of the range presented in the Bank's April 2020 Monetary Policy Report (Poloz et al. 2020), while the second scenario approximates the more severe and prolonged profile. This choice of scenarios is relevant because it represents the information Canadian policymakers considered plausible when they decided which EMP tools to implement. In reality, containment measures varied by province, reopening was often partial and sector-specific, and consumption patterns were affected through both restrictions and voluntary social distancing (see, e.g., Dahlhaus et al. 2022). For clarity, we focus only on full lockdowns of differing durations.

[28]The first scenario corresponds approximately to a profile in the middle of the range presented in the Bank's April 2020 Monetary Policy Report, while the second scenario approximates the more severe and prolonged scenario.

Figure 1. Model Simulations: Real GDP and Inflation without Using the Extended Monetary Policy Toolkit



a *moderate scenario* in which output and core inflation fall by about 4 percent and 1 percent, respectively (charts A and B in Figure 1); and a *severe scenario* with a far more pronounced widening of the output gap, reaching a peak contraction of 10 percent, accompanied by a persistent decline in inflation. In both scenarios, the presence of the ELB aggravates the recession, preventing the central bank from further lowering the monetary policy rate (similar to Kiley 2020 and Costa Junior, Garcia-Cintado, and Junior 2021). In the moderate scenario, the conventional monetary policy under the historical rule calls for the overnight rate to be cut sharply and held at the ELB of 25 bps over the near term, whereas the severe scenario causes the overnight rate to be kept at the ELB for a prolonged duration.

An alternative to scenario forecasts driven by exogenous shocks is offered by Eichenbaum, Rebelo, and Trabandt (2021), who develop a macroepidemiological model to evaluate the economic impact of a pandemic. By modeling the precautionary behavior of individuals facing risk of contagion, this class of model provides theoretical grounding to the interaction between the economy and epidemic dynamics of the COVID-19 pandemic. Households avoid social interactions by reducing both their hours worked and level of consumption. Social containment measures can then be introduced as an exogenous Pigouvian tax on consumption.

These models provide a powerful framework for analyzing the macroeconomic impact of health crises and, in particular, allow the modeler to evaluate the effect of differing parameterizations such as the infection rate, fatality rate, detection rate, and so on. However, as Diez de los Rios (2022) finds in a macroepidemiological model, these parameters can have a large impact on the magnitude of the economic effects of a pandemic. The same holds for the form of expectations that people have. In the author's simulations, the drop in consumption can be anywhere between 3.5 percent and 80 percent following the same shock, depending on expectations assumptions.[29] The two scenarios used in this paper are driven by the interaction of large domestic and foreign demand shocks, and supply constraints, producing outcomes consistent with a macroepidemiological model hit with a new infection. These scenarios capture the high degree of uncertainty about the characteristics of the pandemic in a parsimonious framework.

3.3 Step 2: Introducing Extended Monetary Policy Tools in Sequence

In the second step, we consider the implementation of EMP tools. To mimic the economic context at the onset of the COVID-19 crisis, we restrict specific transmission channels of low policy rates to the real economy in the short term—the assumed containment period. Although EMPs can lower borrowing costs faced by firms and households, both domestic demand and labor supply remain unresponsive during the containment period in the simulation.[30] This assumption models the reality that consumers and firms either cannot or do not want to spend during the containment period, even though interest rates are low. In the moderate scenario, we assume the containment period limits transmission from the second quarter to the third quarter of 2020, whereas in the severe scenario, containment measures get lifted only in the first quarter of 2021.[31]

[29]In Diez de los Rios (2022), households substitute between home and market production. The author allows for naive beliefs about the pandemic, rational expectations, optimistic beliefs, and time-varying inattention. In the author's simulations, market consumption falls 3.5 percent with naive agents, over 30 percent with rational full-information agents, and over 80 percent with agents that have time-varying inattention.

[30]In addition, the labor supply is also held fixed to capture the fact that labor input does not change during the containment period.

[31]By preventing labor and investment from responding to monetary accommodation, we are abstracting from effects that could be present in a structural

Table 1. Sequence Plans for Extended Monetary Policy Tools in Response to the COVID-19 Shock

Sequence Plans		FG* + CE or QE	2020			2021				2022				2023	
			Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
			Containment Period		Recovery Period										
0	FG Only		Containment Period (Severe)			Recovery Period									
1 Start Early and Stagger Policies	1a	CE													
		QE													
	1b	CE													
		QE													
2 Delay and Stagger	2a	CE													
		QE													
	2b	CE													
		QE													
3 Implement All at Once	3a	CE													
		QE													
	3b	CE													
		QE													

*Forward guidance is applied throughout all simulation periods in each sequence plan.
Note: FG is forward guidance; CE is credit easing; QE is quantitative easing.

We consider six different sequence plans as summarized in Table 1. In all sequence plans, the central bank commits in the second quarter of 2020 to holding interest rates at the ELB until quarter-over-quarter inflation reaches 2 percent.[32] The sequence plans are then as follows:

1. In addition to implementing forward guidance, the central bank starts one EMP tool immediately and the second tool after two quarters, once the containment period under the moderate scenario is over. Both policies are in place for two years from their respective implementations. We consider two versions of sequence 1: (a) start credit easing first and delay the start of quantitative easing until the two-quarter containment period is over; and (b) start quantitative easing first and delay the start of credit easing until the two-quarter containment period is over.

2. The central bank delays the implementation of both credit easing and quantitative easing for two quarters. This sequence is motivated by a desire to boost the recovery only after it kicks in. We consider no EMP policies during the containment period and implement the same two variations as in sequence 1, starting only in the fourth quarter of 2020.

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macroepidemiological model. However, as there were strict federal and provincial lockdowns in place, we consider the most important factors for labor and investment recovery were the relaxing of social-distancing restrictions and adapting production and consumption to the pandemic, rather than monetary stimulus. For this reason we view the labor and investment constraints to be a good approximation.

[32]In our simulations, all the sequencing of EMP tools is known in the first quarter, including interest rate liftoff conditions, because agents are forward-looking. Forward guidance is therefore implemented in the first quarter in all simulations; it does not matter when it is actually implemented because agents know it is coming. Note also that, as announced in the Bank's July 2020 interest rate announcement, the Bank did indeed implement forward guidance: "The Governing Council will hold the policy interest rate at the effective lower bound until economic slack is absorbed so that the 2 percent inflation target is sustainably achieved" (Bank of Canada 2020a). The specific liftoff dates in the moderate and severe scenarios are conditional on the set of future unexpected shocks to the Canadian economy.

3. The central bank implements all EMP tools at once, either immediately or after the containment period is over.

4. Evaluating Sequence Plans of Extended Monetary Policy Tools

We evaluate the marginal impact of each sequence plan on GDP and core inflation relative to the benchmark cases, which feature no lower bound on the policy interest rate. This allows us to weigh the benefits and economic costs of different EMP sequence plans.

4.1 A Hypothetical Base Case: No Effective Lower Bound

This benchmark is a best-case (albeit unrealistic) scenario where the policy rate can fall as far below zero (and transmit normally) as needed. The path of the policy rate is determined by the Taylor rule to stabilize output and inflation, ignoring the ELB.[33] This option is shown by the solid green line in Figure 2, charts A and B. Under this scenario, short- and long-term corporate rates fall along with the policy rate below the lower-bound constraint, as do household and mortgage rates. The real and nominal effective exchange rates depreciate sharply and rapidly by as much as 5 percent each in 2021 (relative to the case where the ELB binds), which triggers a faster improvement in Canadian exports and thus the current account balance than when the ELB binds. The zero line in Figure 2, shown in gray, represents the base case simulation with the ELB constraining conventional interest rate policy. The other lines in the two charts show how output and inflation would evolve relative to this base case. In Figure 3, we plot the path of the nominal interest rate in the benchmark case without the ELB against that in the economy where the ELB constrains monetary policy.

[33]This uses the estimated rule and thus we take it to represent the Bank of Canada's preferences toward inflation and output stabilization as well as monetary policy smoothing.

Figure 2. Comparison of Macroeconomic Improvement from Extended Monetary Policy Sequence Plans (percentage difference relative to outcomes under an effective lower bound, no extended policy scenario)

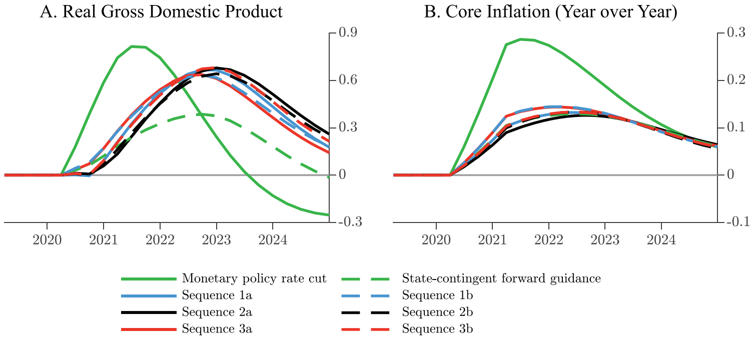
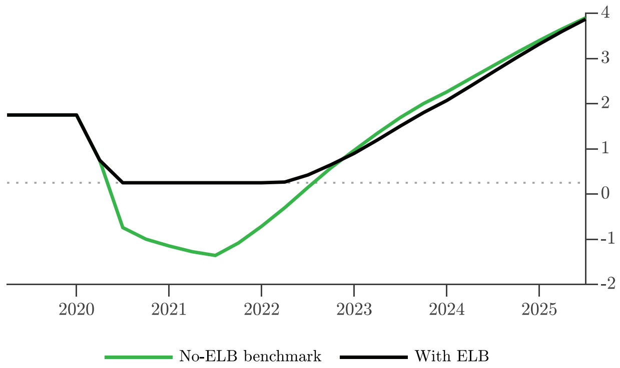


Figure 3. Main Policy Interest Rate under the Benchmark Scenario with an Unconstrained Taylor Rule against the Economy with an ELB but No Additional Policy Actions



Note: The lower bound of 25 bps is indicated by the gray dotted line.

