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Demand for Canadian Banknotes from International Travel: Indirect Evidence from the COVID-19 Pandemic

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Abstract

Recent trends suggest that domestic demand alone may not be enough to explain the increase in overall demand for Canadian banknotes (Engert et al., 2019). Estimating foreign cash demand is difficult due to data availability issues and confounding factors that simultaneously affect domestic demand. In this paper, I provide a quantitative causal estimate of banknote demand from international visitors to Canada by exploiting the exogenous shock from COVID-19 international travel restrictions, which led to an unprecedented drop in cross-border travel. To identify international visitor demand shocks from contemporaneous domestic demand shocks due to the pandemic, I apply a difference-in-differences strategy, taking advantage of foreign traveler demand's distinct regional patterns and data from the Bank of Canada's Bank Note Distribution System. I find that each international visitor brought on average $165 worth of hundred-dollar notes with them to Canada prior to the pandemic. Under plausible assumptions, total holdings by international visitors constitute roughly 10% of total $100 CAD notes in circulation at the end of 2019.

Topics: Bank notes; Central bank research; Coronavirus disease (COVID-19); Financial services; International topics
JEL codes: E41, E42, E58, F22

Résumé

De récentes tendances semblent indiquer que la demande intérieure pourrait ne pas suffire à expliquer à elle seule l'augmentation de la demande globale de billets de banque canadiens (Engert et autres, 2019). Il est difficile d'estimer la demande étrangère de billets en raison de problèmes de disponibilité des données et des facteurs de confusion qui influent simultanément sur la demande intérieure. Dans ce document, je fournis une estimation quantitative causale de la demande de billets de banque provenant de visiteurs étrangers au Canada. Pour ce faire, j'exploite le choc exogène des restrictions de voyage international mises en place durant la pandémie de COVID-19, lesquelles ont entraîné une chute sans précédent des déplacements transfrontaliers. Afin de distinguer les chocs de demande attribuables aux visiteurs étrangers des chocs de demande intérieure contemporains découlant de la pandémie, j'applique une stratégie fondée sur la méthode des doubles différences en tirant parti de la distribution régionale distincte de la demande des visiteurs étrangers et en utilisant les données du Système de distribution des billets de banque de la Banque du Canada. Je constate que chaque visiteur étranger a apporté des billets de 100 $ totalisant une valeur moyenne de 165 $ avec lui au Canada avant la pandémie. Selon certaines hypothèses plausibles, les visiteurs étrangers auraient détenu au total environ 10 % de l'ensemble des billets canadiens de 100 $ en circulation à la fin de 2019.

Sujets : Billets de banque; Recherches menées par les banques centrales; Maladie à coronavirus (COVID-19); Services financiers; Questions internationales
Codes JEL : E41, E42, E58, F22

1 Introduction

Overall, transactional demand of cash in Canada has gradually declined over time, consistent with a decline in the ratio of lower-denomination notes in circulation (NIC) to GDP, from 2% in 1980 to less than 1% today, as shown in Figure 1. The overall NIC/GDP ratio has increased since 2008, however, after decades of stability, within a range of 3% to 3.5%.[1] This increase accelerated after 2015 and especially during the pandemic, driven by an increase in demand for higher-denomination notes. Indeed, prior research suggests that there could be a connection between an increase in demand for larger-denomination Canadian (CAD) dollar notes and an increased number of visitors and immigrants to Canada over the past decade. But the evidence remains anecdotal (Flannigan and Parsons, 2018; Engert *et al.*, 2019).

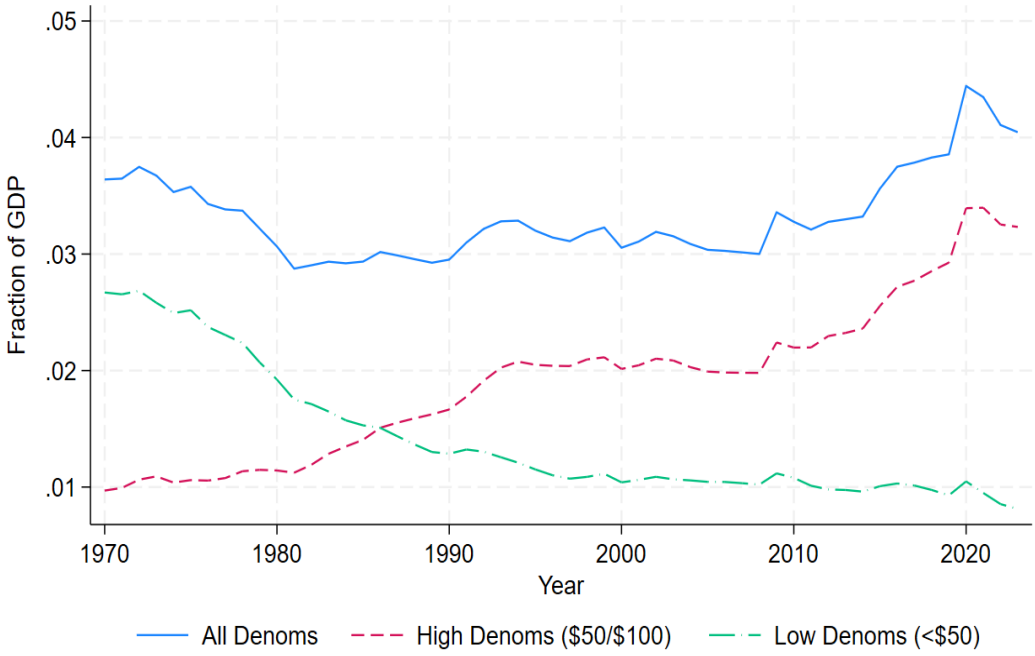
This paper provides a first quantitative causal estimate of international visitor demand for CAD banknotes by exploiting the exogenous shock from COVID-19 international travel restrictions. These travel restrictions were imposed in March 2020 and led to a more than 90% drop in cross-border travel. During this period, potential international visitors, students, investors and immigrants no longer needed to obtain CAD notes before arriving in Canada since their travel plans were either delayed or cancelled.

To identify international visitor demand shocks from contemporaneous domestic cash demand shocks, I formulate a difference-in-differences estimation model that takes advantage of international visitors' distinct regional arrival patterns. My estimation relies on confidential banknote withdrawal and deposit data from the Bank of Canada's Bank Note Distribution System (BNDS), as well demographics and foreign-visitor arrival data from Statistics Canada.

I find that each international visitor brought on average $165 worth of $100 notes with them to Canada prior to the pandemic. Under the assumption that notes used to satisfy demand from foreign visitors spend one year on average outside of the country

[1]The sharp peak in the NIC/GDP ratio in December 1999 was driven by concern about the Y2K transition and normalized one year later.

Figure 1: **Ratio of Total Value of Notes in Circulation to Nominal GDP in Canada**



The ratio is computed by dividing the total value of notes in circulation in a given year against the GDP at current prices for that year. High denominations (denoms) include the total value for $50 and $100 notes, and low denominations (denoms) include the total value for $5, $10 and $20 notes. Source: Bank of Canada, Statistics Canada.

before coming back, total holdings by international visitors of 53 million $100 CAD notes constitute roughly 10% of the total $100 CAD NIC at the end of 2019, or 6% of the total NIC by value across all denominations.

For policymakers, understanding the composition of foreign-traveler vs. domestic-cash demand is important in forecasting cash demand in the short- to medium-term, which affects the number of new banknotes that need to be printed and the associated seignorage revenue. Furthermore, the fact that holdings from international visitors constitute a significant fraction of overall demand for cash will help inform the debate on the long-term future role of cash in Canada (Engert *et al.*, 2022) and possibly in many other small open economies

whose currencies are not major international reserve currencies.

This study contributes to the small but growing literature on estimating non-domestic sources of cash demand. Recent work has used both direct and indirect methods to estimate the amount of banknotes circulating abroad (Feige, 1997, 2012; Judson, 2012, 2024). The direct methods rely on reports of banking sector wholesale cash shipments that cross borders, both in and out of a country (Judson, 2017; European Central Bank, 2022a). Data constraints limit the applicability of such methods, however, since countries like Canada do not distinguish between cash shipments for domestic and foreign destinations. This paper contributes to the literature by proposing an innovative approach that estimates demand from international travelers without relying on detailed foreign cash shipments data.

Indirect methods of estimating foreign cash holdings tend to take advantage of a statistical identity: the average in any given characteristic for all currency in circulation is the weighted average of said characteristic for banknotes in circulation domestically and abroad (Feige, 1997). Previous studies have used differences in demand seasonality (Feige, 1997; Bartzsch *et al.*, 2013a; Judson, 2012, 2024), note age (Bartzsch *et al.*, 2013b), denomination fraction (Bartzsch *et al.*, 2012), and old vs. new note series (Judson, 2012, 2017; Bartzsch and Seitz, 2017) as relevant characteristics to estimate foreign cash holdings using this indirect method. Many of these studies require a reference country whose cash-use patterns are very similar to the home country but without foreign demand for its currencies (Bartzsch *et al.*, 2013a). For the U.S., this reference country is generally Canada (Feige, 1997). For Canada and many other countries around the world, however, it is harder to find plausible reference countries. This paper contributes to the literature by proposing an approach that estimates the quantity of banknotes going abroad due to demand from international travelers, without relying on finding a plausible reference country.

Finally, this paper contributes to the larger literature trying to explain the "cash paradox" of increasing overall demand for cash while cash usage is declining as a method of payment (Bailey, 2009; Williams, 2012). Previous studies have found a role for increased domestic store-of-value demand (Fujiki and Nakashima, 2019), the underground economy (Jiang and Shao, 2020), or foreign store-of-value and transactional demand for major international

reserve currencies such as the U.S. dollar (Judson, 2024). I provide the first empirical evidence that international traveler demand could be a significant contributor to overall cash demand even for currencies that are not major international reserve currencies.

