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Bank of Canada Quarterly Research Update

2023Q2

This quarterly newsletter features the latest research publications by Bank of Canada economists. The report includes papers appearing in external publications and staff working papers published on the Bank of Canada's website.

PUBLISHED PAPERS

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Robert Amano & **Stefano Gnocchi**, "Downward Nominal Wage Rigidity Meets the Zero Lower Bound", *Journal of Money, Credit and Banking*, Vol. 55(4): 859-887, June 2023

Jasmina Arifovic & John Duffy & **Janet Hua Jiang**, "Adoption of a New Payment Method: Experimental Evidence", *European Economic Review*, Vol. 154, May 2023

Jonathan Chiu & **Seyed Mohammadreza Davoodalhosseini** & **Janet Jiang** & **Yu Zhu**, "Bank Market Power and Central Bank Digital Currency: Theory and Quantitative Assessment", *Journal of Political Economy*, Vol. 131(5): 1109-1383, May 2023

Amit Gandhi & **Zhentong Lu** & Xiaoxia Shi, "Estimating Demand for Differentiated Products with Zeroes in Market Share Data", *Quantitative Economics*, Vol. 14(2): 381-418, May 2023

Elisabeth A. Gilmore & **Madanmohan Ghosh** & Peter Johnston & Muhammad-Shahid Siddiqui & Nick Macaluso, "Modeling the Energy Mix and Economic Costs of Deep Decarbonization Scenarios in a Cge Framework", *Energy and Climate Change*, Vol. 4, December 2023

Serafin Grundl & **Yu Zhu**, "Robust Inference in First-Price Auctions: Overbidding as an Identifying Restriction", *Journal of Econometrics*, Vol. 235(2): 484-506, August 2023

Xing Guo & Pablo Ottonello & Diego J. Perez, "Monetary Policy and Redistribution in Open Economies", *Journal of Political Economy Macroeconomics*, Vol. 1(1): 191-241, March 2023

Zhentong Lu & Xiaoxia Shi & Jing Tao, "Semi-Nonparametric Estimation of Random Coefficient Logit Model for Aggregate Demand", *Journal of Econometrics*, Vol. 235(2): 2245-2265, August 2023

Lin Shao & Faisal Sohail & Emircan Yurdagul, "Are Working Hours Complements in Production?", *Journal of Economic Dynamics and Control*, Vol. 153, August 2023

Vladimir Skavysh & **Sofia Priazhkina** & Diego Guala & Thomas R. Bromley, "Quantum Monte Carlo for Economics: Stress Testing and Macroeconomics Deep Learning", *Journal of Economic Dynamics and Control*, Vol. 153, August 2023

Forthcoming

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Daniela Balutel & **Christopher Henry** & **Kim P. Huynh** & Marcel Voia, "Cash in the Pocket, Cash in the Cloud: Cash Holdings of Bitcoin Owners", *International Journal of Central Banking*

Felix Brunner & **Ruben Hipp**, "Estimating Large-Dimensional Connectedness Tables: The Great Moderation Through the Lens of Sectoral Spillovers", *Quantitative Economics*

Alberto Cavallo & **Oleksiy Kryvtsov**, "What Can Stockouts Tell Us About Inflation? Evidence from Online Micro Data", *Journal of International Economics*

Jonathan Chiu & **Mohammad Davoodalhosseini**, "Central Bank Digital Currency and Banking: Macroeconomic Benefits of a Cash-Like Design", *Management Science*

Ajit Desai & **Zhentong Lu** & **Hiru Rodrigo** & **Jacob Sharples** & **Phoebe Tian** & **Nellie Zhang**, "From Lvts to Lynx: Quantitative Assessment of Payment System Transition", *Journal of Payments Strategy and Systems*

Bruno Feunou, "Generalized Autoregressive Gamma Processes", *Journal of Business & Economic Statistics*

Kristin Forbes & **Christian Friedrich** & Dennis Reinhardt, "Stress Relief? Funding Structures and Resilience to the Covid Shock", *Journal of Monetary Economics*

Xing Guo, "Reassessing the Relevance of Financial Shocks in an Estimated Heterogeneous Firm Model", *American Economic Journal: Macroeconomics*

Martin Harding & Jesper Linde & Mathias Trabandt, "Understanding Post-Covid Inflation Dynamics", *Journal of Monetary Economics*

Dmitry Matveev & Francisco Ruge-Murcia, "Tariffs and the Exchange Rate: Evidence from Twitter", *Imf Economic Review*

Cesaire Meh & Vincenzo Quadrini & **Yaz Terajima**, "Limited Nominal Indexation of Optimal Financial Contracts", *Journal of the European Economic Association*

Josef Schroth, "Capital Flows and Growth Across Developing Countries", *Journal of International Money and Finance*

Angelika Welte & **Joy Wu**, "The 2021-22 Merchant Acceptance Survey Pilot Study", *Journal of Payments Strategy and Systems*

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Stephen Ayerst & Faisal Ibrahim & **Gaelan Mackenzie** & Swapnika Rachapalli, "Trade and Diffusion of Embodied Technology: An Empirical Analysis", Bank of Canada Staff Working Paper 2023-21

Michael Irwin, "The Impact of Unemployment Insurance and Unsecured Credit on Business Cycles", Bank of Canada Staff Working Paper 2023-22

Alistair Macaulay & **Wenting Song**, "Narrative-Driven Fluctuations in Sentiment: Evidence Linking Traditional and Social Media", Bank of Canada Staff Working Paper 2023-23