Compared with the ELB case, total hours worked also improves more rapidly from the negative pandemic shock, reaching its prepandemic level faster, i.e., early 2021. This is accompanied by a moderate wage growth, boosted by more than 1 percent at its peak in early 2022. Together, the faster recoveries in hours and wages boost real disposable income by up to 1.5 percent toward the end of 2021. Finally, in addition to supporting aggregate demand, the wealth channel of accommodative monetary policy is also at play: financial wealth increases and real house prices rise sharply in 2020. Taken together, the economy returns to prepandemic levels within a year from the time COVID-19 struck in early 2020, driven largely by a bounceback in consumption that supports the closing of the output gap in early 2021. Year-over-year core inflation is boosted by more than one-quarter percentage point at peak (early 2021), though its return to target is sluggish until early 2023.

Finally, the speedy recovery of the economy also yields a more favorable fiscal outcome: the debt-to-GDP ratio, spiking with the hit of the crisis, improves much faster in a world where the policy rate can go deeply negative. Note that the path of fiscal policy variables (such as government expenditure and the income tax rate) in all sequencing options remains unchanged at the levels in the "no ELB" case to abstract from differential responses in these fiscal policies.

Certainly, a world without a binding ELB is an unrealistic scenario, but it serves as a useful comparison. The area below the green line in Figure 2, charts A and B, indicates the improvement of GDP and inflation, respectively, relative to the case where the ELB is binding.

4.2 The Impact of Sequencing Options when the Effective Lower Bound Binds

We can now evaluate the different policy options against the base case of no ELB. The remaining lines in Figure 2, charts A and B, show the degree to which each of the six EMP sequencing options (from Table 1) can improve GDP and inflation outcomes, respectively, that would arise under the moderate scenario, compared with a case with no policy intervention where the ELB is binding. For example, the gray line shows the GDP improvement under sequence 1b.

Sequence plans that immediately implement quantitative easing and forward guidance (1b, 3a) yield the fastest response of GDP and the best inflation outcomes. Even though the short-term rate is constrained at the ELB, these policies immediately decrease long-term interest rates effectively through both the term structure of the future path of short-term rates and the term premium. Lower effective interest rates faced by both households and firms support consumption, residential investment, and business investment more than in scenarios where EMP policies are absent.

As a result of postponing credit easing for two quarters in sequence 1b, the decline of long-term corporate rates under 1b is less pronounced. Nevertheless, this has little real impact on investment in the short term because the economy and labor supply are constrained by containment measures. This also explains why sequence 1a, which starts with credit easing, is among the least effective sequences in terms of stimulating GDP and inflation: it effectively and immediately lowers corporate rates but fails to lift consumption by as much as quantitative easing does. Lifting consumption has a more widespread impact on interest rates in the economy. Also, sequence 1a does not lead to a more front-loaded response of investment.

Finally, sequences that delay the implementation of EMPs (2a, 2b) yield subpar outcomes for GDP and inflation. Saving monetary policy power for later does not improve the overall outcome; it simply delays its beneficial effects. In sequences 2a and 2b, interest rates relevant for agents' decisions, such as the corporate rate and mortgage rates, only fall in the fourth quarter of 2020 and the second quarter of 2021, delaying and limiting the impact of lower rates on consumption. Moreover, the delayed response of interest rates also means the exchange rate depreciates only slightly and late in the game compared with more front-loaded sequences. As a result, these sequences do little to help export performance or only do so in 2022 and 2023, whereas more front-loaded sequences result in an earlier boost to exports, thereby supporting the recovery.

To provide an alternative metric to quantify the degree of improvement in macroeconomic outcomes delivered by different sequencing options, we also report and compare how cumulative GDP and the average inflation improve after implementing each sequence plan at the ELB. This comparison allows us to measure the efficacy of each EMP sequence. Details of this comparison can be found in Table A.1 in Appendix A.

4.2.1 Key Quantitative Results

We find that starting forward guidance and quantitative easing early and staggering credit easing policies (sequence 1b) or immediately implementing all EMP options (sequence 3a) stabilizes GDP and inflation better in the near term than the delayed sequence plans.

In the moderate scenario, the maximum effect of EMPs reduces the GDP loss due to ELB by about 35 percent and inflation loss by about 45 percent.[34] In contrast, the same EMP package in the severe case would reduce the GDP loss due to ELB by about 15 percent and that of year-over-year inflation by about 16 percent. What this means is that even if all EMP options are implemented immediately, about 65 percent of the GDP loss remains in the moderate scenario and 85 percent in the severe scenario. Therefore, fiscal policy would need to fill this loss to completely offset the COVID-19 shock.

In the moderate scenario, state-contingent forward guidance by itself (sequence 0) reduces nearly 25 percent of the GDP loss and 38 percent of the inflation loss due to the ELB. In contrast, in a severe macroeconomic scenario, forward guidance can only make up about 10 percent of the GDP loss and about 13 percent of the inflation loss that rate cuts below the ELB could deliver. By introducing state-contingent forward guidance, the ELB duration is prolonged in both the moderate and severe scenarios.

As shown in Figure 2 and Table A.1, one of the most effective strategies is a front-loaded approach (sequence 1b) where quantitative easing is enacted immediately and credit easing is delayed until the containment period (for two quarters) has ended. Using the credit easing policy in the near term does not achieve a reduction in the overall macroeconomic loss relative to the ELB. It is important to note that our simulations in ToTEM may underestimate the potential importance of credit easing given model limitations. Credit easing is assumed to work only through the credit channel by focusing on lowering firms' borrowing costs. In practice, credit easing may also have important effects by restoring financial intermediation, reducing default risk, and lifting consumer and business confidence, which are not captured in ToTEM. In addition, due to the containment measures, both business and residential investment are unresponsive in the near term, thereby limiting some of credit

[34]This translates to about a 0.9 percent impact on quarterly GDP and an increase of about 14 percentage points in the year-over-year inflation (for more details, see Table A.1 in Appendix A).

easing's immediate effect.[35] The elevated uncertainty and labor supply contraction during the containment period also greatly limit the effect of the credit easing policy on household spending.

We also find that a delayed all-at-once strategy (sequence 3b) reduces the potential benefit delivered by sequence 1b because the exchange rate adjustment is postponed. Importantly, if monetary policy delays implementation so that it can ease policy support for when the economy recovers, as in sequence 2, the marginal impact of EMPs on GDP is also smaller than it is when measures are implemented earlier, such as in sequence 1. This suggests that there are some costs to not acting aggressively when the shock hits, particularly on stabilizing inflation.

Lastly, we find that when forward guidance is implemented first, EMPs can improve macroeconomic outcomes even in the severe scenario. This is an important takeaway. Our results demonstrate that, because uncertainty around how the COVID-19 shock resolves itself remains high, having a mechanism that helps to anchor inflation expectations is effective.

4.3 Robustness Analysis

To analyze the robustness of our findings, we investigate how sensitive results are to a variation in the parameter that determines the degree of RoT behavior of price setters in the consumption goods sector.[36] Intuitively, a higher share of RoT price setters in the consumption goods sector would be expected to dampen the economic impact of sequence options that delay policy implementation. When there are fewer forward-looking firms, expected future economic activity has a reduced role in current inflation and, thus, policies that are delayed will have a weaker impact.

In this robustness analysis, we vary the share of RoT price setters around a 90 percent confidence interval based on its posterior

[35] In ToTEM, firms seek credit to make capital purchases only. Credit easing may have a greater role in a model with heterogeneity, fixed costs, and default because in such a model firms may seek additional credit to cover running costs as well as capital purchases. In practice, credit easing can have important effects by limiting firm defaults and helping firms bridge the containment period.

[36] As discussed above, this is the share of firms that following a simple rule to set prices, similar to inflation indexation.

distribution. We obtain two results: first, when the share of RoT price setters in the consumption goods sector increases by approximately 7 percent, all sequencing options lead to a relatively worse economic outcome. In contrast, when we lower the share of RoT price setters, the economic outcome under all sequencing options improves because the expectation channel is stronger. Second, a front-loaded sequence plan continues to be the most effective strategy regardless of the degree of RoT behavior. More specifically, sequence plans 1b and 3a continue to yield the best responses of GDP and inflation outcomes.