The rest of the paper is structured as follows. Section 2 describes the exogenous shock of COVID-19 international travel restrictions and how it affected cash demand. Section 3 explains the data and presents a short descriptive analysis. Section 4 formulates the empirical model and discusses the estimation strategy. Section 5 presents the empirical findings, and section 6 concludes.

2 The COVID-19 Pandemic Shock to International Travel

On March 11, 2020, the World Health Organization declared the COVID-19 outbreak to be a pandemic (Cucinotta and Vanelli, 2020). Shortly afterwards, Canada imposed stringent restrictions on all international travel. More specifically, by March 16, 2020, Canada was advising all Canadians to avoid non-essential travel outside the country, had instituted a 14-day mandatory self-isolation period for Canadians returning from abroad, and banned nearly all foreign nationals from entering Canada.[2] Other countries around the world, including the U.S.,[3] countries in the European Union,[4] etc., instituted similar stringent travel restrictions at around the same time. These restrictions were in place for more than a year and were only gradually relaxed in summer and fall 2021, after mass vaccination campaigns. (See Appendix A for a timeline of COVID-19 international travel restrictions in Canada.)

These restrictions led to an unprecedented drop in international travel. As shown in

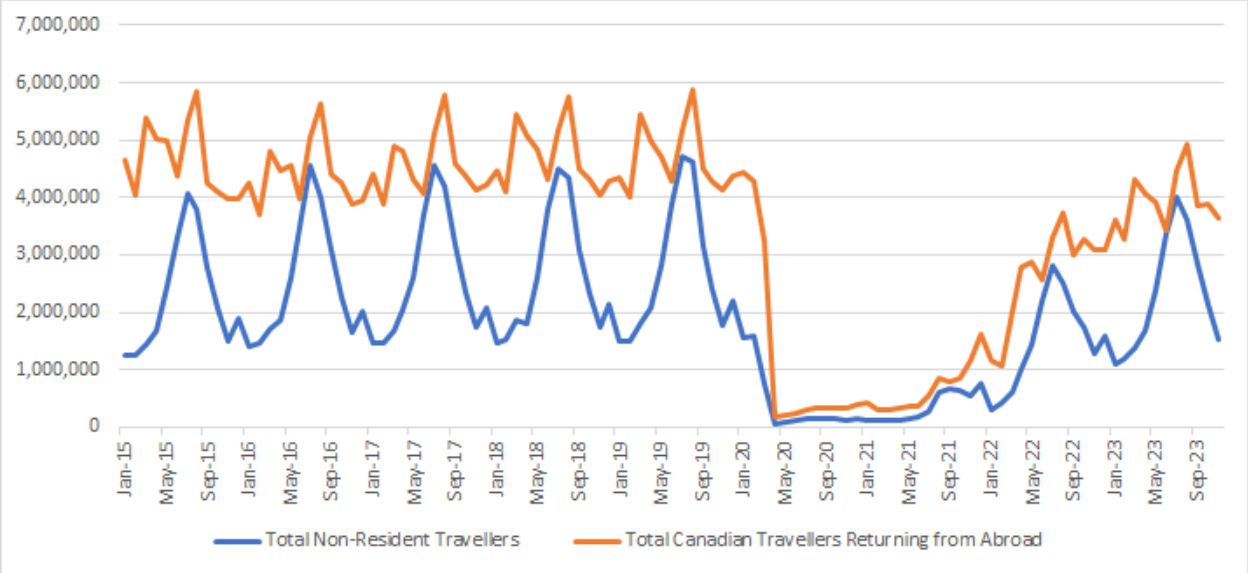
[2]See https://pm.gc.ca/en/news/news-releases/2020/03/16/prime-minister-announces-new-actions-under-canadas-covid-19-response for a detailed list of travel restrictions announced in March 2020.

[3]See https://www.federalregister.gov/documents/2020/03/24/2020-06217/notification-of-temporary-travel-restrictions-applicable-to-land-ports-of-entry-and-ferries-service for measures banning non-essential travel across the Canada-U.S. border.

[4]See https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:115:FIN.

Figure 2, the number of travelers entering Canada dropped by more than 90% between January and April 2020, and stayed low through the rest of 2020 and the first half of 2021, only slowly recovering starting in summer 2021, as restrictions were gradually being relaxed. Despite this recovery, international travel remains far below pre-pandemic trends even today, with border crossings in summer 2023 around 15% below summer 2019 levels.[5]

Figure 2: **Total Number of Travelers Entering Canada by Month**



Source: Statistics Canada

2.1 Effects on Cash Demand

How did the international travel restrictions imposed during the COVID-19 pandemic affect demand for CAD notes? To facilitate my analysis, I classify overall cash demand into 4 categories, as shown in Table 1, based on whether CAD notes are held by Canadian residents

[5]Both the dropoff in international travel at the beginning of the pandemic and the gradual recovery post-summer 2021 were largely symmetric between resident and non-resident travelers. For example, non-resident entry to Canada fell to 3.2% of its 2019 levels in summer 2020 (July and August), while resident entry fell to 5.7%. Non-resident and resident entry recovered to 57.2% and 63.7% of their corresponding 2019 levels by summer 2022, and 71.8% and 75.8% of the corresponding 2019 levels by the 2022 holiday season (December 2022 and January 2023).

or non-residents and whether they are spent or held inside Canada or abroad. Consistent with the approach in the literature (Judson, 2012; Bartzsch *et al.*, 2013a), I define as foreign demand CAD notes that circulate abroad for wealth diversification purposes because it is a safer asset than the local currency. It also includes notes used for transactional purposes abroad. Foreign demand constitutes the bottom right quadrant of Table 1 since notes used for these purposes may stay abroad for a significant period of time before coming back, if they do so at all. On the other hand, the upper-left quadrant in Table 1, notes held by Canadians and spent within Canada, constitutes domestic demand since these notes have never left the country.

Table 1: **Cash Demand Classification**

This table classifies CAD note demand according to holder type and country where notes are held/spent.

	Held/Spent inside Canada	**Held/Spent outside Canada**
Held by Canadian Residents	**Domestic Demand**: Transactional + store-of-value	**Traveler Demand**: International travel by Canadians
Held by Non-residents	**Traveler Demand**: Visitors/students/ investors/immigrants coming to Canada	**Foreign Demand**: Wealth diversification + transactional demand outside Canada

While notes used to satisfy domestic demand or foreign demand would generally stay within Canada or keep circulating abroad, respectively, the two other categories of cash demand are notes that cross the Canadian border frequently, which I define as demand from international travelers. It has two components. The lower-left quadrant in Table 1 consists of cash spent/deposited inside Canada by non-residents. This demand comes from short-term visitors and students needing to pay for transactions inside Canada, non-resident investors looking to purchase real estate and other assets in Canada as a form of wealth diversification, as well as immigrants landing in Canada for the first time. They often do

not have a Canadian bank account, do not have credit cards, or are not sure if the cards they have can be used. Therefore, they obtain CAD notes abroad before entering Canada. The upper-right quadrant in Table 1 consists of cash held outside Canada by Canadian residents. This demand comes from Canadian travelers going abroad for the short-term, carrying some CAD notes in their wallets.

The COVID-19 pandemic potentially produced a shock to all sources of note demand. Domestically, lockdowns and store closings resulted in a large reduction in the transactional demand for cash, while elevated uncertainty drove an increase in households' holdings of cash due to precautionary motives, increasing non-transactional demand for cash (Chen *et al.*, 2020). Demand from international travelers was impacted by the stringent international travel restrictions, while foreign demand could have varied due to the concurrent economic and financial turmoil around the world.

Focusing on the three sources of foreign and traveler demand in Table 1, I believe that the large decrease in international travel mostly affected foreign CAD cash demand via non-residents who took out Canadian cash prior to visiting or studying in Canada. Because they were no longer able to enter the country, these visitors no longer needed to obtain Canadian cash abroad. At the same time, Canadian travelers were also largely prevented from international travel. I believe that banknote demand from this source was *a priori* fairly small, however, since Canadians who travel abroad are more likely to carry USD or EUR notes, which are more easily exchanged to local currencies. Finally, I assume that the amount of Canadian dollar notes held abroad for wealth diversification or transactional purposes held constant during the pandemic.

3 Data and Cash Demand Trends

To quantify the effects of the pandemic shock on note demand from international travelers, I use data from the Bank Note Distribution System (BNDS), through which the Bank of Canada supplies financial institutions (FIs) wholesale with bank notes required to satisfy all sources of demand (see Bilkes *et al.* (1997) for a detailed explanation). When the pandemic

hit, the BNDS had 10 regional distribution points (RDPs) located across the country where FIs could withdraw bank notes to satisfy their need and deposit their surplus notes back to the Bank. These RDPs were located in Vancouver, Calgary, Regina, Winnipeg, Toronto, Ottawa, Montreal, Quebec City, Halifax and St. John's. In the course of normal operations, the Bank collects data on bank note withdrawals and deposits by FIs to and from these RDPs. This panel dataset provides rich regional and time-series variation and has previously been used by Bank researchers to investigate cash demand in Canada (Dunbar, 2019; Jones and Dunbar, 2018).

In particular, I use the following information collected for each bank note shipment:

- Shipment purpose (i.e., withdrawal or deposit)
- Shipment time
- Note denomination
- Shipment value
- Sending and receiving FIs
- Sending and receiving RDCs

Theoretically, it is hard to disentangle foreign/traveler cash demand from domestic demand because the Bank cannot track a note once it is in circulation. Nevertheless, CAD note demand from international visitors has several characteristics that distinguish it from domestic demand. First, it should be concentrated in the highest-denomination note in circulation (i.e., $100), since it is much easier to carry in person. Second, I expect international traveler demand to be much more concentrated than domestic demand in certain regions. As Table 2 shows, there is a disproportionately high number of international visitors and students traveling to certain provinces compared with their population share.[6]

[6]To facilitate the comparison between provincial statistics and BNDS data, I aggregate BNDS withdrawal/deposit data to the provincial level by grouping all RDPs with the province where they are located. New Brunswick and Prince Edward Island (PEI) are grouped with Nova Scotia (i.e., Maritimes) since these two provinces do not have an RDP on their territory. I also group the population, foreign student, and visitor shares of the Maritime provinces together.