Ajit Desai & **Zhentong Lu** & **Hiru Rodrigo** & **Jacob Sharples** & **Phoebe Tian** & **Nellie Zhang**, "From Lvts to Lynx: Quantitative Assessment of Payment System Transition", Bank of Canada Staff Working Paper 2023-24

John Duffy & **Janet Hua Jiang** & Huan Xie, "Pricing Infinitely Lived Assets: Experimental Evidence", Bank of Canada Staff Working Paper 2023-25

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Marc-André Gosselin & **Temel Taskin**, "What Can Earnings Calls Tell Us About the Output Gap and Inflation in Canada?", Bank of Canada Staff Discussion Paper 2023-13

Joshua Fernandes & **Michael Mueller**, "A Review of the Bank of Canada's Support of Key Financial Markets During the Covid-19 Crisis", Bank of Canada Staff Discussion Paper 2023-9

ABSTRACTS

In-Press Published Papers

A Model Intercomparison of the Welfare Effects of Regional Coalitions for Ambitious Climate Mitigation Targets

This paper presents the overall and distributional welfare effects of alternative multi-regional emissions trading coalitions relative to unilateral action. It focusses on meeting Paris Agreement pledges and more emissions reduction targets consistent with 2°C and 1.5°C temperature pathways in 2030. The results from seven computable general equilibrium (CGE) models are compared. Across all models, welfare gains are highest with a global market and increase with the stringency of targets. All regional coalitions also show overall welfare gains, although lower gains than the global market. The models show more variability in the gains by a participant. Depending on the model, participants may benefit more from some regional arrangements than from a global market or face modest losses compared to the domestic reductions alone, due to interactions between carbon targets and fossil fuel markets. The scenario with a joint China–European Union emissions trading system in all sectors is consistently favorable for participants and provides the highest economic gains per unit of emissions abated.

Downward Nominal Wage Rigidity Meets the Zero Lower Bound

We add downward nominal wage rigidity to a standard New Keynesian model where the zero lower bound on nominal interest rates is allowed to bind. Wage rigidity reduces the frequency of zero bound episodes but also mitigates the severity of corresponding recessions. As a result, previous studies abstracting from the presence of wage rigidity may have overemphasized the need for increasing the inflation target to offset the costs associated with hitting the zero bound. Moreover, our findings add to the recent debate on the presumed benefits of wage flexibility that has arisen in the aftermath of the Great Recession.

Adoption of a New Payment Method: Experimental Evidence

We develop a framework for studying the introduction of a new payment method in a controlled laboratory environment, where consumers (buyers) and merchants (sellers) can learn to coordinate their adoption decisions over time. The underlying game exhibits network adoption effects as emphasized by the theoretical literature. We elicit players' beliefs about the adoption decisions of the other side of the market so that we can directly test for network effects. We

investigate how the additional fixed cost of adopting the new payment method, relative to its savings on per transaction costs, affects merchant's decisions to adopt the new payment method and how that in turn affects buyer's adoption decisions. We find that a low fixed cost favors quick adoption of the new payment method by all participants, while for a sufficiently high fixed cost, merchants gradually learn to reject the new payment method. We also find strong evidence of network effects and that the fixed costs are important for the strong response of seller acceptance decisions to buyer adoption decisions. An evolutionary learning model provides a good characterization of the dynamic adjustment paths found in our experimental data.

Bank Market Power and Central Bank Digital Currency: Theory and Quantitative Assessment

This paper develops a micro-founded general equilibrium model of payments to study the impact of a central bank digital currency (CBDC) on intermediation of private banks. If banks have market power in the deposit market, a CBDC can enhance competition, raising the deposit rate, expanding intermediation, and increasing output. A calibration to the US economy suggests that a CBDC can raise bank lending by 1.57% and output by 0.19%. These crowding-in effects remain robust, albeit with smaller magnitudes, after taking into account endogenous bank entry. We also assess the role of a non-interest-bearing CBDC as the use of cash declines.

Estimating Demand for Differentiated Products with Zeroes in Market Share Data

In this paper, we introduce a new approach to estimating differentiated product demand systems that allows for products with zero sales in the data. Zeroes in demand are a common problem in differentiated product markets, but fall outside the scope of existing demand estimation techniques. We show that with a lower bound imposed on the expected sales quantities, we can construct upper and lower bounds for the conditional expectation of the inverse demand. These bounds can be translated into moment inequalities that are shown to yield consistent and asymptotically normal point estimators for demand parameters under natural conditions. In Monte Carlo simulations, we demonstrate that the new approach works well even when the fraction of zeroes is as high as 95%. We apply our estimator to supermarket scanner data and find that correcting the bias caused by zeroes has important empirical implications, for example, price elasticities become twice as large when zeroes are properly controlled.