5. Policy Considerations for Implementation

This section discusses the complementarity of fiscal policy and EMPs as well as their implementation limits.

5.1 The Role of Complementary Fiscal Policy

We have shown that an immediate deployment of all EMP tools offsets 35 percent of the GDP gap created by the presence of an ELB on interest rates. This leaves about 65 percent of the gap to be potentially filled by fiscal policy if the objective is to completely offset the COVID-19 shock. Importantly, these estimates hinge on the underlying scenarios and could vary significantly should the economy evolve differently. Nevertheless, for illustrative purposes, we can quantify the increase of fiscal stimulus required to complement the EMP tools at the ELB in order to fully offset the loss the ELB creates. We find that under the moderate scenario, $7 billion of additional fiscal stimulus would be required for the first year to fill the gap. Under the severe scenario, however, the gap left for fiscal spending is much bigger: about 87 percent of the GDP loss, or $28 billion.[37] In addition, under the severe case, if we use universal

[37] This assumes a fiscal multiplier of 1 in the moderate scenario and 1.2 in the severe scenario. Fiscal multipliers are generally higher in recessions and when the nominal interest rate is constrained by the ELB (Office of the Parliamentary Budget Officer 2016). Note that the estimates of required fiscal measures are in addition to amounts already committed to and integrated into the scenarios at the time of the April Monetary Policy Report (Poloz et al. 2020), amounting to roughly $120 billion. Since then, the government enacted additional measures for a total of about $400 billion (International Monetary Fund 2021).

transfers to fill the remaining GDP loss due to the ELB, we would need up to \$113 billion, or up to \$68 billion if we consider targeted transfers to borrowers and hand-to-mouth households. The moderate scenario would require between \$30 billion and \$113 billion of fiscal stimulus to fill the remaining 65 percent of the GDP loss due to the ELB. This amount depends on the type of fiscal instrument used once the EMP package has had its maximum effect. For details of the estimated magnitude of fiscal policy, see Table A.2 in Appendix A.

5.2 Scalability of Extended Monetary Policy Tools

Given that the sequences we present can reduce the gaps in GDP created by the ELB by up to only 35 percent under the moderate scenario, we now discuss if it is possible to implement even more aggressive EMPs and scale the stimulus.

5.2.1 Forward Guidance

Rather than conditioning the guidance on reaching the 2 percent inflation target, the Bank could temporarily commit to holding rates at the ELB until inflation reaches a higher target. While this should provide more monetary easing in the short term, there is a trade-off. On the one hand, a temporarily higher target would result in an overshoot of inflation above that target, which would provide stimulus by lowering the real interest rate. On the other hand, as inflation increases above the Bank's core target, the Bank would need to bring inflation expectations back to 2 percent by quickly raising interest rates.

5.2.2 Quantitative Easing

In practice, quantitative easing has diminishing returns and price and quantitative limits. It is also likely that sizable programs would increase costs beyond the benefits they generate.

First, in the context of an already flat yield curve at the onset of the crisis, it is reasonable to assume that quantitative easing would be unable to compress yields by more than 30 bps. While in practice the yield curve could steepen as the recovery takes hold, simulations show only a slight increase in the term premium, suggesting that quantitative easing could have only small additional effects on long-term rates even later.

Second, there is a quantitative limit to how much the central bank wants to buy before it becomes too dominant in the government debt market.[38] For Canada, the quantitative easing assumption (weekly purchases of $5 billion each) implied holdings of government bonds of about 40 percent of outstanding marketable government bonds by the end of the fiscal year 2020–21.[39] To the extent that marketable debt continued to increase thereafter, the assumption of a two-year quantitative easing program was not expected to result in issues in the government debt market. Liquidity issues could start to arise if purchases were expanded further to reach or surpass a certain quantitative limit in terms of percent of outstanding debt. That said, central banks have tools to mitigate them (for a review of costs, as well as measures to mitigate them, see Aldridge, Cimon, and Vala 2023). Some jurisdictions have limited QE purchases to a certain percentage of outstanding marketable debt (by maturity sector), e.g., 70 percent in the U.K. and the U.S. This suggests central banks consider purchases below such thresholds as manageable (see, e.g., Federal Reserve Bank of New York 2022).

5.2.3 Credit Easing

Purchases of corporate bonds and commercial paper could be further scaled up and expanded to other asset classes. Beyond the purchases considered in the simulations, the Bank could also scale up purchases of other impaired assets, such as provincial government bonds. That said, the amount and effectiveness of scaled-up purchases are also subject to limits.

First, returns to scale are decreasing. In fact, spreads can likely not be compressed beyond a certain point. If we assume that 100 bps of the 150 bps spike at the peak of the crisis in spreads are due

[38]See Santor and Suchanek (2016). From international experience, dominance in debt markets can cause some liquidity strains when purchases go beyond 40–50 percent of outstanding debt (Sano and Uetake 2018). For example, the Bank of Japan (owning 45 percent of the Japanese government bond market) and the Sveriges Riksbank (up to 45 percent of the Swedish government bond market) caused some liquidity strains.

[39]Retrospectively, the Bank of Canada's holdings as a percentage of domestic outstanding marketable debt indeed peaked at 43.67 percent in October 2021. There does not seem to have been a material issue with market functioning in Canada (Aldridge, Cimon, and Vala 2023).

to a higher liquidity premium (as opposed to default risk), further asset purchases would not be able to reduce spreads more than that. Our simulations already assume the risk spread declines by 80 bps, which implies that asset purchases could be scaled up to achieve an additional 20 bps. In practice, credit easing also becomes less effective as market functioning improves. This would limit the efficacy of credit easing once spreads fall back as the recovery kicks in.

Second, even if it were possible to scale up credit easing, the credit risk on the Bank's balance sheet would increase. Concerns about the exposure to such risk or even actual losses could potentially affect credibility and public perception of central bank independence if the nature of purchases is not well communicated to and fully understood by the public. This, in turn, could affect the Bank's ability to steer inflation toward its target.

6. A Review of the Model's Forecast Performance

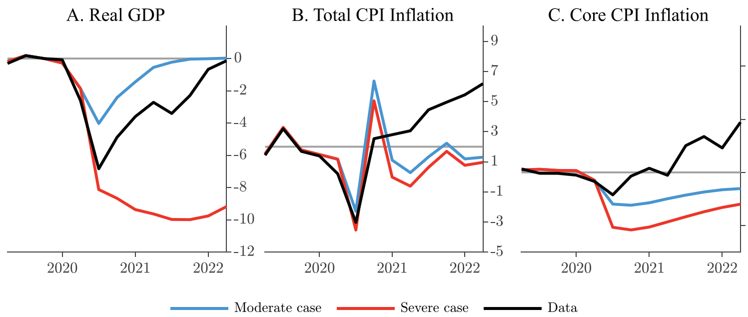
When the Bank of Canada began to implement the policy response to the COVID-19 pandemic, there was a substantial degree of uncertainty regarding the severity and duration of the crisis. This was compounded by the uncertain path for lockdown measures. In retrospect, the evolution of real variables during the onset of the pandemic fell between the moderate and the severe scenario as highlighted in Figure 4.

Beyond the headline measure of GDP, its individual components came closer to those under the severe scenario in 2020:Q2, with consumption and investment falling at or below the severe scenario forecast. Both government spending and net exports were higher than expected, lifting real GDP above the severe scenario projection. Over the medium run, the economy evolved closer to the moderate scenario, as households and firms acclimated faster than expected to lockdowns, supported by large fiscal packages.

Total CPI inflation fell sharply in the first half of 2020 but rebounded just as sharply due to volatility in global energy prices.[40] A historical variance decomposition estimated using ToTEM finds

[40] Canadian oil prices fell around 90 percent between 2019:Q4 and 2020:Q2 but returned close to where they had been by the end of the year (see https://www.aer.ca/).

Figure 4. Forecasts under the Moderate and Severe Scenarios with Realized Data



Note: Variables in % with real GDP normalized to zero in 2019:Q4 and detrended using the method proposed in Quast and Wolters (2022). Inflation is quarter-over-quarter annualized.
Source: Statistics Canada.

that the fall in output during the crisis was primarily driven by demand shocks: a large contraction in domestic demand and a large drop in foreign demand.[41] The main initial drivers of inflation were a combination of the demand shocks and supply-side technology shocks. These effects were partly offset by wage pressures keeping core CPI toward the top of the scenario forecasts.[42]

While the factors driving the economic volatility during the crisis are broadly consistent with both the scenario forecasts and conventional wisdom, it is perhaps surprising that positive supply (technology) shocks lowered inflation as well as offset the fall in output during the first quarter of the crisis. However, as households withdrew labor, the capital-labor ratio rose, increasing productivity and lowering marginal costs. As discussed in Section 3, the shocks that generate the observed dynamics can be made partly endogenous within a macroepidemiological model. Indeed, the central simulations in Diez de los Rios (2022) produce dynamics that are qualitatively

[41]Historical decomposition plots are presented in Appendix D.