Table 2: **Population and Foreign Student/Visitor Distribution in Canada**

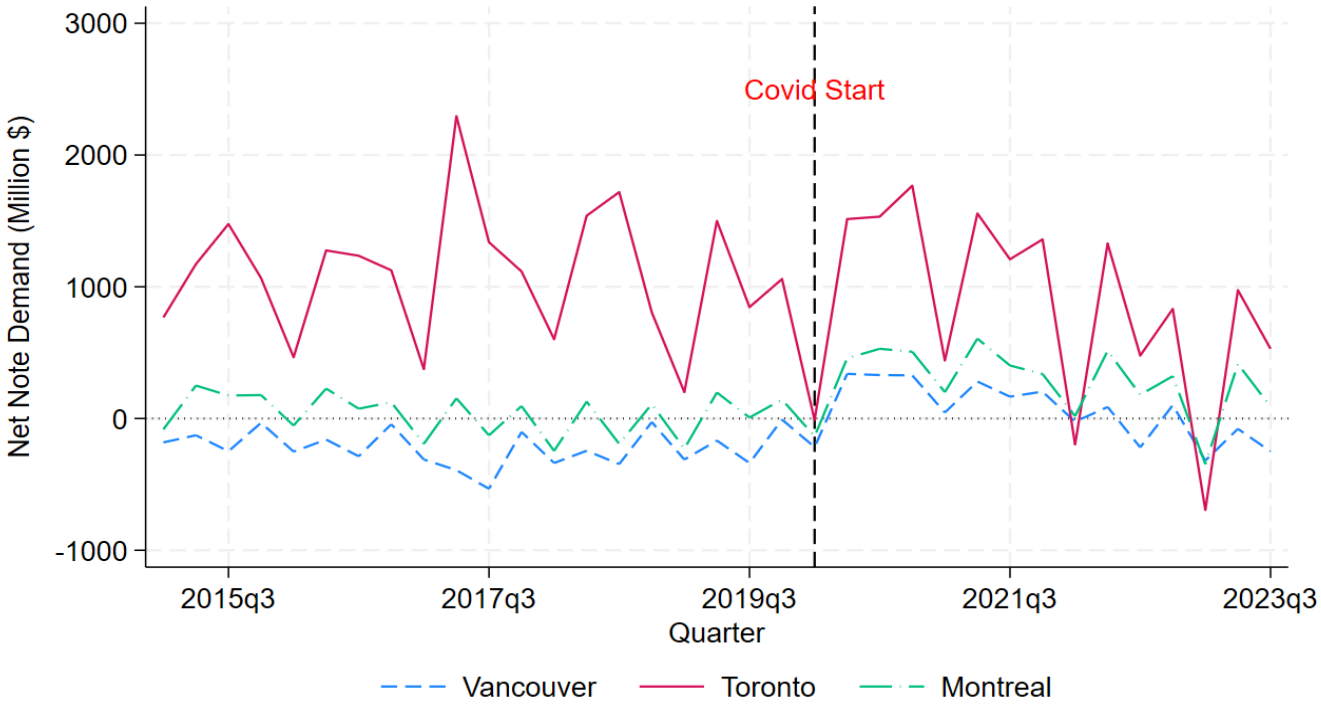
Region	Population Share in Canada	Foreign Student as % of Total	Foreign Visitor as % of Total
British Columbia	13.6%	22.6%	26.5%
Alberta	11.6%	5.2%	3.7%
Saskatchewan	3.1%	1.7%	0.4%
Manitoba	3.6%	3.0%	1.2%
Ontario	38.7%	47.9%	50.7%
Quebec	22.6%	13.8%	12.3%
Maritimes	5.1%	4.5%	3.6%
NFL & Labrador	1.4%	0.7%	0.2%

Source: Statistics Canada. In this table New Brunswick and Prince Edward Island (PEI) are grouped together with Nova Scotia (i.e., Maritimes) since these two provinces do not have an RDP on their territory. The fractions are calculated using data from 2019, the year before the pandemic started.

Combining these two points, Figure 3 plots net $100 note demand in the three largest RDPs in the country and shows evidence of international visitor demand pre-pandemic: the net $100 note demand in the Vancouver region was consistently negative for years prior to the pandemic, and the net demand in Montreal hovered around zero. In both cases, I would have expected a positive net demand if only domestic demand were in play, given the increase in the NIC/GDP ratio shown in Figure 1. Meanwhile, the net $100 note demand in Toronto consistently represents more than 80% of the overall net demand for $100 notes across the country, a much larger share than Ontario's corresponding domestic population share. These pieces of evidence suggest that notes satisfying foreign traveler demand are leaving the country from Toronto and returning to Canada through Vancouver. This distinguishing circulation pattern forms the basis for my estimation strategy.

During the first two years of the pandemic, there was a large change in net cash demand, with both Vancouver and Montreal moving into consistently positive net demand territory, as shown in Figure 3. These trends were consistent with domestic demand for $100 notes dominating in 2020 and 2021 as foreign traveler demand decreased due to the dropoff in

Figure 3: **$100 Note Net Demand by RDP by Quarter**



Source: Bank of Canada

the number of international visitors.[7] As international travel gradually resumed in 2022, the net demand in Vancouver dipped back into negative territory in 2022Q3 and was consistently negative during the first three quarters of 2023. This return to pre-pandemic norms is consistent with a return of international traveler demand due to the return of foreign visitors to Canada.

In summary, the $100 net demand time trends by RDP provide suggestive evidence that demand from international travelers accounted for a significant proportion of the overall demand for $100 CAD notes when international travel was not highly restricted. Since simultaneous shocks occurred to both domestic and traveler cash demand during the pandemic, however, the next step is to formulate a methodological framework that can isolate the changes in cash demand from international travelers, and provide a quantitative estimate to this demand.

4 Estimation Strategy

To quantify the effect of the pandemic on cash demand from international travelers, I start with a simplified model of demand for $100 notes with the following assumptions. First, I assume that there is no difference in domestic residents' average demand for $100 notes across regions, which also implies that demand shocks would be the same across regions. This assumption is plausible since according to the 2021 Methods of Payment Survey, Canadians in most regions hold on average the same amount of $100 notes in their wallet (Henry *et al.*, 2022).[8] The simultaneous COVID-19 lockdowns across Canadian regions in Spring 2020 also support this assumption.[9] Second, I assume that foreign demand for CAD notes (i.e., for wealth diversification and transactional purposes abroad) did not change during the pandemic.

[7] Note that BNDS note withdrawal and deposit functions were always operational during the pandemic, so these trends were not impacted by a disruption in BNDS operations.

[8] Domestic demand includes cash holdings by households, businesses, and FIs.

[9] Specifically, all provinces and territories issued strict lockdown orders in the second half of March 2020, and after easing over the summer, the second wave of lockdowns occurred in close proximity in October and November 2020 across Canada. Source: https://www.cihi.ca/en/canadian-covid-19-intervention-timeline.

Given these assumptions, total NIC outstanding for $100 notes during period t is the sum of domestic holdings and notes held by international travelers:

$$N_t = R_t D_t^R + F_t \ , \tag{1}$$

where R_t is the number of Canadian residents, D_t^R is the average domestic holdings of $100 notes per resident, and F_t is the amount of $100 notes held by international travelers to Canada.

I then compute the net demand for $100 notes during time period t using the second-order Taylor expansion for the domestic demand term $R_t D_t^R$, which results in

$$\Delta N_t = \Delta R_t D_t^R + R_t \Delta D_t^R + \Delta R_t \Delta D_t^R + \Delta F_t \ , \tag{2}$$

where the change in total domestic demand can be decomposed into three components: a change in total resident population, a change in resident per capita demand, and a second-order effect combining the two.

Next, I make several simplifying assumptions to international traveler demand for $100 notes. First, I assume that all wholesale shipments of $100 notes to foreign countries leave from the Toronto RDP, which is supported by the descriptive analysis presented above. Second, I assume that all international visitors have the same demand for $100 notes.[10] The third assumption is that international visitors use up all the $100 notes they acquired abroad in the province of entry, either using them to pay for transactions or depositing them at a financial institution branch. Given these assumptions, the net demand equation for period t in any region A that is not Ontario becomes

$$\Delta N_t^A = \Delta R_t^A D_t^R + R_t^A \Delta D_t^R + \Delta R_t^A \Delta D_t^R - I_t^A D^I \ , \tag{3}$$

[10]This is only assumed to hold in the short-run, since the number of notes brought in per visitor might change in the long-run given inflation and other changes in the economic environment. This assumption holds in the baseline estimation because the comparison is always between two periods that are separated by only one or two years.

where I_t^A is the number of international travelers entering Canada via region A in period t and D^I is the average demand for \$100 notes per international traveler. For any region that is not Ontario, international travelers contribute negatively to the \$100 net demand because they spend and/or deposit notes that they acquired abroad. Since all wholesale foreign note shipments are assumed to originate from Ontario (i.e., the Toronto RDP), there is no compensating positive contribution of foreign traveler demand on overall net demand in regions outside Ontario.