Modeling the Energy Mix and Economic Costs of Deep Decarbonization Scenarios in a Cge Framework

This paper investigates the energy mix and welfare implication of deep decarbonization pathways with net negative emission technologies for North America and globally to 2050 in a computable general equilibrium (CGE) framework. The analysis uses an integrated assessment model (IAM), the Global Change Assessment Model (GCAM), to develop three bounding emission scenarios: i) A business as usual pathway (BAU), ii) A pathway bounded by the Nationally Determined Contributions and attaining a 2°C end of century target (NDC-2°C), and iii) An increasing ambition pathway that attains a 1.5°C end of century target (NDC-1.5°C). The energy mix and economic impacts of these emissions pathways are then evaluated using Environment Canada's Multi-Sector, Multi-Regional (EC-MSMR) CGE model. When bioenergy with carbon capture and storage (BECCS) and direct air capture (DAC) are available, they play an important role in achieving emission reductions. Allowing the use of DAC preserves an additional 5% to 20% of the share of fossil fuels in North America. Including DAC in deep decarbonization pathways lowers the welfare loss by up to ~1% globally compared to those without DAC in 2050. This finding is robust to both the estimated price of and constraints on DAC deployment. Increasing the potential for fuel switching in the CGE model further reduces the welfare effects for deep decarbonization.

Robust Inference in First-Price Auctions: Overbidding as an Identifying Restriction

Laboratory experiments find consistently that bidding in first-price auctions tends to be more aggressive than predicted by the risk-neutral Bayesian Nash Equilibrium (RNBNE) — a finding known as the overbidding puzzle. Several alternative models can explain the overbidding puzzle, but no canonical alternative to RNBNE has emerged. Instead of estimating a particular model of overbidding, we use the overbidding restriction itself for identification, which allows us to bound the valuation distribution and the seller's revenue under counterfactual reserve prices in the spirit of Haile and Tamer (2003). These bounds are consistent with RNBNE and all models of overbidding, and the bounds remain valid even if there is unobserved heterogeneity in bidding strategies. We evaluate the validity of the bounds numerically and in experimental data.

Monetary Policy and Redistribution in Open Economies

This paper develops an open-economy heterogeneous-agent New Keynesian model in which households differ in their income, wealth, and real and financial integration with international markets. We use the model to reassess classic questions in international macroeconomics from a distributional perspective. Our analysis yields two main takeaways. First, heterogeneity in households' international integration plays a central role in driving the unequal consumption responses to external shocks, more so than income and wealth. Second, the conduct of monetary policy in open economies faces a stabilization-inequality trade-off, with fixed exchange rate regimes leading to amplified but more equal consumption responses to external shocks.

Semi-Nonparametric Estimation of Random Coefficient Logit Model for Aggregate Demand

In this paper, we propose a two-step semi-nonparametric estimator for the widely used random coefficients logit demand model. The approach applies to the same setup as Berry et al. (1995, BLP)-type of models with many products, but has the advantage of not requiring computing demand inversion. In particular, the first step of our approach estimates the fixed coefficients via a computationally very easy linear sieve generalized method of moments (GMM). The second step uncovers the distribution of the random coefficient via a sieve minimum distance or GMM procedure. We show identification and derive the asymptotic properties of the estimator in a large market environment. Monte Carlo simulations and empirical illustrations support the theoretical results and demonstrate the usefulness of our estimator in practice.

Are Working Hours Complements in Production?

This paper studies the degree of complementarity in working hours among coworkers in production. Using matched employer-employee data, we first present facts on the within-establishment relationship between wages and hours worked that are consistent with the presence of complementarities in working hours. Next, we estimate the elasticity of substitution in working hours and find it to be 0.69 in the aggregate and between 0.52 and 1.03 across industries. We validate our elasticity estimates by showing that industries with higher elasticities exhibit greater flexibility in hours. Our results suggest that working hours are gross complements in production rather than perfect substitutes, as is typically assumed. An accounting exercise using our model estimations suggests that hours-wage penalties, due to complementarities in hours, can explain 5 to 30 percent of the gender wage gap over the life-cycle.

Quantum Monte Carlo for Economics: Stress Testing and Macroeconomics Deep Learning

Computational methods both open the frontiers of economic analysis and serve as a bottleneck in what can be achieved. We are the first to study whether Quantum Monte Carlo (QMC) algorithm can improve the runtime of economic applications and challenges in doing so. We provide a detailed introduction to quantum computing and especially the QMC algorithm. Then, we illustrate how to formulate and encode into quantum circuits (a) a bank stress testing model with credit shocks and fire sales, (b) a neoclassical investment model solved with deep learning, and (c) a realistic macro model solved with deep neural networks. We discuss potential computational gains of QMC versus classical computing systems and present a few innovations in benchmarking QMC.

Forthcoming Published Papers

Trade and Diffusion of Embodied Technology: An Empircal Analysis

Using global patents, citations, inter-sectoral sales, and trade data, we examine the international diffusion of technology through imported inputs. We use citations and sales data to characterize knowledge and production input-output tables for individual countries. Using these tables, we construct a measure of the flow of knowledge-weighted and production-weighted technology embodied in inputs imported from the US. We develop an instrumental variable strategy to establish that increases in embodied technology imports lead to increased innovation and knowledge diffusion in sectors within importing countries. Effects are substantially larger for knowledge-weighted imports of embodied technology.

Cash in the Pocket, Cash in the Cloud: Cash Holdings of Bitcoin Owners

We estimate the effect of Bitcoin ownership on the level of cash holdings of Canadian consumers. Bitcoin ownership positively correlates with cash holdings even after accounting for selection into ownership via a control function approach. On average, Bitcoin owners hold 83 percent (in 2018) to 95 percent (in 2017) more cash than non-owners. Focusing on the quantiles of cash holdings, we find that Bitcoin ownership has a highly nonlinear effect. For example, the difference in cash holdings between Bitcoin owners and non-owners in 2017 varies from 63 percent at the 25th quantile of cash to 176 percent at the 95th quantile of cash. Our results provide some evidence to reject the hypothesis that new digital currencies or technologies, such as Bitcoin, will lead to a decline in cash holdings.