[42]In ToTEM, the large rise in inflation heading into 2021 is mainly attributed to domestic wage and price cost-push shocks. The cause of this inflation episode is the subject of ongoing debate and research.

similar to those found in ToTEM.[43] Benmir, Jaccard, and Vermandel (2023) estimate an Eichenbaum, Rebelo, and Trabandt (2021) type model using euro-area data, showing that an infection shock can be mapped to demand-side factors and to cost-push type effects through the Phillips curve, consistent with the drivers estimated using ToTEM.[44]

7. Discussion and Conclusion

To our knowledge, our research is the first to use a theoretical model setup to study the optimal sequencing of EMPs during the COVID-19 pandemic. Our framework allows assessing different EMP tools and their implementation, specifically regarding how to best sequence such tools. Using ToTEM simulations of two scenarios (moderate and severe) in response to a large pandemic shock, our analysis suggests that EMPs can help improve economic outcomes when the policy rate is constrained at the ELB. Gradual sequencing of EMP tools, including forward guidance, credit easing, and quantitative easing, can provide some support to inflation and GDP at the ELB. However, more front-loaded packages where quantitative easing is implemented immediately (starting in the second quarter of 2020) achieve a larger reduction of the economic loss. Indeed, quantitative easing supports the economic recovery through both broader interest rate channels and the exchange rate channel. Quantitative easing provides stimulus to both firms and households, the latter benefiting from lower effective long-term mortgage rates. The relative speed and magnitude of the additional exchange depreciation generated by quantitative easing also play a vital role in considering appropriate sequencing options. Due to containment measures, implementing credit easing to lower borrowing costs faced by firms

[43] As highlighted before, there is a large range of possible quantitative values for the depth of the downturn that depend on assumptions regarding household expectations and information.

[44] Benmir, Jaccard, and Vermandel (2023) decompose the shocks driving real and nominal activity during the COVID-19 pandemic, finding that the infection shock plus demand shocks explain the observed consumption dynamics, and that inflation dynamics were mainly driven by demand-side factors initially, but the cost-push effects caused by the infection shock pushed up inflation over the medium term.

and households offers limited advantages in the short term. Credit easing can, however, provide some support when used after the containment period. We would like to stress that while we assess the effectiveness of EMPs during the COVID-19 pandemic, the framework can be used to assess policy options in pandemic crises more generally. Our analysis shows how central banks can use scenario analysis and model containment during a pandemic to assess the implications of shocks and policy options, calibrating to the severity of GDP fallout and extent of containment measures.

Several caveats warrant mentioning. First, the modeling framework we use has some important limitations. ToTEM has no endogenous precautionary savings channel such as in heterogeneous agent New Keynesian models. Therefore, our analysis may underestimate the importance of labor market adjustments. Following a pandemic with a global impact, precautionary savings motives could potentially amplify the shock and further reduce aggregate output.

Also, the results may understate the benefits of credit easing. This EMP tool can play a key role in restoring financial intermediation and reducing default risk. ToTEM III does not capture either of these channels. Moreover, the scope of our analysis has some limitations. For example, the estimated effects of EMPs rely on an assumption of perfect foresight in which the sequence of policies is known to agents; i.e., agents know that the central bank will implement additional measures (e.g., credit easing) in a subsequent quarter. This implies that the Bank would need to announce the sequence before implementing it for it to achieve the documented benefit. In the absence of perfect foresight (or Bank communication informing the public of the policies it will implement), the quantified effects could be smaller.[45]

[45]In addition, forward guidance will be less effective if the markets incorrectly expect inflation to return to target earlier than projected.

Appendix A. Scenario Simulation Results

Table A.1. A Comparison of Marginal Improvement of Using Policy Options at the Effective Lower Bound (moderate scenario, severe scenario)

Scenario	Detail	Cumulative GDP Impact Over the First Five Quarters (pp)	Relative GDP Improvement to Offset ELB (%)	Average Y/Y Inflation Impact Over the First Five Quarters (pp)	Relative Inflation Improvement to Offset ELB (%)
ELB	No Additional Policy	(0, 0)	(0%, 0%)	(0, 0)	(0%, 0%)
No ELB	Impact of Allowing Interest Rates Below ELB	(2.71, 9.37)*	(100%, 100%)	(0.19, 0.75)	(100%, 100%)
0	FG Only	(0.64, 0.79)	(23%, 8%)†	(0.07, 0.1)	(38%, 13%)
1 Start Early and Stagger	1a: First FG and CE, then QE	(0.62, 0.82)	(23%, 9%)	(0.07, 0.1)	(37%, 13%)
	1b: First FG and QE, then CE	(0.94, 1.20)‡	(35%, 13%)	(0.09, 0.12)	(45%, 16%)
2 Delay and Stagger	2a: First FG, then CE, then QE	(0.46, 0.65)	(17%, 7%)	(0.06, 0.09)	(33%, 12%)
	2b: First FG, then QE, then CE	(0.50, 0.74)	(19%, 8%)	(0.07, 0.1)	(36%, 14%)
3 Implement All at Once	3a: All Options (Immediate)	(0.93, 1.17)	(35%, 13%)	(0.09, 0.12)	(45%, 16%)
	3b: All Options (Delayed)	(0.63, 0.85)	(23%, 9%)	(0.07, 0.1)	(37%, 14%)

*The first entry of 2.71 indicates the percent improvement in the level of GDP if the rate is allowed to go below the ELB, under the moderate case.
†The effect of 23 percent means that, by itself, forward guidance can achieve 23 percent of the gain that is delivered by a rate cut (second row); i.e., forward guidance can compensate for nearly 25 percent of the GDP loss due to the ELB.
‡The GDP effect in the moderate scenario would be about 0.8 percent if evaluated over the next four quarters.
Note: These numbers are based on simulations around a proxy of moderate and severe scenarios in the April 2020 Monetary Policy Report (Poloz et al. 2020). Options in green font denote the best-performing policy options. FG is forward guidance; CE is credit easing; QE is quantitative easing. GDP is gross domestic product, and ELB is the effective lower bound.

Table A.2. Estimated Amount of Fiscal Policy Required to Make Up for the GDP Loss Due to the Effective Lower Bound (moderate scenario, severe scenario)

		Economic Impact of Different Sequence Options			Additional Fiscal Policy Required		
Scenario	**Detail**	**Cumulative GDP Impact Over the First Five Quarters (pp)**	**Relative GDP Improvement to Offset ELB (%)**	**% GDP Improvement Required from Fiscal to Offset ELB (%)**	**Government Spending Required to Offset ELB ($bn/year)**	**Universal Transfers Required to Offset ELB ($bn/year)**	**Transfers to Hand-to-Mouth Households Required to Offset ELB ($bn/year)**
ELB	No Additional Policy	(0, 0)	(0%, 0%)	(100%, 100%)	(11, 32)	(56, 129)	(22, 77)
No ELB	Impact of Allowing Interest Rates Below ELB	(2.71, 9.37)	(100%, 100%)	(0%, 0%)	(0, 0)	(0, 0)	(0, 0)
0	FG Only	(0.64, 0.79)	(23%, 8%)	(77%, 92%)	(9, 30)	(43, 118)	(17, 71)
1 Start Early and Stagger	1a: First FG and CE, then QE	(0.62, 0.82)	(23%, 9%)	(77%, 91%)	(9, 30)	(43, 117)	(17, 70)
	1b: First FG and QE, then CE	(0.94, 1.20)	(35%, 13%)	(65%, 87%)	(7, 28)	(36, 112)	(15, 67)
2 Delay and Stagger	2a: First FG, then CE, then QE	(0.46, 0.65)	(17%, 7%)	(83%, 93%)	(9, 30)	(46, 120)	(19, 72)
	2b: First FG, then QE, then CE	(0.50, 0.74)	(19%, 8%)	(81%, 92%)	(9, 30)	(45, 119)	(18, 71)
3 Implement All at Once	3a: All Options (Immediate)	(0.93, 1.17)	(35%, 13%)	(65%, 87%)	(7, 28)	(37, 113)	(15, 68)
	3b: All Options (Delayed)	(0.63, 0.85)	(23%, 9%)	(77%, 91%)	(9, 29)	(43, 117)	(17, 70)

Note: Forward guidance is applied throughout all simulation periods in each sequence plan. Options in green font denote the best-performing policy options. FG is forward guidance; CE is credit easing; QE is quantitative easing. GDP is gross domestic product, and ELB is the effective lower bound.

Appendix B. Model Description

This appendix outlines the model environment. We provide only an overview of the model building blocks. For a full description with complete definitions and explanation, we direct the reader to Dorich et al. (2013) and Corrigan et al. (2021).

ToTEM is a large-scale open-economy, DSGE model with five distinct finished-product sectors and a commodity-producing sector. There are four sets of agents: households, firms, the central bank, and a fiscal authority, or government. The model is estimated with a Bayesian methodology using 50 quarterly data series that run from 1995:Q1 through 2015:Q4. Full details of the estimation strategy are given in Corrigan et al. (2021).