I then obtain the per capita net demand for \$100 notes by dividing both sides of the equation by the regional population R_t^A:

$$\frac{\Delta N_t^A}{R_t^A} = \frac{\Delta R_t^A}{R_t^A} D_t^R + \Delta D_t^R + \frac{\Delta R_t^A}{R_t^A} \Delta D_t^R - \frac{I_t^A}{R_t^A} D^I \ . \tag{4}$$

Since I assume that the average Canadian resident across regions experienced the same shock in domestic note demand, I compute a first difference between regions A and B (also not Ontario) to minimize these simultaneous shocks:

$$\frac{\Delta N_t^A}{R_t^A} - \frac{\Delta N_t^B}{R_t^B} = \left(\frac{\Delta R_t^A}{R_t^A} - \frac{\Delta R_t^B}{R_t^B} \right) (D_t^R + \Delta D_t^R) - \left(\frac{I_t^A}{R_t^A} - \frac{I_t^B}{R_t^B} \right) D^I \ . \tag{5}$$

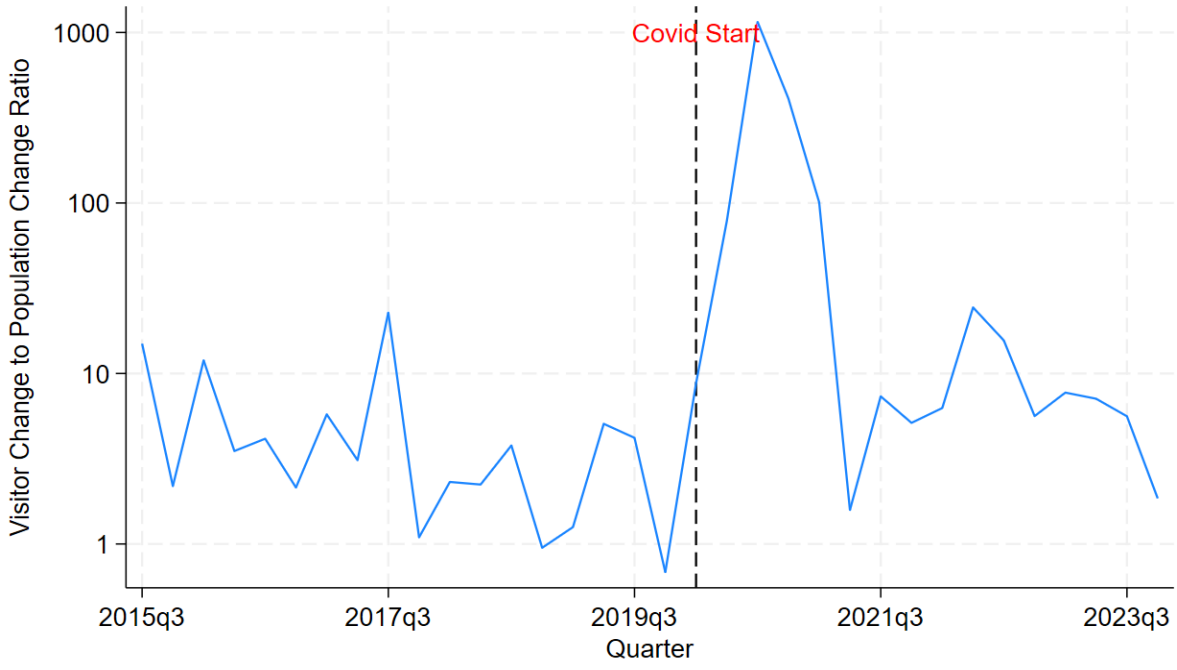
To further minimize the domestic population growth terms relative to the international traveler term, I subtract the equation from period t against that from a different time period, $t-k$, to obtain the following difference-in-differences specification:

$$\begin{aligned} \left(\frac{\Delta N_t^A}{R_t^A} - \frac{\Delta N_t^B}{R_t^B} \right) - \left(\frac{\Delta N_{t-k}^A}{R_{t-k}^A} - \frac{\Delta N_{t-k}^B}{R_{t-k}^B} \right) = \\ \left(\frac{\Delta R_t^A}{R_t^A} - \frac{\Delta R_t^B}{R_t^B} \right) (D_t^R + \Delta D_t^R) - \left(\frac{\Delta R_{t-k}^A}{R_{t-k}^A} - \frac{\Delta R_{t-k}^B}{R_{t-k}^B} \right) (D_{t-k}^R + \Delta D_{t-k}^R) \\ + \left[\left(\frac{I_{t-k}^A}{R_{t-k}^A} - \frac{I_{t-k}^B}{R_{t-k}^B} \right) - \left(\frac{I_t^A}{R_t^A} - \frac{I_t^B}{R_t^B} \right) \right] D^I \ . \end{aligned} \tag{6}$$

By differencing between time periods, I take advantage of the natural experiment of the pandemic-related international travel restrictions to amplify the "signal" of changes in international travelers entering Canada (i.e., the term in blue) against the "noise" from

the changes in domestic demand terms (i.e., the terms in red). While population growth rates change relatively slowly from year to year, even during the pandemic, the number of international travelers decreased by more than 90% year-over-year, as shown in Figure 2. Comparing the time periods just before the COVID-19 pandemic started against the first year of the pandemic yields the greatest "signal-to-noise" ratio of large changes in per capita foreign visitors against per capita population growth rates. I decrease the "noise" further by comparing quarterly periods rather than annual periods, since population growth rates are mechanically smaller during shorter time intervals. As shown in Figure 4, the "signal-to-noise" ratio is consistently below 10 in the years before the pandemic, shoots up to more than 1000 during the first year of the pandemic, and then comes back down to around 10 after the first year.

Figure 4: **Ratio of Year-over-Year Changes in Per Capita Foreign Visitors over Quarterly Per Capita Population Growth**



Source: Bank of Canada, Statistics Canada, author's calculations.

Therefore, for my main specification, I estimate the following bivariate regression (Equation 7) during the first full year of the international travel restrictions, comparing identical quarters year-over-year to eliminate potential seasonal confounders (population growth rates and households' cash holding behaviors could display seasonal patterns).

$$\left(\frac{\Delta N_t^A}{R_t^A} - \frac{\Delta N_t^B}{R_t^B}\right) - \left(\frac{\Delta N_{t-k}^A}{R_{t-k}^A} - \frac{\Delta N_{t-k}^B}{R_{t-k}^B}\right) \approx \left[\left(\frac{I_{t-k}^A}{R_{t-k}^A} - \frac{I_{t-k}^B}{R_{t-k}^B}\right) - \left(\frac{I_t^A}{R_t^A} - \frac{I_t^B}{R_t^B}\right)\right] D^I. \quad (7)$$

Taking the model to the data, ΔN_t^A is the quarterly net withdrawal of \$100 notes from BNDS region A, R_t^A is the quarterly population estimate for the same region A from Statistics Canada, and I_t^A is the number of non-resident visitors entering Canada in region A. All parameters except for D^I are known, so I can estimate the average holdings of CAD \$100 notes per international visitor via bivariate regression.

For robustness checks, I also estimate the full specification via Equation 6. While both D_t^R and ΔD_t^R are not observed in the data, I observe their coefficients in that equation, which consist of differences in regional-level population growth. Therefore, the full specification can be estimated by including these population growth differences as explanatory variables, which explicitly controls for simultaneous shocks to the domestic demand of \$100 notes, given the assumption that D_t^R is identical across regions but can vary over time. Some examples of these shocks include the slowdown in overall domestic population growth, sanitation concerns and lockdown measures decreasing transactional demand for banknotes (Chen *et al.*, 2021), the general economic uncertainty increasing the store-of-value demand for banknotes (Chen *et al.*, 2020), and an increase in accessibility of \$100 notes as a few major FIs (RBC and TD) introduced the denomination in their ATMs across the country. By definition, the full specification also explicitly controls for differential changes in population growth across regions.

5 Results and Discussions

5.1 Baseline Estimates

I estimate the bivariate regression from Equation 7 as the baseline specification. Since COVID-19 related international travel restrictions came into force part way through 2020Q1, I look at four separate quarterly comparisons between one pre-pandemic quarter and one quarter in the first year of the pandemic: 2019Q1 vs. 2021Q1, 2019Q2 vs. 2020Q2, 2019Q3 vs. 2020Q3, and 2019Q4 vs. 2020Q4. There are 21 observations for each comparison, which is equal to the number of distinct pairings of the 7 BNDS regions excluding Ontario.

The baseline bivariate regression results are illustrated in Figure 5. The four graphs correspond to the four quarterly comparisons. Each dot in the graphs represents a region pair. Its horizontal coordinate is the difference between changes in the per capita number of foreign visitors to the two regions between 2019 and the first full year of the COVID-19 pandemic, corresponding to the explanatory variable on the right hand side of Equation 7. Its vertical coordinate is the difference between changes in the per capita net demand for $100 notes (in value terms) for the two regions between 2019 and the first full year of the COVID-19 pandemic, corresponding to the term on the left hand side of Equation 7. Therefore, the red line represents the linear fit, whose slope is equal to the estimated demand of $100 notes per foreign visitor.

At first glance, it is apparent that region pairs that include BC (i.e., the Vancouver RDP) show the largest variations in per capita foreign visitors, which is expected since it's the province with the highest foreign-visitor and student-to-population ratios pre-pandemic (see Table 2). These region pairs also show the largest changes in per capita net demand for $100 notes during the pandemic, consistent with these changes being primarily driven by changes in international traveler demand. While the other region pairs show less variation, they are nevertheless clustered around the fit line, with an increase in difference-in-differences of per capita foreign visitors generally corresponding to an increase in difference-in-differences of the per capita net $100 note demand.[11]

[11]Note that the range of the horizontal axis is different across the four quarterly comparisons, driven by larger influxes of foreign students and visitors in Q2 and Q3, during the spring and summer months,

The estimated demand of $100 notes per foreign visitor is the slope of the fitted lines in Figure 5. It ranges from a low of $132 for the Q3 comparison to a high of $195 for the Q1 comparison. Estimates for the two other quarter comparisons sit squarely in the middle, with $165 and $168 per foreign visitor for Q2 and Q4, respectively. For all comparison quarters, the region pairs are tightly clustered around the linear fit line, suggesting that the estimates are significant and that the bivariate coefficient can explain most of the variation in the data.