Estimating Large-Dimensional Connectedness Tables: The Great Moderation Through the Lens of Sectoral Spillovers

We estimate sectoral spillovers around the Great Moderation with the help of forecast error variance decomposition tables. Obtaining such tables in high dimensions is challenging because they are functions of the estimated vector autoregressive coefficients and the residual covariance matrix. In a simulation study, we compare various regularization methods on both and conduct a comprehensive analysis of their performance. We show that standard estimators of large connectedness tables lead to biased results and high estimation uncertainty, both of which are mitigated by regularization. To explore possible causes for the Great Moderation, we apply a cross-validated estimator on sectoral spillovers of industrial production in the US from 1972 to 2019. We find that the spillover network has considerably weakened, which hints at structural change, e.g., through improved inventory management, as a critical explanation for the Great Moderation.

What Can Stockouts Tell Us About Inflation? Evidence from Online Micro Data

We use a detailed micro dataset on product availability and stockouts to construct a direct high-frequency measure of consumer product shortages during the 2020–2022 pandemic. We document a widespread multi-fold rise in stockouts in nearly all sectors early in the pandemic. Over time, the composition evolved from temporary to more permanently discontinued products, concentrated in fewer sectors. We show that unexpected shocks to stockout levels have significant inflationary effects within three months. These effects are larger and more persistent for imported goods and import-intensive sectors. We develop a model of inventories in a sector facing both demand and cost disturbances, and use the observed joint dynamics of stockouts and prices to show that these effects can be associated with elevated costs of replenishing inventories and higher exposure to trade.

Central Bank Digital Currency and Banking: Macroeconomic Benefits of a Cash-Like Design

Many central banks are considering issuing a central bank digital currency (CBDC). How will the CBDC affect the macroeconomy? Will its design matter? To answer these questions, we theoretically and quantitatively assess the effects of a CBDC on consumption, banking and welfare. Our model captures the competition between different means of payment and incorporates a novel general equilibrium

feedback effect from transactions to deposit creation. The general equilibrium effects of a CBDC are decomposed into three channels: payment efficiency, price effects and bank funding costs. We show that a cash-like CBDC is more effective than a deposit-like CBDC in promoting consumption and welfare. Interestingly, a cash-like CBDC can also crowd in banking, even in the absence of bank market power. In a calibrated model, at the maximum, a cash-like CBDC can increase bank intermediation by 10.2% and welfare by 0.059% and capture up to 23.3% of the payment market.

From Lvts to Lynx: Quantitative Assessment of Payment System Transition

Modernizing Canada's wholesale payments system to Lynx from the Large Value Transfer System (LVTS) brings two key changes: (1) the settlement model shifts from a hybrid system that combined components of both real-time gross settlement (RTGS) and deferred net settlement (DNS) to an RTGS system; (2) the policy regarding queue usage changes from discouraging it to encouraging the adoption of the new liquidity-saving mechanism. We utilize this unique opportunity to quantitatively assess the effects of those changes on the behaviour of participants in the high-value payments system. Our analysis reveals the following: (1) At the system level, most payments are settled in a single stream with the liquidity-savings mechanism in Lynx—facilitating liquidity pooling and leading to higher efficiency than LVTS where payments were distributed in two streams. Moreover, due to Lynx's liquidity-saving mechanism, many payments arrive earlier than those in LVTS, providing more opportunities for liquidity saving at the cost of slightly increased payment delay. (2) At the participant level, the responses are rather heterogeneous; however, our analysis suggests that liquidity efficiency is improved for several participants, and most experience slightly longer payment delays in Lynx than in LVTS.

Generalized Autoregressive Gamma Processes

We introduce Generalized Autoregressive Gamma (GARG) processes, a class of autoregressive and moving average processes which extends the class of existing Autoregressive Gamma (ARG) processes in one important dimension: each conditional moment dynamic is driven by a different and identifiable moving average of the variable of interest. The paper provides ergodicity conditions for GARG processes and derives closed-form conditional and unconditional moments. The paper also presents estimation and inference methods, illustrated by an application to European option pricing where the daily realized variance follows GARG dynamic. Our

results show substantial pricing errors reductions of GARG dynamic over ARG.

Stress Relief? Funding Structures and Resilience to the Covid Shock

How did funding structures—the source, instrument, currency, and counterparty location of financing—relate to the financial stress experienced in different countries and sectors during Covid-19? Banks and corporates with a higher share of funding from non-bank financial institutions (NBFIs) or in US dollars experienced significantly greater stress, while more funding in debt instruments (versus loans) or cross-border (versus domestically) did not affect resilience. Policies targeting these structural vulnerabilities (US$ swap lines and NBFI policies) were more effective at mitigating stress than policies supporting banks, even controlling for macroeconomic policies. Macroprudential regulations should prioritize exposures to NBFI and dollar funding.

Reassessing the Relevance of Financial Shocks in an Estimated Heterogeneous Firm Model

I study the transmission of financial shocks using an estimated heterogeneous firm model. Following a contractionary financial shock, financially constrained firms cut investment, but unconstrained firms increase investment due to the lower capital price and interest rate. After matching the empirical dynamics of prices and the price elasticity of investment, I find a limited role of the unconstrained firms' response in dampening the aggregate investment decline. Non-financial capital adjustment friction is the key to generating this result. Without the capital adjustment friction, unconstrained firms' investment becomes unrealistically sensitive to prices, and the model would understate the financial shocks' aggregate relevance.