B.1 Households

There are four types of consumers: two types of lifetime-income consumers, unrestricted and restricted; current-income consumers (i.e., hand-to-mouth households); and borrowers. The unrestricted households can trade in both short- and long-term bond markets whereas restricted households can only trade in long-term bond markets. Current-income consumers, by contrast, do not borrow or save, but consume all disposable income every period. Borrowers differ from lifetime-income households in their degree of impatience and, in equilibrium, finance some of their spending using loans from lifetime-income households.

Lifetime-income consumers and borrowers each provide a different type of labor, with both groups supplying differentiated labor across a continuum of types. Within each group there is a union setting wages subject to nominal wage rigidities. Current-income consumers receive the wage rate received by the lifetime-income consumers.

The period t utility functions for the households are functionally the same. The period utility for the representative household of type i is

$$U_t^i = \frac{\mu}{\mu-1}\left(C_t^i - \xi C_{t-1}^i\right)^{\frac{\mu-1}{\mu}} \times \exp\left(\frac{\eta(1-\mu_L)}{\mu_L(1+\eta)}\eta_L \int_0^1 \left(E_t N_t^i(h)\right)^{\frac{1+\eta}{\eta}} dh\right)$$

$$+ \zeta_t^{hl,i} \frac{\mu_{HL}}{\mu_{HL}-1} \left(HL_t^i - \xi_{HL} HL_{t-1}^i\right)^{\frac{\mu_{HL}-1}{\mu_{HL}}}$$
$$+ \zeta_t^{inv,i} \frac{\mu_{INV}}{\mu_{INV}-1} \left(INV_t^i - \xi_{INV} INV_{t-1}^i\right)^{\frac{\mu_{INV}-1}{\mu_{INV}}}, \quad \text{(B.1)}$$

where C_t is consumption; E_t is work effort; $N_t(h)$ is labor supply of labor-type h consumers; HL_t is housing stock; and INV_t is the stock of inventories, where exogenous preference shifter $\zeta_t^{inv,i} \neq 0$ only for lifetime-income consumers and $\zeta_t^{inv,i} = \zeta_t^{hl,i} = 0$ for current-income consumers.

Housing is a composite of residential structures and land using

$$HL_t^i = \zeta_t^{HL\frac{\sigma_{HL}}{\sigma_{HL}-1}} \left[s_{RS}^{\frac{1}{\sigma_{HL}}} RS_t^{i\frac{\sigma_{HL}-1}{\sigma_{HL}}} + (1-s_{RS})^{\frac{1}{\sigma_{HL}}} LAND_t^{i\frac{\sigma_{HL}-1}{\sigma_{HL}}} \right]^{\frac{\sigma_{HL}}{\sigma_{HL}-1}}. \quad \text{(B.2)}$$

Residential structures depreciate at a rate δ_{RS} and are costly to install. In particular, the law of motion for residential structures is

$$RS_{t+1}^i = (1-\delta_{RS}) RS_t^i + I_t^{RS,i} - \frac{\chi_{RS}}{2} I_t^{RS,i} \left(\frac{I_t^{RS,i}}{I_{t-1}^{RS,i}} - 1 \right)^2, \quad \text{(B.3)}$$

where $I_t^{RS,i}$ is residential investment of household type i. Residential land is tradable but the aggregate supply is fixed. Households face a cost when adjusting their stock. The law of motion for land is

$$LAND_{t+1}^i = LAND_t^i + I_t^{LAND,i} - \frac{\chi_{LAND}}{2} \left(I_t^{LAND,i} - I_{t-1}^{LAND,i} \right)^2, \quad \text{(B.4)}$$

where $I_t^{LAND,borir}$ is the household's investment in land.

B.1.1 Borrowers

Focusing on the borrowers, the stock of household debt evolves according to

$$D_t^{borr} = (1-\kappa) D_{t-1}^{borr} + L_t^{borr}, \quad \text{(B.5)}$$

where D_t^{borr} is the stock of household debt and L_t^{borr} is the amount of new loans. The debt service is given by

$$M_t^{borr} = \left(R_{t-1}^{M,borr} + \kappa\right) D_{t-1}^{borr}, \tag{B.6}$$

where $R_t^{M,borr}$ represents the *effective* interest rate faced by the borrowers. New loans carry an interest rate R_t^L, which corresponds to the current long-term household rate, and a fraction Φ of existing loans are renegotiated at this rate in each period. The effective interest rate borrowers face is

$$R_t^{M,borr} = (1-\Phi)\left(1 - \frac{L_t^{borr}}{D_t^{borr}}\right) R_{t-1}^{M,borr} + \left[\frac{L_t^{borr}}{D_t^{borr}} + \Phi\left(1 - \frac{L_t^{borr}}{D_t^{borr}}\right)\right] R_t^L. \tag{B.7}$$

New loans are subject to a collateral constraint specified as the sum of two components:

$$L_t^{borr} = \alpha_{ltv}\left(P_t^{RS} I_t^{RS,borr} + P_t^{LAND} I_t^{LAND,borr}\right) + \alpha_{heloc}\left(P_t^H HL_t^{borr} - (1-\kappa) D_{t-1}^{borr}\right). \tag{B.8}$$

The budget constraint that a representative borrower faces is

$$P_{c,t}^{tot} C_t^{borr} + P_t^{RS} I_t^{RS,borr} + P_t^{LAND} I_t^{LAND,borr} + M_t^{borr} = (1-\tau_{w,t}) \int_0^1 W_t^{borr}(h) N_t^{borr}(h) dh + L_t^{borr} + TF_t^{borr} + Div_t^{borr}, \tag{B.9}$$

where $P_{c,t}^{tot}$ is the aggregate consumption price level, $\tau_{w,t}$ is the labor income tax rate, $W_t^{borr}(h)$ is the nominal wage rate received by the borrower's labor type h, TF_t^{borr} is the level of nominal transfers received from the government by the borrowers, and Div_t^{borr} denotes the dividends received from firms.

The borrower household seeks to maximize their expected discounted sequence of future utilities.

B.1.2 Lifetime-Income Households

The budget constraint of unrestricted lifetime-income households is given by

$$(1+\tau_{c,t})P_{c,t}^{tot}C_t^i+P_t^{RS}I_t^{RS,i}+P_t^{LAND}I_t^{LAND,i}+P_t^cI_t^{INV,i}+\frac{B_t^i}{(1+R_{RF,t})}$$
$$+\frac{e_tB_t^{*,i}}{(1+R_t^*)(1+\vartheta_t)}+\frac{(1+\phi_t)B_t^{20,i}}{(1+R_t^{20})^{20}}+L_t^i=B_{t-1}^i+e_tB_{t-1}^{*,i}+B_{t-20}^{20,i}+M_t^i$$
$$+(1-\tau_{w,t})\int_0^1 W_t^i(h)N_t^i(h)dh+TF_t^i+Div_t^i, \quad \text{(B.10)}$$

where B_t^i is domestic short-term bonds, $R_{RF,t}$ is the short-term risk-free interest rate (= 0 for the restricted types), e_t is the nominal exchange rate, $B_t^{*,i}$ is foreign short-term bonds (= 0 for the restricted types), R_t^* is the foreign short-term interest rate, ϑ_t is a country-specific risk premium, ϕ_t is the transaction cost of trading domestic long-term bonds, $B_t^{20,i}$ is domestic long-term bonds, R_t^{20} is the domestic long-term interest rate, L_t^i is new loans provided to borrowers, and M_t^i is received repayments.

The risk premium ϑ_t is given by

$$\vartheta_t=\varsigma\left[\exp\left(-\frac{e_tB_t^*}{P_tY_t}\right)-1\right]+\varepsilon_t^{\vartheta}, \quad \text{(B.11)}$$

where $\varepsilon_t^{\vartheta}$ is an exogenous shock defined as $\varepsilon_t^{\vartheta}=\rho\varepsilon_{t-1}^{\vartheta}+\upsilon_t^{\vartheta}$.