This tight clustering is reflected in the very high R-squared for all four quarterly bivariate regressions, as shown in Table 3. In all cases, more than 80% of the variation in the differences of the per capita net demand for $100 notes can be explained by the changes in the per capita number of foreign visitors entering Canada. The coefficients of interest are highly significant as well, with a p-value far below 1%.

Table 3: **Baseline Estimates of Demand for $100 Notes per Foreign Visitor**

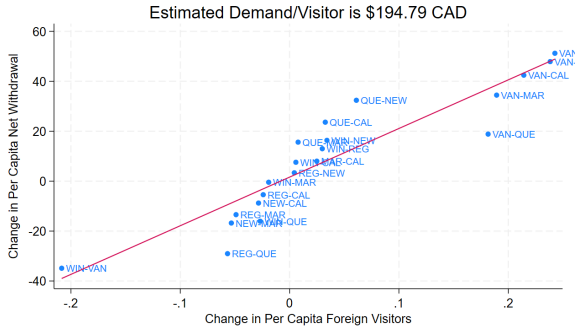
	(1) 2019Q1–2021Q1	(2) 2019Q2–2020Q2	(3) 2019Q3–2020Q3	(4) 2019Q4–2020Q4
VARIABLES	Demand DiD	Demand DiD	Demand DiD	Demand DiD
Visitor DiD	194.8***	165.1***	131.7***	168.2***
	(19.61)	(13.13)	(11.93)	(16.21)
Constant	1.617	-4.048	10.17***	3.697*
	(2.314)	(2.842)	(3.461)	(2.045)
Observations	21	21	21	21
R-squared	0.839	0.893	0.865	0.850

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

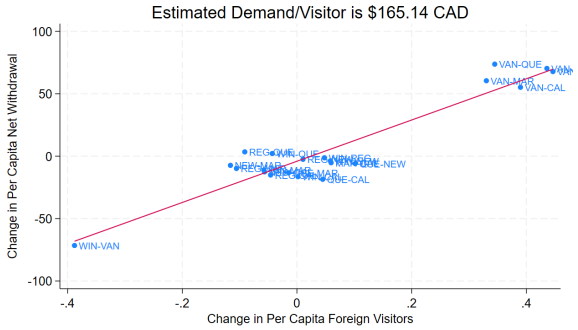
Taking the average of coefficients for all four quarters, I find that each foreign visitor coming to Canada brought on average $165 worth of $100 notes with them in 2019. Over

compared to Q1 and Q4. These fluctuations impact BC the most, but robustness checks excluding BC show estimates that are very similar to our baseline results. See Appendix B.1 for details.

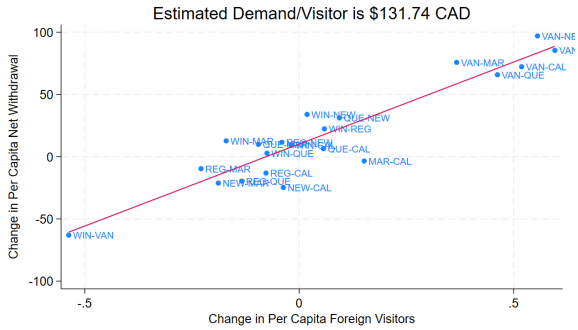
Figure 5: **Baseline Estimates of Demand for $100 Notes per Foreign Visitor**



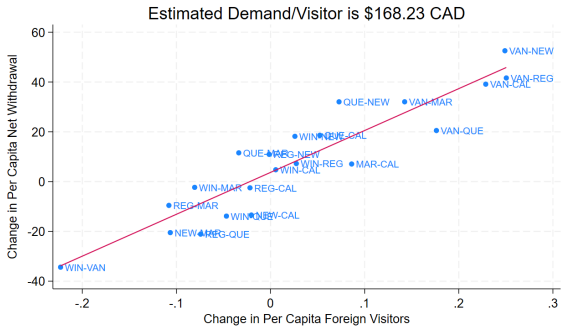
(a) 2019Q1 vs. 2021Q1



(b) 2019Q2 vs. 2020Q2



(c) 2019Q3 vs. 2020Q3



(d) 2019Q4 vs. 2020Q4

The vertical axis in each figure represents the difference-in-differences in per capita net withdrawal of $100 notes for a region pair between two quarters, and the horizontal axis represents the difference-in-differences in per capita foreign visitors entering each of the two regions between the two quarters. Each dot represents a region pair (excluding pairs with Ontario). The red line represents the linear fit, with its slope equal to the estimated demand per foreign visitor in terms of $100 notes. Source: Bank of Canada, Statistics Canada, author's calculations.

that same year, Canada welcomed 32.4 million non-resident visitors. Multiplying both numbers together gives the total value of $100 notes brought in from international travelers to Canada, which is $5.34 billion per year, or the equivalent of 53.4 million $100 notes per year.

Does demand from international travelers constitute a significant fraction of overall $100 CAD notes in circulation? For a valid comparison, the total number of notes brought in by foreign visitors per year, which is a flow variable, needs to be converted to a stock variable. In order to do so, I make the assumption that notes going out of Canada to satisfy demand by international travelers take one year on average to be brought back into Canada. Therefore, at any one time, around 53 million $100 notes are held outside Canada to satisfy demand by foreign visitors, constituting roughly 10% of the 527.3 million $100 notes in circulation at the end of 2019.

5.2 Robustness Checks

The first robustness check consists of estimating the full specification in Equation 6 by including the population change terms. Results for all four quarterly comparisons are shown in Table 4. The estimated $100 note demand per foreign visitor is largely the same compared with the baseline bivariate results, with all four coefficients being highly positive and significant. The average across these coefficients becomes $152 per foreign visitor, very close to the $165 obtained from baseline estimates. This result is just as I expected, since the change in the per capita population growth rate ("noise") is more than two orders of magnitude smaller than the change in the per capita number of foreign visitors ("signal") during the pandemic natural experiment. So, including the former does not change the result.

Since Equation 7 applies identically to all time period comparisons, a second robustness check would be to combine all four quarter comparisons and estimate the baseline bivariate regression on the full sample of $21 * 4 = 84$ region pairs (excluding Ontario). The results are illustrated in Figure 6. The estimated demand for $100 notes per foreign visitor is around $150, very close to the baseline estimate. Observations are clustered around the linear fit line, suggesting that the amount of variation explained by the independent variable is very

Table 4: **Full Specification Regressions of Demand of $100 Notes per Foreign Visitor**

	(1) 2019Q1–2021Q1	(2) 2019Q2–2020Q2	(3) 2019Q3–2020Q3	(4) 2019Q4–2020Q4
VARIABLES	Demand DiD	Demand DiD	Demand DiD	Demand DiD
Visitor DiD	209.5***	157.2***	112.6***	128.8**
	(17.88)	(21.54)	(10.64)	(47.93)
Observations	21	21	21	21
R-squared	0.895	0.913	0.947	0.888

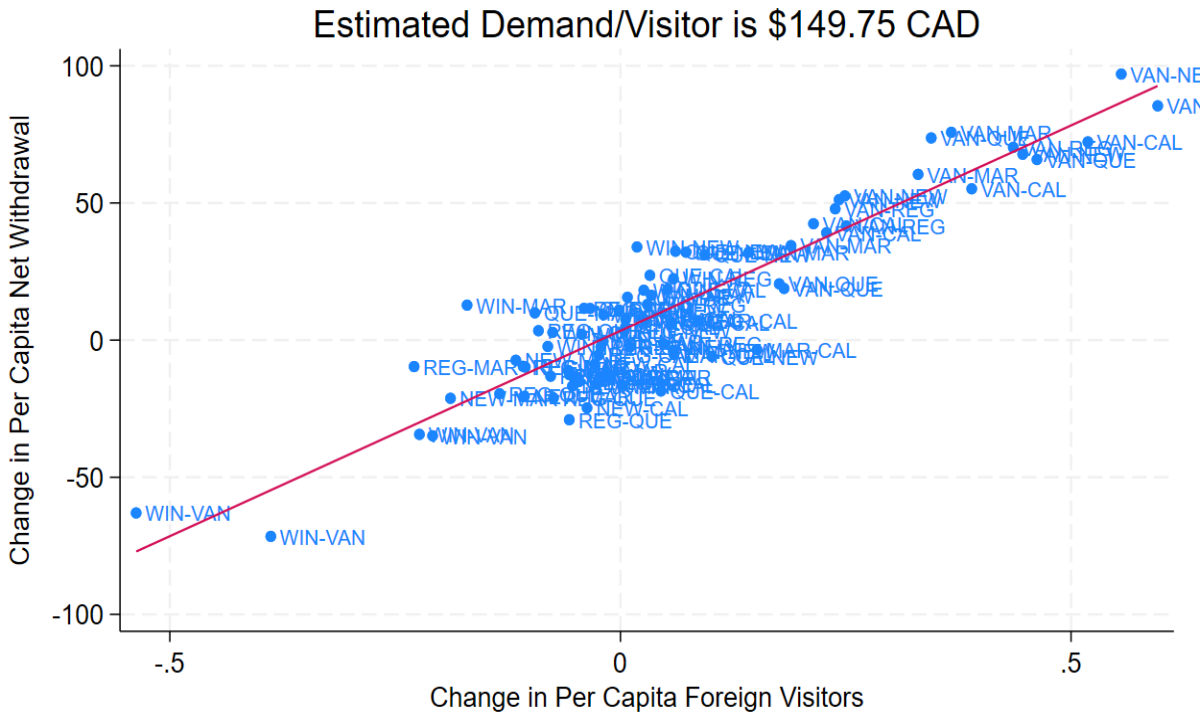
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

high.