Understanding Post-Covid Inflation Dynamics

We propose a macroeconomic model with a nonlinear Phillips curve that has a flat slope when inflationary pressures are subdued and steepens when inflationary pressures are elevated. The nonlinear Phillips curve in our model arises due to a quasi-kinked demand schedule for goods produced by firms. Our model can jointly account for the modest decline in inflation during the Great Recession and the surge in inflation during the post-COVID period. Because our model implies a stronger transmission of shocks when inflation is high, it generates conditional heteroskedasticity in inflation and inflation risk. Hence, our model can generate more sizeable inflation surges due to cost-push and demand shocks than a standard linearized model. Finally, our model implies that the central bank faces a more severe

trade-off between inflation and output stabilization when inflation is elevated.

Tariffs and the Exchange Rate: Evidence from Twitter

This paper examines the conjecture that an increase in tariffs in a flexible exchange rate regime leads to the appreciation of the local currency. We focus on the reaction of the exchange rate market to tweets by U.S. President Donald Trump regarding possible tariff increases on Canadian and Mexican goods. The anticipation of trade restrictions leads to the appreciation of the U.S. dollar by 2.6 bps and 4.6 bps vis-a-vis the Canadian dollar and Mexican peso, respectively, within five minutes of the tweet, and the effect is statistically significant for up to 3 days after the tweet. These results suggest that the view that exchange rate appreciation may mitigate expenditure-switching towards local goods after a tariff increase is empirically plausible.

Limited Nominal Indexation of Optimal Financial Contracts

When financial contracts are not fully enforceable and firms observe their own nominal sales before the observation of the aggregate nominal price, the optimal financial contract is not fully indexed to inflation. Because of the limited nominal indexation, which is endogenous in the model, unanticipated inflation affects aggregate investment and future economic activity. The macroeconomic volatility induced by price uncertainty, however, is not monotone: It first increases and then decreases with nominal price uncertainty. We also show that the degree of nominal indexation declines with real idiosyncratic volatility and the impact of an inflation shock decreases with nominal indexation. Using firm-level data from Canada, we find that both predictions are supported by the data.

Capital Flows and Growth Across Developing Countries

Foreign direct investment inflows are positively related to economic growth across developing countries — but so are savings in excess of investment. This paper develops an explanation for these known empirical findings by focusing on the limited availability of consumer credit in developing countries, together with general equilibrium effects. In the model, fast-growing developing countries scale up their holdings of debt assets, which creates net capital outflows — despite inflows of foreign direct investment — and reduces the world interest rate. Slow-growing developing countries reduce their holdings of debt assets in response, which creates net capital inflows despite outflows of foreign direct investment.

The 2021-22 Merchant Acceptance Survey Pilot Study

In recent years, the rise in digital payment innovations such as contactless cards and Interac e-Transfer has spurred a discussion about the future of cash at the point of sale. The COVID-19 pandemic has also contributed to this discussion: While consumers reported that some merchants started to refuse cash early on in the pandemic, such reported refusals dropped as the pandemic progressed. The Bank of Canada's most recent Merchant Acceptance Survey (MAS) took place in 2018, prompting a need for updated data to study merchant cash acceptance, payment trends and conditions for the potential issuance of a central bank digital currency (Lane 2020, 2021a). Against this background, the Bank conducted the 2021–22 MAS Pilot Study to monitor payment methods accepted by small and medium-sized businesses (SMBs). Survey data was collected from merchants in two batches, in late 2021 and early 2022. Our results show that 97% of SMBs in Canada accepted cash in 2021–22 and only 3% have plans to stop accepting cash. For cards and digital payments, merchant acceptance has increased since 2018. Additionally, the acceptance of different payment methods varies by the size of the merchant, industry and region.

Staff Working Papers

Demographic Origins of the Decline in Labor's Share

Since 1980, the earnings share of older workers has risen in the United States. At the same time, labor's share of income has declined significantly. We hypothesize that an aging workforce has contributed to the decline in labor's share of income. We formalize this hypothesis in an on-the-job search model in which employers of older workers may have substantial monopsony power due to the decline in labor market dynamism that accompanies aging. The greater monopsony power manifests as a growing wedge between a worker's earnings and their marginal product over the life cycle. We estimate the profile of these wedges using cross-industry variation in labor's share and the age distribution of earnings. We find that a 60-yearold worker receives half the marginal product relative to when they were 20. Together with recent demographic trends, this can account for 59% of the recent decline in labor's share of earnings in the United States.

Trade and Diffusion of Embodied Technology: An Empirical Analysis

Using data from patents, citations, inter-sectoral sales and customs, we examine the international diffusion of technology through imports of sectoral knowledge and production inputs. We construct measures of the flow of technology embodied in imports. These measures are weighted by inter-sectoral knowledge and production input-output

linkages that capture the relevance of this technology for generating new innovations in different sectors in importing countries. We develop an instrumental variable strategy to identify the causal effects of technology embodied in imports on innovation and diffusion outcomes. For sectors in importing countries, increases in both knowledge- and production-weighted embodied technology imports lead to technology diffusion (measured using backward citations in new patent applications) and increases in the rate of new innovations (measured using the forward citations those patents receive). Effects are substantially larger for knowledge-weighted imports of embodied technology, which also lead to improvements in the average quality of new innovations.