B.2 Finished Goods Sectors

There are five finished goods production sectors: consumption, business investment, residential investment, government, and noncommodity exports. Except for commodities, the sectors are functionally symmetric. We therefore focus on the consumption sector, but analogous conditions hold in the remaining noncommodity sectors. Firms in the consumption goods sector choose labor input, commodity input, imported inputs, and capital investment to maximize their value:

$$\mathcal{V}_t^c = \mathbf{E}_t \sum_{s=t}^{\infty} \mathcal{R}_{t,s} \big(P_s^{c,va} Y_t^{c,va} - W_s H_s^c - P_s^{com} COM_s^c - P_s^I I_s^c - P_s^M M_s^c \big), \tag{B.12}$$

subject to

$$Y_t^{c,va} = Y_t^{c,g} - \frac{\chi^I}{2} \left(\frac{I_t^c}{I_{t-1}^c} - 1 \right)^2 I_t^c \tag{B.13}$$

$$Y_t^{c,g} = \left(\left(\alpha_{lkcom}^{mult}\right)^{\frac{1}{\sigma}} \left(\mathcal{H}\left(\mathcal{G}, COM_t^c\right)\right)^{\frac{\sigma-1}{\sigma}} + (1-\alpha_{lkcom}^{mult})^{\frac{1}{\sigma}} (M_t^c \xi_t^{M,c})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{B.14}$$

$$\mathcal{H}\left(\mathcal{G}, COM_t^c\right) = \left(\begin{array}{c} \left(\alpha_{lk}^{mult}\right)^{\frac{1}{\sigma}} \mathcal{G}(A_t L_t^c \xi_t^{H,c}, u_t^c K_t^c \xi_t^{K,c})^{\frac{\sigma-1}{\sigma}} \\ + (1-\alpha_{lk}^{mult})^{\frac{1}{\sigma}} \left(COM_t^c \xi_t^{COM,c} \right)^{\frac{\sigma-1}{\sigma}} \end{array} \right)^{\frac{\sigma}{\sigma-1}} \tag{B.15}$$

$$\mathcal{G}(A_t L_t^c \xi_t^{H,c}, u_t^c K_t^c \xi_t^{K,c}) = \left(\begin{array}{c} \left(\alpha_{l}^{mult}\right)^{\frac{1}{\sigma}} (A_t^c L_t^c \xi_t^{H,c})^{\frac{\sigma-1}{\sigma}} \\ + (1-\alpha_{l}^{mult})^{\frac{1}{\sigma}} \left(u_t^c K_t^c \xi_t^{K,c} \right)^{\frac{\sigma-1}{\sigma}} \end{array} \right)^{\frac{\sigma}{\sigma-1}} \tag{B.16}$$

and adjustment costs

$$\xi_t^{H,c} = 1 - \frac{\chi^H}{2} \left(\frac{H_t^c}{H_{t-1}^c} - 1 \right)^2 \tag{B.17}$$

$$\xi_t^{K,c} = 1 - \frac{\chi^K}{2} \left(\frac{K_{t+1}^c / Y_t^{c,g}}{K_t^c / Y_{t-1}^{c,g}} - 1 \right)^2 \tag{B.18}$$

$$\xi_t^{COM,c} = 1 - \frac{\chi^{COM}}{2} \left(\frac{COM_t^c / Y_t^{c,g}}{COM_{t-1}^c / Y_{t-1}^{c,g}} - 1 \right)^2 \tag{B.19}$$

$$\xi_t^{M,c} = 1 - \frac{\chi^M}{2} \left(\frac{M_t^c / Y_t^{c,g}}{M_{t-1}^c / Y_{t-1}^{c,g}} - 1 \right)^2 \tag{B.20}$$

and where labor input $L_t^c = H_t^c E_t^c$ comprises observed employment, H_t^c, and unobserved labor effort, E_t^c. u_t^c is the rate of capital utilization where capital depreciates according to

$$K_{t+1}^c = (1 - \omega\left(u_t^c\right))K_t^c + I_t^c, \tag{B.21}$$

where ω is the quarterly rate of capital depreciation, expressed as a function of the capital utilization

$$\omega\left(u_t^c\right) = \omega_0 + \overline{\omega} e^{\rho^c\left(u_t^c - 1\right)} + \varepsilon_t^{\omega_c}. \tag{B.22}$$

Distribution of the final good is subject to nominal friction whereby there are two different groups of price setters: a share ω of rule-of-thumb and $1 - \omega$ forward-looking. For each group of price setters, there are two different price-setting rules. With probability θ, both rule-of-thumb and forward-looking firms index their own price to the inflation target. With probability $1 - \theta$, rule-of-thumb firms follow the following rule:

$$p_t^b = p_{t-1} + \gamma\pi_{t-1} + (1 - \gamma)\overline{\pi_t} + \Theta\widehat{\mu}_t^n, \tag{B.23}$$

where $\overline{\pi_t}$ denotes the inflation target in period t and $\widehat{\mu}_t^n$ represents deviations of the markup from steady state. With probability $1 - \theta$, forward-looking firms choose the optimal price p_t^0 that satisfies the following equation:

$$p_t^0 - p_t = \beta\theta E_t\left\{p_{t+1}^* - p_{t+1}\right\} \tag{B.24}$$

$$+ \left\{1 - \beta\theta\right\}\left[\widehat{rmc_t^c} + \widehat{\mu}_t^n\right] + \beta\theta E_t\left\{\pi_{t+1} - \overline{\pi_{t+1}}\right\}. \tag{B.25}$$

B.2.1 Commodity Goods Sector

In the commodity goods sector, firms use commodity inputs, labor capital, and a fixed amount of land, $\mathcal{L}$. Firms maximize value subject to

$$\mathcal{G}_t^{com} = \left(\delta_{com}^{\frac{1}{\sigma_{kl}}}\left(A_t L_t^{com}\xi_t^{com,L}\right)^{\frac{\sigma_{kl}-1}{\sigma_{kl}}} + (1 - \delta_{com})^{\frac{1}{\sigma_{kl}}}\left(u_t^{com} 4K_t^{com}\xi_t^{com,K}\right)^{\frac{\sigma_{kl}-1}{\sigma_{kl}}}\right)^{\frac{\sigma_{kl}}{\sigma_{kl}-1}} \tag{B.26}$$

$$\mathcal{H}_t^{com} = \left(\upsilon_{com}^{\frac{1}{\sigma_{klc}}} \left[\mathcal{G}_t^{com}\right]^{\frac{\sigma_{klc}-1}{\sigma_{klc}}} + (1-\upsilon_{com})^{\frac{1}{\sigma_{klc}}} \left(COM_t^{com}\xi_t^{com,COM}\right)^{\frac{\sigma_{klc}-1}{\sigma_{klc}}} \right)^{\frac{\sigma_{klc}}{\sigma_{klc}-1}} \tag{B.27}$$

$$\mathcal{F}_t^{com} = \left(\gamma_{com}^{\frac{1}{\sigma_{klcm}}} \left(\mathcal{H}_t^{com}\right)^{\frac{\sigma_{klcm}-1}{\sigma_{klcm}}} + (1-\gamma_{com})^{\frac{1}{\sigma_{klcm}}} \left(A_t\mathcal{L}\right)^{\frac{\sigma_{klcm}-1}{\sigma_{klcm}}} \right)^{\frac{\sigma_{klcm}}{\sigma_{klcm}-1}} \tag{B.28}$$

$$Y_t^{com,va} = \mathcal{F}_t^{com} - \frac{\chi^I}{2}\left(\frac{I_t^{com}/\mathcal{F}_t^{com}}{I_{t-1}^{com}/\mathcal{F}_{t-1}^{com}} - 1\right) \tag{B.29}$$

$$K_t^{com} = \left(1-\delta_{t-1}^{com}\right)K_{t-1}^{com} + 0.25 I_{t-1}^{com} \tag{B.30}$$

$$\delta_t^{com} = u_{com} + \frac{u_{com}^{ss}}{u}\exp\left(u\varepsilon_{u,t}u_{com,t} - 1\right) \tag{B.31}$$

$$L_t^{com} = H_t^{com}. \tag{B.32}$$

Appendix C. Monetary and Fiscal Policy

The central bank sets the short-term risk-free interest rate $R_{RF,t}$ according to

$$R_{RF,t} = \Theta_R R_{RF,t-1} + (1-\Theta_R)\left(\bar{r} + \bar{\pi} + \Theta_\pi\left(E_t\left[\frac{1}{4}\sum_{j=1}^{4}\pi_{t+j}\right] - \bar{\pi}\right) + \Theta_y\widehat{y}_t\right). \tag{C.1}$$

Tax rules are specified for the levels of real government spending and transfers, both of which are allowed to increase in response to a decline in labor. Real government spending and transfers are determined according to

$$\ln g_t = \rho_g \ln g_{t-1} + (1-\rho_g)\left(\Theta_H^g\widehat{H}_t + \ln\overline{g}\right) + v_t^g,\ v_t^g = \rho_{v,g}v_{t-1}^g + \varepsilon_t^g \tag{C.2}$$

$$\ln tf_t = \rho_{tf} \ln tf_{t-1} + (1 - \rho_{tf}) \left(\Theta_H^{tf} \widehat{H}_t + \ln \overline{tf} \right) + v_t^{tf}, v_t^{tf} = \rho_{v,tf} v_{t-1}^{tf} + \varepsilon_t^{tf}, \tag{C.3}$$

where g_t is real government spending, $\bar{g}$ is the steady-state level of government spending, $\widehat{H}_t$ is the log-deviation of total hours worked from their steady state (hours gap), Θ_H^g is the sensitivity of real government spending to movements in the hours gap, tf_t is real transfers, $\overline{tf}$ is the steady-state level of transfers, and Θ_H^{tf} is the sensitivity of real transfers to movements in the hours gap. Lastly, $\varepsilon_t^g \sim iid(0, \sigma_g^2)$ and $\varepsilon_t^{tf} \sim iid(0, \sigma_{tf}^2)$.

Appendix D. Historical Decomposition

This presents historical decomposition of output (Figure D.1) and total and core CPI inflation (Figures D.2 and D.3) during the crisis episodes.