A third concern is that seasonal domestic-note demand patterns may be different from year to year given holidays that move across quarters from one year to the next, such as Easter, which moves between March and April, and Ramadan, which moves through the year. (Dunbar, 2019) While these year-over-year changes should largely be controlled for by the baseline difference-in-differences strategy, I conduct an additional robustness check using half-year time periods instead of quarters, since both Easter and Ramadan between 2019 and 2021 occurred during the first half of the year. The results are shown in Table 5 and are very similar to the baseline estimates.

Another concern is that the international travel restrictions imposed during the pandemic not only affected the demand of CAD notes by international visitors, but may have also affected its supply to foreign countries. The decline in the number of passenger flights could have severely restricted the ability of Canadian FIs to satisfy banknote demand abroad, since cargo is often carried in conjunction with passengers on these flights. In that case, the few foreign visitors to Canada may not have been able to obtain CAD notes prior to entering Canada, meaning that the decline in the number of visitors carrying cash is greater than the observed decline in the total number of visitors, biasing the estimate upward.

Figure 6: **Full-Year Estimate of Demand of $100 Notes per Foreign Visitor**



The vertical axis represents the difference-in-differences in per capita net withdrawal of $100 notes for a region pair between two quarters, and the horizontal axis represents the difference-in-differences in the number of per capita foreign visitors entering each of the two regions between two quarters. Each dot represents a region pair (excluding pairs with Ontario). The red line represents the linear fit, with its slope equal to the estimated demand per foreign visitor in terms of $100 notes. Source: Bank of Canada, Statistics Canada, author's calculations.

I address this concern in two ways. First, Figure 7 shows that supply constraints may not be binding because air cargo shipments rebounded quickly after the first couple of months of the pandemic. Second, I compute a lower bound estimate assuming that supply constraints were binding such that no foreign visitor could obtain CAD notes before entering Canada. For these estimates, I set the visitor number $I_t = 0$ after the start of the pandemic and re-estimate my baseline specification. The results are shown in Table 6 and are basically unchanged from the baseline estimates.

Table 5: **Estimates Using Half-Year Time Intervals**

	(1) 2019H1–2021H1	(2) 2019H2–2020H2
VARIABLES	Demand DiD	Demand DiD
Visitor DiD	161.9***	141.6***
	(9.781)	(12.47)
Observations	21	21
R-squared	0.935	0.872

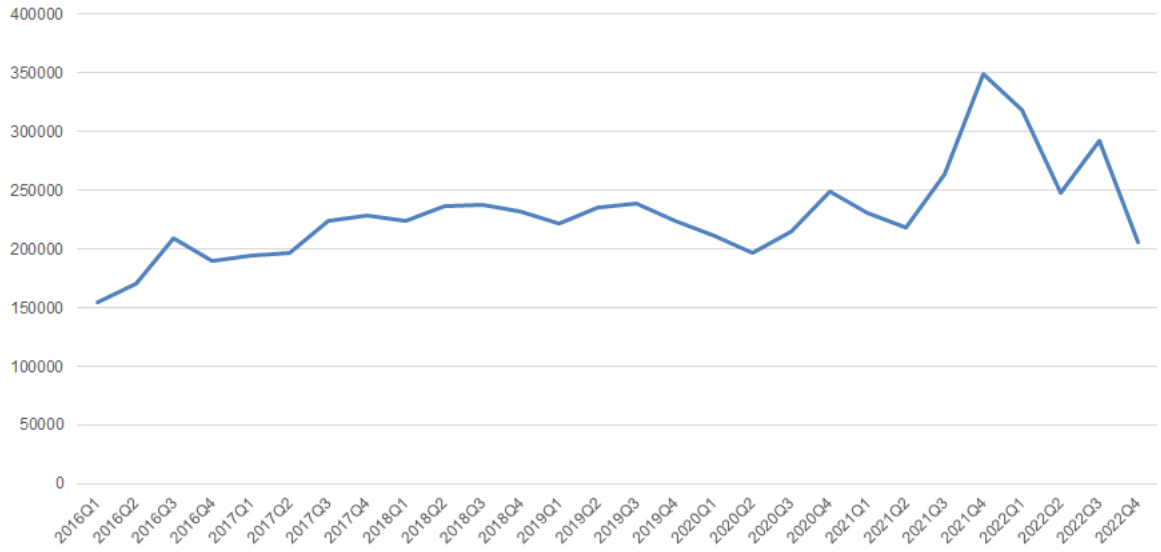
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: **Lower Bound Estimates Accounting for Supply-Side Disruptions**

	(1) 2019Q1–2021Q1	(2) 2019Q2–2020Q2	(3) 2019Q3–2020Q3	(4) 2019Q4–2020Q4
VARIABLES	Demand DiD	Demand DiD	Demand DiD	Demand DiD
Visitor DiD	183.8***	161.9***	128.5***	159.0***
	(18.77)	(12.68)	(11.66)	(15.44)
Observations	21	21	21	21
R-squared	0.835	0.896	0.865	0.848

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 7: **Goods Carried as Air Cargo by Canadian Air Carriers (kg)**



The vertical axis represents the total amount of air cargo carried by Canadian air carriers in each quarter. Source: Statistics Canada

Finally, I relax the assumption that each region in Canada has similar domestic per capita holdings for $100 notes on average. In an alternative specification, I explicitly allow for differences in average domestic cash holdings between regions, which is consistent with survey results that show that average cash holdings in some regions, e.g. Quebec, are less than the Canadian average, while average cash holdings in other regions, e.g. BC, are more than the Canadian average (Henry *et al.*, 2018, 2022). Relaxing this assumption and calibrating average domestic demand to data from surveys would also allow for differentiated shocks to per capita domestic holdings during the first year of the pandemic.

Including regional differences in average domestic demand implies adding a superscript to regional per capita domestic demand. Then Equation 3 becomes

$$\Delta N_t^A = \Delta R_t^A D_t^{R,A} + R_t^A \Delta D_t^{R,A} + \Delta R_t^A \Delta D_t^{R,A} - I_t^A D^I \ , \tag{8}$$

where $D_t^{R,A}$ is the average domestic demand per resident in region A in period t. Dividing by regional population on both sides of the equation and subtracting the net demand

in region A against the net demand in region B produces the following first difference equation:

$$\frac{\Delta N_t^A}{R_t^A} - \frac{\Delta N_t^B}{R_t^B} = \left(\frac{\Delta R_t^A}{R_t^A} D_t^{R,A} - \frac{\Delta R_t^B}{R_t^B} D_t^{R,B}\right) + (\Delta D_t^{R,A} - \Delta D_t^{R,B}) + \left(\frac{\Delta R_t^A}{R_t^A} \Delta D_t^{R,A} - \frac{\Delta R_t^B}{R_t^B} \Delta D_t^{R,B}\right) - \left(\frac{I_t^A}{R_t^A} - \frac{I_t^B}{R_t^B}\right) D^I \ . \tag{9}$$

To simplify this equation and focus on the differences between average regional holdings of $100 notes in this alternative specification, I make the assumption that the per capita population growth rate differences between Canadian regions is negligible and can be ignored. This assumption is supported by the fact that including changes in regional population growth rates in the full specification regression previously did not affect the estimated coefficients. Furthermore, average regional cash holdings may have experienced double-percentage changes in the span of a few years (Henry *et al.*, 2018, 2022). Incorporating this assumption simplifies the regional differences equation to the following:

$$\frac{\Delta N_t^A}{R_t^A} - \frac{\Delta N_t^B}{R_t^B} = \frac{\Delta R_t^{CAN}}{R_t^{CAN}} (D_t^{R,A} - D_t^{R,B}) + \left(1 + \frac{\Delta R_t^{CAN}}{R_t^{CAN}}\right) (\Delta D_t^{R,A} - \Delta D_t^{R,B}) - \left(\frac{I_t^A}{R_t^A} - \frac{I_t^B}{R_t^B}\right) D^I \ , \tag{10}$$

where $\frac{\Delta R_t^{CAN}}{R_t^{CAN}}$ is the quarterly population growth rate in the entire country. We then apply the second difference between time periods to obtain the alternative full specification:

$$\begin{aligned} \left(\frac{\Delta N_t^A}{R_t^A} - \frac{\Delta N_t^B}{R_t^B}\right) - \left(\frac{\Delta N_{t-k}^A}{R_{t-k}^A} - \frac{\Delta N_{t-k}^B}{R_{t-k}^B}\right) = \\ \frac{\Delta R_t^{CAN}}{R_t^{CAN}} (D_t^{R,A} - D_t^{R,B}) - \frac{\Delta R_{t-k}^{CAN}}{R_{t-k}^{CAN}} (D_{t-k}^{R,A} - D_{t-k}^{R,B}) + \\ \left(1 + \frac{\Delta R_t^{CAN}}{R_t^{CAN}}\right) (\Delta D_t^{R,A} - \Delta D_t^{R,B}) - \left(1 + \frac{\Delta R_{t-k}^{CAN}}{R_{t-k}^{CAN}}\right) (\Delta D_{t-k}^{R,A} - \Delta D_{t-k}^{R,B}) + \\ \left[\left(\frac{I_{t-k}^A}{R_{t-k}^A} - \frac{I_{t-k}^B}{R_{t-k}^B}\right) - \left(\frac{I_t^A}{R_t^A} - \frac{I_t^B}{R_t^B}\right)\right] D^I \ . \end{aligned} \tag{11}$$

Taking this alternative specification to the data, I use average household-level regional cash holdings of $100 notes from surveys taken just before and during the pandemic. More specifically, I use average regional cash holdings from the 2017 Methods-of-Payment (MOP) survey conducted in 2017Q4,[12] the 2019 Cash Alternative Survey conducted in 2019Q3, and the 2021 MOP survey conducted in 2021Q4.[13] To obtain average regional cash holdings at the quarterly frequency, I make a linear interpolation for average regional cash holdings between these data points, which also produces the average change in cash holdings per quarter.