The Impact of Unemployment Insurance and Unsecured Credit on Business Cycles

I study how unsecured credit affects the extent to which unemployment insurance (UI) policies smooth cyclical fluctuations in aggregate consumption. To do so, I develop a real business cycle model with incomplete asset markets, frictional labor markets, and defaultable debt. Using empirically consistent unemployment dynamics over the business cycle, the model generates the cyclical properties of unsecured revolving credit balances and consumer bankruptcies in the data. The model is used to quantify the aggregate implications of a policy that extends the duration of UI during recessions. The main quantitative result of this paper is that unsecured credit amplifies the extent to which UI policies smooth aggregate consumption fluctuations over the business cycle. Extensions in the duration of UI mitigate the rise in consumer bankruptcies during recessions. They also mitigate the rise in the risk premium on unsecured borrowing, which allows households to better smooth consumption.

Narrative-Driven Fluctuations in Sentiment: Evidence Linking Traditional and Social Media

This paper studies the role of narratives for macroeconomic fluctuations. We micro-found narratives as directed acyclic graphs and show how exposure to different narratives can affect expectations in an otherwise standard macroeconomic model. We capture such competing narratives in news media’s reports on a US yield curve inversion by using techniques in natural language processing. Linking these media narratives to social media data, we show that exposure to a recessionary narrative is associated with a more pessimistic sentiment, while exposure to a nonrecessionary narrative implies no such change in sentiment. In a model with

financial frictions, narrative-driven beliefs create a trade-off for quantitative easing: extended periods of quantitative easing make narrative-driven waves of pessimism more frequent, but smaller in magnitude.

From LVTS to Lynx: Quantitative Assessment of Payment System Transition

Modernizing Canada's wholesale payments system to Lynx from the Large Value Transfer System (LVTS) brings two key changes: (1) the settlement model shifts from a hybrid system that combined components of both real-time gross settlement (RTGS) and deferred net settlement (DNS) to an RTGS system; (2) the policy regarding queue usage changes from discouraging it to encouraging the adoption of the new liquidity-saving mechanism. We utilize this unique opportunity to quantitatively assess the effects of those changes on the behaviour of participants in the high-value payments system. Our analysis reveals the following: (1) At the system level, most payments are settled in a single stream with the liquidity-savings mechanism in Lynx—facilitating liquidity pooling and leading to higher efficiency than LVTS where payments were distributed in two streams. Moreover, due to Lynx's liquidity-saving mechanism, many payments arrive earlier than those in LVTS, providing more opportunities for liquidity saving at the cost of slightly increased payment delay. (2) At the participant level, the responses are rather heterogeneous; however, our analysis suggests that liquidity efficiency is improved for several participants, and most experience slightly longer payment delays in Lynx than in LVTS.

Pricing Infinitely Lived Assets: Experimental Evidence

We study indefinitely lived assets in experimental markets and find that the traded prices of these assets are, on average, about 40% of the risk-neutral fundamental value. Neither uncertainty about the value of total dividend payments nor horizon uncertainty about the duration of trade can account for this low traded price. An Epstein and Zin (1989) recursive preference specification that models the dynamic realization of dividend payments and incorporates risk preferences can rationalize the low traded price observed in our indefinitely lived asset market.

How Banks Create Gridlock to Save Liquidity in Canada's Large Value Payment System

Using detailed data from Canada's new high-value payment system (HVPS), we show how participants of the system save liquidity by exploiting the new gridlock resolution arrangement. These observed

behaviors are consistent with the equilibrium of a “gridlock game” that captures the key incentives that participants face in the system. The findings have important implications for the design of HVPSs and shed light on financial institutions’ liquidity preference.

An Investigation into the Effects of Border Carbon Adjustments on the Canadian Economy

This paper examines how border carbon adjustments (BCAs) may address the unintended consequences of uncoordinated global climate action, focusing on the economic implications for Canada. We investigate these implications under different BCA design features and by considering a coalition of countries and regions that adopt BCAs. We find that BCAs, in the form of import tariffs, reduce Canada’s carbon leakage to the rest of the world and improve its domestic and foreign competitiveness when Canada is part of a coalition of countries and regions that implement BCAs that includes the United States. We show that these results may change if Canada imposes BCAs on a different set of sectors than the rest of the coalition or includes export rebates and free emissions allowances to firms. When the United States is not part of the coalition, we show that Canada’s carbon leakage increases, domestic competitiveness dampens and foreign competitiveness improves. Compared with a case where no countries have BCAs, welfare improves in Canada if revenues from BCAs, in the form of import tariffs, are transferred to households. This finding holds regardless of the United States’ participation in the coalition.

Crowdfunding and Risk

This paper examines the role of rewards-based and equity-based crowdfunding in funding new businesses. In this model, crowdfunding is a unique technology that serves as a real option for production and eliminates downside risk. It affords entrepreneurs who face uncertain consumer demand a viable means of funding new projects. Crowdfunding performs well for projects with a high variability in demand and a low probability of success. Conversely, crowdfunding does not perform well for large projects with little variability in demand or for projects where the production side is uncertain.