Figure D.1. Historical Decomposition of Real GDP Estimated Using ToTEM III

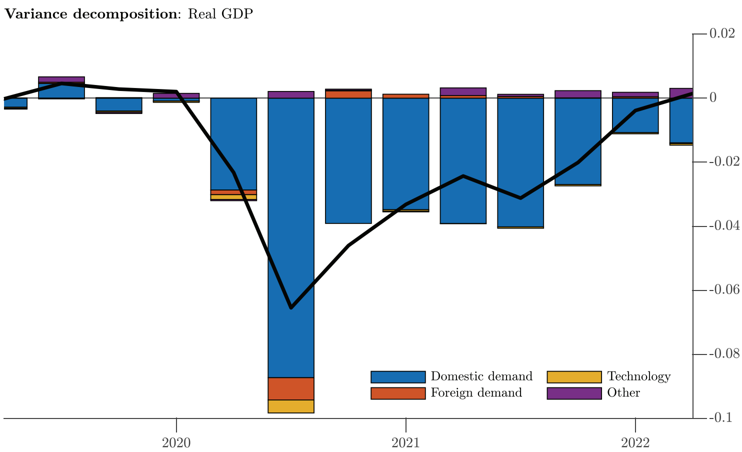


Figure D.2. Historical Decomposition of Quarter-over-Quarter Total CPI Inflation Estimated Using ToTEM III

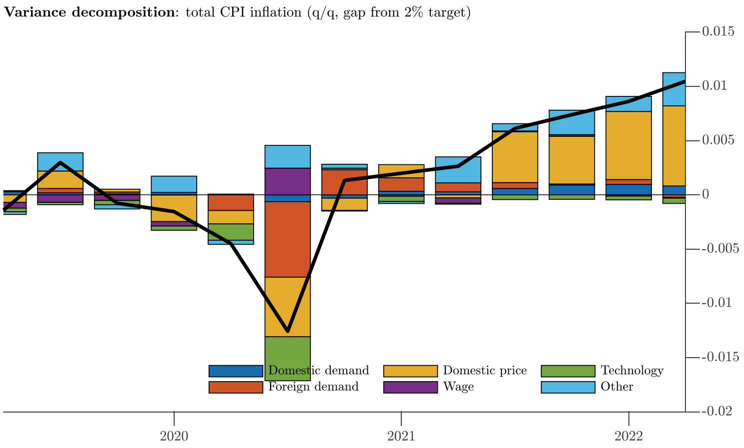
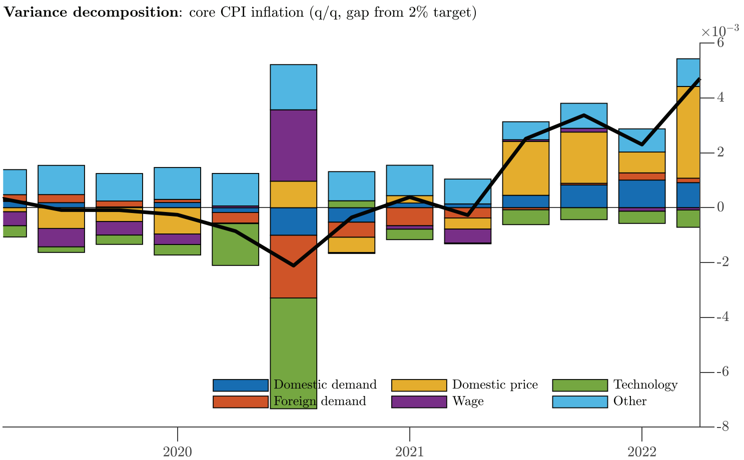


Figure D.3. Historical Decomposition of Quarter-over-Quarter Core CPI Inflation Estimated Using ToTEM III



References

Abidi, N., and I. Miquel-Flores. 2018. "Who Benefits from the Corporate QE? A Regression Discontinuity Design Approach." Working Paper No. 2145, European Central Bank.

Acurio Vásconez, V., O. Damette, and D. W. Shanafelt. 2023. "Macroepidemics and Unconventional Monetary Policy." *Economic Modelling* 126 (September): Article 106431.

Adrian, T., K. Kimbrough, and D. Marchioni. 2011. "The Federal Reserve's Commercial Paper Funding Facility." *Economic Policy Review* (Federal Reserve Bank of New York) 17 (1): 25–39.

Akkaya, Y., C.-J. Belfrage, P. D. Casola, and I. Strid. 2023. "Effects of Foreign and Domestic Central Bank Government Bond Purchases in a Small Open Economy DSGE Model: Evidence from Sweden Before and During the Coronavirus Pandemic." Working Paper No. 421, Sveriges Riksbank.

Aldridge, P., D. A. Cimon, and R. Vala. 2023. "Central Bank Crisis Interventions: A Review of the Recent Literature on Potential Costs." Staff Discussion Paper No. 2023-30, Bank of Canada.

André, J., J. D. López-Salido, and E. Nelson. 2004. "Tobin's Imperfect Asset Substitution in Optimizing General Equilibrium." *Journal of Money, Credit and Banking* 6 (4): 665–90.

Arora, R., G. Bédard-Pagé, G. O. Leblanc, and R. Shotlander. 2020. "Could Canadian Bond Funds Add Stress to the Financial System?" Staff Analytical Note No. 2019-9, Bank of Canada.

Arora, R., S. Gungor, K. McRae, and J. Witmer. 2020. "Announcing the Bankers' Acceptance Purchase Facility: A COVID-19 Event Study." Staff Analytical Note No. 2020-23, Bank of Canada.

Arora, R., S. Gungor, J. Nesrallah, G. Ouellet Leblanc, and J. Witmer. 2021. "The Impact of the Bank of Canada's Government Bond Purchase Program." Staff Analytical Note No. 2021-23, Bank of Canada.

Bank of Canada. 2015. "Framework for Conducting Monetary Policy at Low Interest Rates." Bank of Canada. https://www.bankofcanada.ca/wp-content/uploads/2015/12/framework-conducting-monetary-policy.pdf.

———. 2020a. "Bank of Canada Will Maintain Current Level of Policy Rate until Inflation Objective Is Achieved, Continues Program of Quantitative Easing." Press release, July 15.

https://www.bankofcanada.ca/2020/07/fad-press-release-2020-07-15/.

———. 2020b. "COVID-19: Actions to Support the Economy and Financial System." Bank of Canada. https://www.bankofcanada.ca/markets/market-operations-liquidity-provision/covid-19-actions-support-economy-financial-system/.

Bank of England. 2019. "Markets and Operations." *Quarterly Bulletin* (Bank of England) (2019 Q3).

Beaudry, P. 2020. "Our Quantitative Easing Operations: Looking Under the Hood." Speech delivered to the Greater Moncton Chamber of Commerce, the Fredericton Chamber of Commerce, and the Saint John Region Chamber of Commerce, December 10. https://www.bankofcanada.ca/2020/12/our-quantitative-easing-operations-looking-under-the-hood/.

Belsham, T., A. Rattan, and R. Maher. 2017. "Corporate Bond Purchase Scheme: Design, Operation and Impact." *Quarterly Bulletin* (Bank of England) (2017 Q3): 170–81.

Benmir, G., I. Jaccard, and G. Vermandel. 2023. "Optimal Monetary Policy in an Estimated SIR Model." *European Economic Review* 156 (July): Article 104502.

Bernanke, B. 2020. "The New Tools of Monetary Policy." *American Economic Review* 110 (4): 943–83.

Blattner, T., and J. Swarbrick. 2021. "Monetary Policy and Cross-Border Interbank Market Fragmentation: Lessons from the Crisis." *B.E. Journal of Macroeconomics* 21 (1): 323–68.

Boneva, L., C. de Roure, and B. Morley. 2018. "The Impact of the Bank of England's Corporate Bond Purchase Scheme on Yield Spreads." Working Paper No. 719, Bank of England.

Boyarchenko, N., R. Crump, and A. Kovner. 2020. "The Commercial Paper Funding Facility." Federal Reserve Bank of New York, *Liberty Street Economics* (blog), May 15. https://libertystreeteconomics.newyorkfed.org/2020/05/the-commercial-paper-funding-facility.html.

Breedon, F., J. S. Chadha, and A. Waters. 2012. "The Financial Market Impact of UK Quantitative Easing." *Oxford Review of Economic Policy* 28 (4): 702–28.

Cecchetti, S. 2020. "A Quantitative Analysis of Risk Premia in the Corporate Bond Market." *Journal of Risk and Financial Management* 13 (1): 1–33.

Chen, H., V. Cúrdia, and A. Ferrero. 2012. "The Macroeconomic Effects of Large-Scale Asset Purchase Programmes." *Economic Journal* 122 (564): F289–F315.

Christiano, L. J., M. Eichenbaum, and C. L. Evans. 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy* 113 (1): 1–45.

Chu, V., and Y. Zhang. 2022. "Harnessing the Benefit of State-Contingent Forward Guidance." Staff Analytical Note No. 2022-13, Bank of Canada.

Chung, H. T., E. Gagnon, T. Nakata, M. Paustian, B. Schlusche, J. Trevino, D. Vilán, and W. Zheng. 2019. "Monetary Policy Options at the Effective Lower Bound: Assessing the Federal Reserve's Current Policy Toolkit." Finance and Economics Discussion Series No. 2019-003, Board of Governors of the Federal Reserve System.