Since the surveys above only account for household holdings of cash, they underestimate overall domestic cash demand by ignoring business cash holdings and cash held by FIs, such as in branches and ATMs. Given the lack of data on these two other sources of domestic cash demand, I impose the assumption that non-household domestic demand for cash is proportional to household demand with a factor m. In addition to non-household domestic demand, m could also account for the surveys missing household cash holdings in the extreme right tail of the distribution. The final estimating equation becomes

$$\begin{aligned}\left(\frac{\Delta N_t^A}{R_t^A} - \frac{\Delta N_t^B}{R_t^B}\right) - \left(\frac{\Delta N_{t-k}^A}{R_{t-k}^A} - \frac{\Delta N_{t-k}^B}{R_{t-k}^B}\right) = \\ m\left[\frac{\Delta R_t^{CAN}}{R_t^{CAN}}(D_t^{R,A} - D_t^{R,B}) - \frac{\Delta R_{t-k}^{CAN}}{R_{t-k}^{CAN}}(D_{t-k}^{R,A} - D_{t-k}^{R,B})\right] + \\ m\left[\left(1 + \frac{\Delta R_t^{CAN}}{R_t^{CAN}}\right)(\Delta D_t^{R,A} - \Delta D_t^{R,B}) - \left(1 + \frac{\Delta R_{t-k}^{CAN}}{R_{t-k}^{CAN}}\right)(\Delta D_{t-k}^{R,A} - \Delta D_{t-k}^{R,B})\right] + \\ \left[\left(\frac{I_{t-k}^A}{R_{t-k}^A} - \frac{I_{t-k}^B}{R_{t-k}^B}\right) - \left(\frac{I_t^A}{R_t^A} - \frac{I_t^B}{R_t^B}\right)\right] D^I \ .\end{aligned} \tag{12}$$

Given that population growth numbers can be obtained from Statistics Canada and the average domestic household holdings of $100 notes comes from the MOP surveys described previously, both coefficients for m in Equation 12 are known, so I can include the sum of

[12] These surveys typically ask each respondent how many notes of each denomination they hold in their wallet ("cash on hand") or otherwise at home ("other cash holdings").

[13] Note that Canada is divided into five regions in these surveys: Atlantic, Quebec, Ontario, Prairies and British Columbia. To match these survey results against the BNDS regions, I match Alberta, Saskatchewan and Manitoba to the average cash holdings in the Prairies region. I also match both Newfoundland and the Maritimes to the average cash holdings in the Atlantic region.

both as an explanatory variable in the estimation, which controls for regional differences in domestic $100 note holdings.

Results for estimating Equation 12 are shown in Table 7. On a four-quarter average basis, each foreign visitor brought in $182 worth of $100 CAD notes, which is again very close to the baseline estimate of $165, demonstrating that my results are robust to regional differences in domestic demand for $100 notes.

Table 7: **Demand Estimates for Including Regional Differences**

	(1) 2019Q1–2021Q1	(2) 2019Q2–2020Q2	(3) 2019Q3–2020Q3	(4) 2019Q4-2020Q4
VARIABLES	Demand DiD	Demand DiD	Demand DiD	Demand DiD
Visitor DiD	195.5***	162.7***	127.8***	240.3***
	(22.45)	(12.95)	(7.27)	(7.37)
Observations	17	17	17	17
R-squared	0.845	0.926	0.962	0.989

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In further robustness checks detailed in Appendix B, I show that no one region completely drives the baseline results, that applying my estimation strategy to smaller denominations where demand from foreign visitors is less plausible does not show significant results, and that using the relaxation of international travel restrictions after 2021 gives similar results to the baseline estimates.

5.3 Ontario and Evidence for Foreign Hoarding Demand

Ontario represents a separate case from all the other BNDS regions given the assumption that all wholesale foreign shipments of banknotes go out from the Toronto RDP. Therefore, the net demand for $100 notes in Ontario differs from other regions and contains one

additional term:

$$\Delta N_t^O = \Delta R_t^O D_t^R + R_t^O \Delta D_t^R + \Delta R_t^O \Delta D_t^R - I_t^O D^I + I_t^{CAN} D^I \ , \tag{13}$$

where the superscript O represents the Ontario region and I_t^{CAN} represents the number of foreign visitors entering Canada during time period t. Here I make the additional assumption that all banknotes used to satisfy demand from international travelers entering Canada during a time period are also sent out during the same time period.

Following the same derivation as in the section above, Equation 7 for other regions becomes the following equation for Ontario:

$$\begin{aligned} & \left(\frac{\Delta N_t^O}{R_t^O} - \frac{\Delta N_t^B}{R_t^B}\right) - \left(\frac{\Delta N_{t-k}^O}{R_{t-k}^O} - \frac{\Delta N_{t-k}^B}{R_{t-k}^B}\right) \\ \approx & \left[\left(\frac{I_{t-k}^O}{R_{t-k}^O} - \frac{I_{t-k}^B}{R_{t-k}^B}\right) - \left(\frac{I_t^O}{R_t^O} - \frac{I_t^B}{R_t^B}\right) + \left(\frac{I_t^{CAN}}{R_t^O} - \frac{I_{t-k}^{CAN}}{R_{t-k}^O}\right)\right] D^I \ , \end{aligned} \tag{14}$$

where the additional term represents the change in the overall number of foreign visitors entering Canada year-over-year, divided by the number of domestic residents in Ontario.

As a final robustness check, I estimate an overall regression that includes all region pairs, applying Equation 7 for all region pairs without Ontario and Equation 14 for all region pairs with Ontario. The estimated coefficients are shown in Table 8. All quarterly estimates show clear attenuation from the baseline estimates in Table 3, suggesting that the regression is misspecified. The attenuation bias is especially severe for the Q4 regression, where the percentage of variation explained by the independent variable falls to less than 30%.

The reason for the attenuation bias is clear in the scatter plots of all region pairs, shown in Figure 8: the pairs including Ontario (i.e., the Toronto RDP) are shifted leftward compared with the other pairs. This misspecification is consistent with an unobserved source of increasing foreign demand for CAD $100 notes that occurred simultaneously with

Table 8: **Demand Estimates for All Region Pairs**

	(1) 2019Q1–2021Q1	(2) 2019Q2–2020Q2	(3) 2019Q3–2020Q3	(4) 2019Q4-2020Q4
VARIABLES	Demand DiD	Demand DiD	Demand DiD	Demand DiD
Visitor DiD	153.8***	131.8***	89.11***	64.21***
	(13.56)	(9.620)	(10.33)	(19.87)
Observations	28	28	28	28
R-squared	0.832	0.878	0.741	0.287

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

the first year of the pandemic, which would be satisfied via wholesale shipments abroad out of the Toronto RDP. This increase in unmodeled foreign demand is negatively correlated with the change in the number of foreign visitors (large decrease in 2020Q1–2021Q1) and results in negatively biased estimates in Table 8.

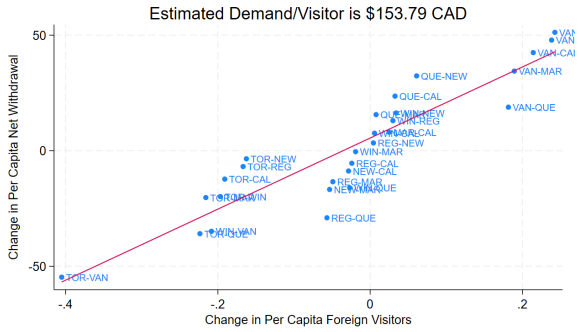
The additional foreign demand could come from an increase in foreign hoarding demand for CAD $100 notes for wealth diversification purposes, which I assumed to be constant in the estimation model.[14] One corroborating piece of evidence in favour of this hypothesis is the increase in official foreign exchange reserves held in Canadian dollars between 2019Q4, when it totaled $206 billion USD, and 2021Q4, when it grew to $287 billion USD.[15]

Mathematically, a non-negligible foreign hoarding demand component would only affect net demand of $100 notes at the Toronto RDP, since these notes are going out of the country without coming back. Mathematically, the estimating equation for Ontario becomes the following:

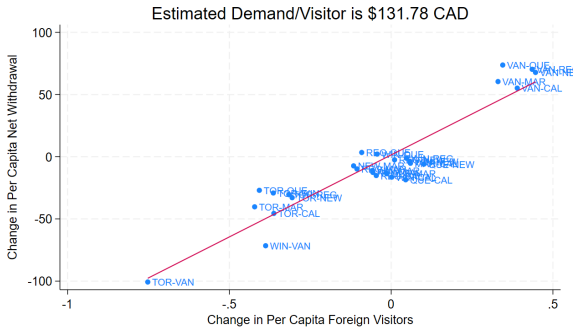
[14] CAD note demand for transactional purposes abroad is unlikely to be significant for the $100 note, given that it is the largest denomination available.

[15] These numbers come from the International Monetary Fund, at https://data.imf.org/regular.aspx?key=41175.