Time Use and Macroeconomic Uncertainty

We estimate the effects of economic uncertainty on time use and discuss its macroeconomic implications. Using data from the American Time Use Survey, we first infer cyclical variation in home production and leisure time. We then document that higher uncertainty increases housework and reduces market hours worked,

with modest effects on leisure. Finally, we propose a model of housework with time-varying uncertainty that quantitatively accounts for these results. We use the model to demonstrate that substitution between market and non-market work provides an additional insurance margin to households, weakening precautionary savings and labor supply. However, time-use reallocation also lowers aggregate demand, ultimately amplifying the contractionary effects of uncertainty. Policies that reallocate time use toward housework (e.g., lockdown restrictions) amplify the recessionary effects of uncertainty and can result in aggregate dynamics consistent with a supply-side shock.

Understanding Inflation Dynamics: The Role of Government Expenditures

This paper studies the impact government expenditure has on inflation by examining an augmented Phillips curve implied from a structural New Keynesian model. Our estimation results, based on external instruments, show that the augmented Phillips curve has a flatter slope than the canonical specification and that government expenditure has a negative coefficient. Changes in government expenditure account for a substantial portion of inflation variations and provide new insights into the “missing disinflation” puzzle. We also find that inflation and inflation expectations respond negatively to fiscal spending shocks, reaffirming the supply-side channel through which inflation responds to fiscal expansions.

The Macroeconomic Effects of Portfolio Equity Inflows

I provide evidence that portfolio equity inflows can have expansionary effects on GDP and inflation if not offset by monetary policy. I use a shift-share instrument to estimate equity inflows based on plausibly exogenous timing of inflows into mutual funds with heterogeneous country portfolios. For countries with fixed exchange rates, GDP rises for at least two years following an exogenous inflow with a peak effect of 0.8 percent after 18 months. This is driven by rises in investment and exports, where the latter response is inconsistent with standard expenditure switching channel mechanisms. Non-fixing countries maintain GDP roughly at the same pre-shock levels but achieve this with higher interest rates.

Sme Failures Under Large Liquidity Shocks: An Application to the Covid-19 Crisis

We study the effects of financial frictions on firm exit when firms face large liquidity shocks. We develop a simple model of firm cost-minimization that introduces a financial friction that limits firms’

borrowing capacity to smooth temporary shocks to liquidity. In this framework, firm exit arises from the interaction between this financial friction and fluctuations in cash flow due to aggregate and sectoral changes in demand conditions, as well as more traditional shocks to productivity. To evaluate the implications of our model, we use firm-level data on small and medium-sized enterprises (SMEs) in 11 European countries. We confirm that our framework is consistent with official failure rates in 2017–2019, a period characterized by standard business cycle fluctuations in demand. To capture a large liquidity shock, we apply our framework to the COVID-19 crisis. We find that, in the absence of government support, SME failure rates would have increased by 6.01 percentage points, putting 3.1 percent of employment at risk. Our results are consistent with the premise that financial frictions lead to inefficient exit as, without government support, the firms failing due to COVID-19 have similar productivity and past growth to firms that survive the COVID-19 crisis.

Privacy-Preserving Post-Quantum Credentials for Digital Payments

Digital payments and decentralized systems enable the creation of new financial products and services for users. One core challenge in digital payments is the need to protect users from fraud and abuse while retaining privacy in individual transactions. We propose a pseudonymous credential scheme for use in payment systems to tackle this problem. The scheme is privacy-preserving, efficient for practical applications, and hardened against quantum computing attacks. We present a constant-round, interactive, zero-knowledge proof of knowledge (ZKPOK) that relies on a one-way function and an asymmetric encryption primitive—both of which need to support at most one homomorphic addition. The scheme is implemented with SWIFFT as a post-quantum one-way function and ring learning with errors as a post-quantum asymmetric encryption primitive, with the protocol deriving its quantum-hardness from the properties of the underlying primitives. We evaluate the performance of the ZKPOK instantiated with the chosen primitive and find that a memory footprint of 85 KB is needed to achieve 200 bits of security. Comparison reveals that our scheme is more efficient than equivalent, state-of-the-art post-quantum schemes. A practical and interactive credential mechanism was constructed from the proposed building blocks, in which users are issued pseudonymous credentials against their personally identifiable information that can be used to register with financial service providers without revealing personal information. The protocol is shown to be secure and free of information leakage, preserving the user's privacy regardless of the number of registrations.

Unpacking Moving: A Quantitative Spatial Equilibrium Model with Wealth

We argue that the interaction between mobility and wealth provides a view that rationalizes low geographic migration rates, despite migration costs being lower than currently thought. We reach this conclusion by developing and solving a quantitative dynamic spatial equilibrium model with endogenous wealth accumulated through liquid and illiquid assets. We estimate a yearly moving cost between Canadian cities of 196,303 CAD for an average adult, substantially lower than previous estimates. To demonstrate the model's validity, we study policies advocated to reduce disparities: Do moving vouchers or housing affordability policies enhance welfare, especially for the poor? Our findings suggest that moving vouchers only marginally increase the welfare of eligible households, and those who receive the vouchers tend to move to locations with lower house prices and wages. In contrast, our model shows that lower housing regulations in Vancouver can decrease the welfare gap between rich and poor by lowering house prices nationwide through spatial reallocation. Thus, the insurance value of living in high-income cities becomes higher, reducing the incentive for low-wealth families to move precautionarily to locations with low housing costs.