Corrigan, P., H. Desgagnés, J. Dorich, V. Lepetyuk, W. Miyamoto, and Y. Zhang. 2021. "ToTEM III: The Bank of Canada's Main DSGE Model for Projection and Policy Analysis." Technical Report No. 119, Bank of Canada.

Costa Junior, C. J., A. C. Garcia-Cintado, and K. M. Junior. 2021. "Macroeconomic Policies and the Pandemic-Driven Recession." *International Review of Economics and Finance* 72 (March): 438–65.

Dahlhaus, T., D. Hyun, A. Poulin-Moore, J. Trujillo, S. Sheikh, and B. Straus. 2022. "COVID-19, Containment and Consumption." Discussion Paper No. 2022-5, Bank of Canada.

De Rezende, R. B., D. Kjellberg, and O. Tysklind. 2015. "Effects of the Riksbank's Government Bond Purchases on Financial Prices." Economic Commentaries No. 13, Sveriges Riksbank.

De Rezende, R. B., and A. Ristiniemi. 2023. "A Shadow Rate without a Lower Bound Constraint." *Journal of Banking and Finance* 146 (January): Article 106686.

Diez de los Rios, A. 2022. "A Macroeconomic Model of an Epidemic with Silent Transmission and Endogenous Self-Isolation." *Canadian Journal of Economics* 55 (S1): 581–625.

Diez de los Rios, A., and M. Shamloo. 2017. "Quantitative Easing and Long-Term Yields in Small Open Economies." Staff Working Paper No. 2017-26, Bank of Canada.

Dominguez, K. M., and A. Foschi. 2024. "Whatever-It-Takes Policymaking during the Pandemic." Working Paper No. 32115, National Bureau of Economic Research.

Dorich, J., M. Johnston, R. Mendes, S. Murchison, and Y. Zhang. 2013. "ToTEM II: An Updated Version of the Bank of Canada's Quarterly Projection Model." Technical Report No. 100, Bank of Canada.

Dorich, J., N. L. St-Pierre, V. Lepetyuk, and R. R. Mendes. 2018. "Could a Higher Inflation Target Enhance Macroeconomic Stability?" *Canadian Journal of Economics* 51 (3): 1029–55.

Drought, S., R. Perry, and A. Richardson. 2018. "Aspects of Implementing Unconventional Monetary Policy in New Zealand." *Bulletin* (Reserve Bank of New Zealand) 81 (4): 3–22.

Duygan-Bump, B., P. Parkinson, E. Rosengren, G. A. Suarez, and P. Willen. 2013. "How Effective Were the Federal Reserve Emergency Liquidity Facilities? Evidence from the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility." *Journal of Finance* 68 (2): 715–37.

Eichenbaum, M. S., S. Rebelo, and M. Trabandt. 2021. "The Macroeconomics of Epidemics." *Review of Financial Studies* 34 (11): 5149–87.

European Central Bank. 2016. "Box 2: The Corporate Bond Market and the ECB's Corporate Sector Purchase Programme." *Economic Bulletin* 5 (August 4).

Federal Reserve Bank of New York. 2022. "FAQs: Treasury Purchases." Accessed May 4, 2024. https://www.newyorkfed.org/markets/treasury-reinvestments-purchases-faq.html.

Fontaine, J.-S., C. Garriott, J. Johal, J. Lee, and A. Uthemann. 2021. "COVID-19 Crisis: Lessons Learned for Future Policy Research." Staff Discussion Paper No. 2021-2, Bank of Canada.

Fontaine, J.-S., L. Suchanek, and J. Yang. 2017. "Unconventional Monetary Policy: The Perspective of a Small Open Economy." *Bank of Canada Review* (Spring): 19–30.

Galí, J., and M. Gertler. 1999. "Inflation Dynamics: A Structural Econometric Analysis." *Journal of Monetary Economics* 44 (2): 195–222.

Hayashi, F., and J. Koeda. 2019. "Exiting from Quantitative Easing." *Quantitative Economics* 10 (3): 1069–107.

Hirose, Y., and S. Ohyama. 2010. “Identifying the Effect of the Bank of Japan’s Liquidity Facilities: The Case of Commercial Paper Operations during the Financial Turmoil.” *International Finance* 13 (3): 461–83.

International Monetary Fund. 2021. “Policy Responses to COVID-19.” Policy Tracker. https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19.

Joyce, M., A. Lasaosa, I. Stevens, and M. Tong. 2011. “The Financial Market Impact of Quantitative Easing in the United Kingdom.” *International Journal of Central Banking* 7 (3): 113–61.

Joyce, M., M. Tong, and R. Woods. 2011. “The United Kingdom’s Quantitative Easing Policy: Design, Operation and Impact.” *Quarterly Bulletin* (Bank of England) (2011 Q3): 200–212.

Kabaca, S. 2016. “Quantitative Easing in a Small Open Economy: An International Portfolio Balancing Approach.” Working Paper No. 2016-55, Bank of Canada.

Kiley, M. T. 2020. “Pandemic Recession Dynamics: The Role of Monetary Policy in Shifting a U-Shaped Recession to a V-Shaped Rebound.” Finance and Economics Discussion Series No. 2020-083, Board of Governors of the Federal Reserve System.

Lane, T. 2020. “Our COVID-19 Response: Policy Actions.” https://www.bankofcanada.ca/2020/05/our-policy-actions-in-the-time-of-covid-19/.

Laubach, T. 2009. “New Evidence on the Interest Rate Effects of Budget Deficits and Debt.” *Journal of the European Economic Association* 7 (4): 858–85.

Leboeuf, M., and D. Hyun. 2018. “Is the Excess Bond Premium a Leading Indicator of Canadian Economic Activity?” Staff Analytical Note No. 2018-4, Bank of Canada.

Macklem, T., C. A. Wilkins, T. Lane, L. Schembri, P. Beaudry, and T. Gravelle. 2020. “Monetary Policy Report, July 2020.” Bank of Canada.

Meaning, J., and J. Warren. 2015. “The Transmission of Unconventional Monetary Policy in UK Government Debt Markets.” *National Institute Economic Review* 234 (1): R40–R47.

Office of the Parliamentary Budget Officer. 2016. “Budget 2016: Key Issues for Parliamentarians.” April 6.

Poloz, S. S., C. A. Wilkins, T. Lane, L. Schembri, P. Beaudry, and T. Gravelle. 2020. "Monetary Policy Report, April 2020." Bank of Canada.

Potter, S. M., and F. Smets. 2019. "Unconventional Monetary Policy Tools: A Cross-country Analysis." CGFS Paper No. 63, Bank for International Settlements.

Quast, J., and M. H. Wolters. 2022. "Reliable Real-Time Output Gap Estimates Based on a Modified Hamilton Filter." *Journal of Business and Economic Statistics* 40 (1): 152–68.

Rebucci, A., J. S. Hartley, and D. Jiménez. 2020. "An Event Study of Covid-19 Central Bank Quantitative Easing in Advanced and Emerging Economies." Working Paper No. 27339, National Bureau of Economic Research.

Rostagno, M., C. Altavilla, G. Carboni, W. Lemke, R. Motto, and A. S. Guilhem. 2021. "Combining Negative Rates, Forward Guidance and Asset Purchases: Identification and Impacts of the ECB's Unconventional Policies." Policy Brief No. 204, SUERF.

Sano, H., and T. Uetake. 2018. "Bank of Japan's Balance Sheet Now Larger than Country's GDP." Reuters, November 12.

Santis, D., A., R., A. Geis, A. Juskaite, and L. V. Cruz. 2018. "The Impact of the Corporate Sector Purchase Programme on Corporate Bond Markets and the Financing of Euro Area Non-financial Corporations." *Economic Bulletin* (European Central Bank) 3/2018: 66–84.

Santor, E., and L. Suchanek. 2016. "A New Era of Central Banking: Unconventional Monetary Policies." *Bank of Canada Review* (Spring): 29–42.

Sims, E., and C. Wu. 2020. "Are QE and Conventional Monetary Policy Substitutable?" *International Journal of Central Banking* 16 (1): 195–230.

———. 2021. "Evaluating Central Bank's Tool Kit: Past, Present, and Future." *Journal of Monetary Economics* 118 (March): 135–60.

Smets, F., and R. Wouters. 2007. "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach." *American Economic Review* 97 (3): 586–606.

Vayanos, D., and J.-L. Vila. 2009. "An Event Study of Covid-19 Central Bank Quantitative Easing in Advanced and Emerging

Economies." Working Paper No. 15487, National Bureau of Economic Research.

Vissing-Jorgensen, A. 2021. "The Treasury Market in Spring 2020 and the Response of the Federal Reserve." *Journal of Monetary Economics* 124 (November): 19–47.

Witmer, J., and J. Yang. 2016. "Estimating Canada's Effective Lower Bound." *Bank of Canada Review* (Spring): 3–14.

Zaghini, A. 2019. "The CSPP at Work: Yield Heterogeneity and the Portfolio Rebalancing Channel." *Journal of Corporate Finance* 56 (June): 282–97.