Monetary Policy Transmission, Bank Market Power, and Wholesale Funding Reliance

I study the impact of banking market concentration and wholesale funding reliance on the transmission of monetary policy shocks to mortgage rates. I empirically demonstrate that in the United States, banks with higher reliance on wholesale funding in concentrated (competitive) deposit markets transmit monetary policy shocks less (more) to mortgage rates. I study this imperfect transmission through the lens of a New Keynesian model with monopolistically competitive banks and costly access to wholesale funding. I find that high market power banks with greater wholesale funding transmit monetary policy less to deposit rates, generating lower liability. This leads to lower mortgage lending, house prices, and borrower consumption. If monetary policy shocks become persistent, this negative effect is amplified with banks shifting away from deposits more towards wholesale funding.

What People Believe About Monetary Finance and What We Can(’t) Do About It: Evidence from a Large-Scale, Multi-Country Survey Experiment

We conduct an experiment within a large-scale household survey on public finance in France, the Netherlands and Italy. We elicit prior beliefs via open-ended questions and introduce a measure of macroeconomic policy literacy. An educational blog post from a central bank (CB) that opposes monetary-financed policies preceded by a short video on public finance can induce less support for monetary-financed proposals and more support for fiscal discipline and CB independence, no matter the respondent's level of literacy. However, prior beliefs matter, and contradictory information may be polarizing. Information affects the respondents' views by shifting their inflation and tax expectations associated to these policies.

Global Demand and Supply Sentiment: Evidence from Earnings Calls

This paper quantifies global demand, supply and uncertainty shocks and compares two major global recessions: the 2008–09 Great Recession and the COVID-19 pandemic. We use two alternate approaches to decompose economic shocks: text mining techniques on earnings calls transcripts and a structural Bayesian vector autoregression model. The results highlight sharp contrast in the size of supply and demand shocks over time and across sectors. While the Great Recession was characterized by demand shocks, COVID-19 caused sizable disruptions to both demand and supply. These shocks were broad-based with varying relative importance across major sectors. Furthermore, certain sub-sectors, such as professional and business services, internet retail, and grocery/department stores, fared better than others during the pandemic.

Staff Discussion Papers

Reviewing Canada's Monetary Policy Implementation System: Does the Evolving Environment Support Maintaining a Floor System?

At the onset of the pandemic, the Bank of Canada transitioned its framework for monetary policy implementation from a corridor system to a floor system, which it has since decided to maintain. This decision was informed by the analysis and assessment of the two frameworks in this paper. We provide a comprehensive analysis of both frameworks and assess their relative merits based on five key criteria that define a sound framework. Our evaluation includes a discussion of how these relative merits have changed since the pandemic began. Specifically, we examine the evolving regulatory landscape, changes in payment systems, and the Bank's quantitative easing program to understand their implications for the relative strengths of the two frameworks for monetary policy implementation.

Why Consumers Disagree About Future Inflation

Since 2022, consumer inflation expectations have shifted, with a significant increase in those expecting high inflation in the coming year and a surge in those expecting deflation further in the future. Using data from the Canadian Survey of Consumer Expectations, this paper seeks to assess the factors that influence people to expect high inflation, moderate inflation or deflation. While expectations of high inflation are largely based on perceptions about current inflation, most of those anticipating future deflation do not see the Canadian economy as currently deflationary. Rather, their deflationary outlook since 2022 has hinged on the belief that current inflation-inducing supply and demand factors such as supply chain issues are temporary and will reverse, triggering price declines.

Estimating the Slope and Demand Function at Auctions for Government of Canada Bonds

We use detailed data on the bids at auctions for Government of Canada bonds between 1999 and 2021 to gauge the yield sensitivity of these bonds to the issuance amount. We propose a new metric that captures the slope of the demand function at each auction by using the information in the multiple bids (quantity and yield) that each bidder submits. In the absence of an established theoretical framework, we estimate the slope of the aggregate demand function simply by weighing the slopes of the individual demand functions, where the weights are the maximum bids of each participant. We show that these slopes can provide insights into the relationship between the supply and yield of a government debt security.

What Can Earnings Calls Tell Us About the Output Gap and Inflation in Canada?

We construct new indicators of the imbalance between demand and supply for the Canadian economy by using natural language processing techniques to analyze earnings calls of publicly listed firms. The results show that the text-based indicators are highly correlated with official inflation data and estimates of the output gap and improve the accuracy of inflation forecasts. This suggests that these indicators could help central banks foresee inflationary pressures in the economy. Our examination of other topics in earnings calls, such as supply chain disruptions and capacity constraints, points to the potential benefits of using textual data to quickly draw insights on a range of relevant topics. We conclude that text-based measures of economic slack should be included in central banks' monitoring and forecasting toolkits.

A Review of the Bank of Canada's Support of Key Financial Markets During the Covid-19 Crisis

The COVID-19 pandemic placed unprecedented strain on the global financial system. We describe how the Bank of Canada responded to the rapidly deteriorating liquidity in core Canadian fixed-income markets. We also describe how market functioning improved after the Bank intervened. The Bank implemented several emergency facilities to ease market-wide liquidity strains, restore market functioning and support the stabilization and recovery of the Canadian economy. Over time, market functioning improved, and liquidity returned to prepandemic levels. The Bank's facilities helped resolve market dysfunction and ensured that credit continued to be extended to households and businesses.

UPCOMING EVENTS

Pedro Gomis-Porqueras (Queensland University of Technology)
Organizer: BAP Visiting Speaker
Date: 14 July 2023

Lorena Keller (The Wharton School at the University of Pennsylvania)
Organizer: EFR FMD/FSD Seminar Series
Date: 18 July 2023