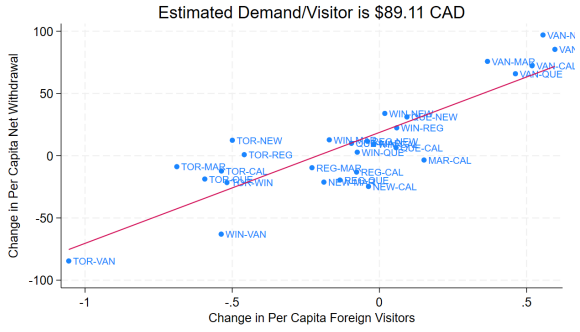
Figure 8: **All Pairs Estimates of Demand of $100 Notes per Foreign Visitor**



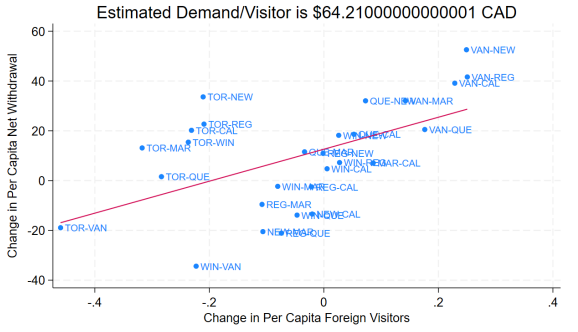
(a) 2019Q1 vs. 2021Q1



(b) 2019Q2 vs. 2020Q2



(c) 2019Q3 vs. 2020Q3



(d) 2019Q4 vs. 2020Q4

The vertical axis in each figure represents the difference-in-differences in per capita net withdrawal of $100 notes for a region pair between two quarters, and the horizontal axis represents the difference-in-differences in per capita foreign visitors entering each of the two regions between two quarters. Each dot represents a region pair. The red line represents the linear fit, with its slope equal to the estimated demand per foreign visitor in terms of $100 notes. Source: Bank of Canada, Statistics Canada, author's calculations.

$$\begin{aligned}
&\left(\frac{\Delta N_t^O}{R_t^O} - \frac{\Delta N_t^B}{R_t^B}\right) - \left(\frac{\Delta N_{t-k}^O}{R_{t-k}^O} - \frac{\Delta N_{t-k}^B}{R_{t-k}^B}\right) \\
\approx &\left[\left(\frac{I_{t-k}^O}{R_{t-k}^O} - \frac{I_{t-k}^B}{R_{t-k}^B}\right) - \left(\frac{I_t^O}{R_t^O} - \frac{I_t^B}{R_t^B}\right) + \left(\frac{I_t^{CAN}}{R_t^O} - \frac{I_{t-k}^{CAN}}{R_{t-k}^O}\right)\right] D^I \\
&+ \left(\frac{D_t^F}{R_t^O} - \frac{D_{t-k}^F}{R_{t-k}^O}\right) ,
\end{aligned} \tag{15}$$

where D_t^F represents the unobserved foreign hoarding demand during period t. Since the additional term (highlighted in red) is likely to be positive during the first year of the pandemic, adding back this unobserved demand shock would shift the region pairs including Ontario towards the right and towards the other region pairs in Figure 8.

6 Conclusion

For major international reserve currencies such as the U.S. dollar (Judson, 2024) and the euro (Bartzsch *et al.*, 2013a), research has shown that a large percentage of notes in circulation are held abroad. This fact has major implications in terms of seignorage revenue and can affect a central bank's independence and ability to conduct monetary policy (Fung *et al.*, 2014). It also constitutes a partial explanation to the "cash paradox" of increasing notes in circulation despite declining cash usage at points of sale (Jiang and Shao, 2020). Due to data and other constraints, however, this result has not been extended to smaller economies such as Canada.

In this paper, I estimate the demand for CAD banknotes from international visitors to Canada by exploiting the exogenous shock from COVID-19 international travel restrictions. A difference-in-differences strategy identifies international visitor demand shocks separately from contemporaneous domestic demand shocks due to the pandemic. I find that each international visitor brought on average $165 worth of $100 notes with them to Canada prior to the pandemic. Under plausible assumptions, total holdings by international visitors constitute roughly 10% of total $100 CAD notes in circulation at the end of 2019, which is a significant proportion of overall CAD notes in circulation.

This finding raises questions that provide fruitful avenues for future research. First, does this result apply to other small and medium-sized economies that do not possess major international reserve currencies? Since COVID-19 travel restrictions were imposed worldwide, a similar strategy could be used to explore this question in many other countries. Second, has demand from international visitors always been a significant contributor to overall note demand in Canada? The current finding provides a snapshot in time, taking advantage of a one-time shock in international travel due to the pandemic, so other shocks may be needed to identify this effect in the more distant past. Finally, the possibility of significant foreign hoarding demand for CAD notes needs to be further explored, as the intriguing results for region pairs that include Ontario tantalizingly suggest.

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A Timeline of COVID-19 International Travel Restrictions in Canada

- January 29, 2020: First travel advisory against non-essential travel to China issued.
- February 29, 2020: Travel advisory warning against all travel to the cities of Daegu and Cheongdo issued.
- March 18, 2020: All foreign nationals (except from the U.S.) barred from entering Canada.
- March 21, 2020: All U.S. nationals barred from entering Canada via land or air for "non-essential" travel.
- March 24, 2020: Mandatory 14-day self-isolation for Canadians returning from international travel.
- June 21, 2021: New immigrants (permanent residents) allowed to land in Canada.
- July 5, 2021: Fully vaccinated travelers who are permitted to enter Canada no longer have to quarantine.
- September 7, 2021: Fully vaccinated foreign nationals can enter the country for "non-essential" reasons.
- April 1, 2022: Fully vaccinated travelers no longer required to provide a pre-entry test result.
- October 1, 2022: Removal of all remaining COVID-19 entry restrictions, as well as testing, quarantine and isolation requirements for unvaccinated travelers.

B Additional Results

In this section, I produce additional robustness checks by considering whether one region is completely driving the baseline results, conducting falsification tests using other denominations where demand from foreign visitors is less plausible, and using the relaxation of international travel restrictions after 2021 to estimate a treatment reversal effect. Finally, I examine potential heterogeneity in foreign-visitor cash demand by origin country.

B.1 Outlier Regions

To find out whether my results are driven by demand changes in any particular region, I estimate the baseline bivariate regression for subsamples that leave out one region in addition to Ontario. The estimates are shown in Table A1 and are very close to each other and to the baseline $165 estimate.

Table A1: **Leave-One-Region-Out Estimates of Demand of $100 Notes per Foreign Visitor**

Region Left Out	**Four-Quarter Average Estimate ($ value of $100 Notes)**
British Columbia	182.8
Alberta	166.0
Saskatchewan	164.1
Manitoba	167.8
Quebec	164.8
Maritimes	169.0
NFL & Labrador	158.7

Source: Author's calculations. In this table New Brunswick and PEI are grouped together with Nova Scotia (i.e., Maritimes) since these two provinces do not have an RDP on their territory. The estimate represents the four-quarter average value of $100 notes carried per foreign visitor in each subsample that leaves the specified region out.

B.2 Falsification Tests Using Smaller Denominations

In principle, the methodology I develop in this paper can be applied to estimate foreign-visitor demand for notes of any denomination. I focus my analysis on $100 notes based on the assumption that demand from foreign visitors is negligible for other denominations. In this section, I test this assumption by applying the baseline bivariate regression (Equation 7) to both $50 and $20 notes. I chose $50 notes because they are the second-highest Canadian banknote denomination and $20 notes because they are the most widely held denomination in circulation.

Table A2: **Demand Estimates for $50 Notes**

	(1) 2019Q1–2021Q1	(2) 2019Q2–2020Q2	(3) 2019Q3–2020Q3	(4) 2019Q4–2020Q4
VARIABLES	Demand DiD	Demand DiD	Demand DiD	Demand DiD
Visitor DiD	-31.00**	57.76***	23.28***	26.48
	(14.06)	(8.621)	(4.296)	(16.53)
Observations	21	21	21	21
R-squared	0.204	0.703	0.607	0.119

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Results are shown in Tables A2 and A3. In contrast to the $100 note estimates, the estimated values held per foreign visitor for $50 and $20 notes are largely insignificant and inconsistent across the four quarterly comparisons, confirming my prior assumption that there is relatively little international traveler demand for the smaller denominations.

B.3 Treatment Reversal

Starting in summer 2021, international travel restrictions were gradually relaxed, with fully vaccinated foreign visitors permitted to enter Canada for "non-essential" reasons by September 2021. All remaining travel restrictions on foreign visitors were lifted by

Table A3: **Demand Estimates for $20 Notes**

	(1) 2019Q1–2021Q1	(2) 2019Q2–2020Q2	(3) 2019Q3–2020Q3	(4) 2019Q4–2020Q4
VARIABLES	Demand DiD	Demand DiD	Demand DiD	Demand DiD
Visitor DiD	-23.61	33.73	-35.04***	-19.35
	(54.46)	(24.96)	(6.673)	(17.21)
Observations	21	21	21	21
R-squared	0.010	0.088	0.592	0.062

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

October 1, 2022. Consequently, there was a steady recovery in the number of international travelers entering the country, up to 60% of pre-pandemic levels by summer 2022 and 85% of pre-pandemic levels by summer 2023 (see Figure 2).

The return of foreign visitors implies a return of international traveler demand for Canadian $100 notes. To test for this treatment reversal effect, I estimate the baseline bivariate regression (Equation 7) for four quarterly comparisons between one quarter during the first year of the pandemic and one quarter after the lifting of the international travel restrictions. Specifically, the comparisons are 2021Q1 vs. 2023Q1, 2021Q2 vs. 2023Q2, 2020Q3 vs. 2022Q3, and 2020Q4 vs. 2022Q4.

Results are shown in Table A4. The estimated demand of $100 notes per foreign visitor is positive and significant for all four quarterly comparisons. The four-quarter average estimate is $152 per foreign visitor, which is very close to the $165 baseline result per pre-pandemic foreign visitor.

Table A4: **Treatment Reversal Estimates**

	(1) 2021Q1–2023Q1	(2) 2021Q2–2023Q2	(3) 2020Q3–2022Q3	(4) 2020Q4–2022Q4
VARIABLES	Demand DiD	Demand DiD	Demand DiD	Demand DiD
Visitor DiD	165.1***	85.09***	156.5***	201.2***
	(42.27)	(20.23)	(11.44)	(35.45)
Observations	21	21	21	21
R-squared	0.445	0.482	0.908	0.629

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

B.4 Heterogeneity by Visitor Origin

There could be differences between the amount of Canadian dollar banknotes brought by visitors from different countries. For example, U.S. visitors may not bring as much cash with them since the cash share of transactions is fairly low in the United States compared to other countries around the world (Cubides and O'Brien, 2023; European Central Bank, 2022b) and debit and credit cards issued in the U.S. can widely be used in Canada.

In this section, I analyze foreign-visitor cash demand heterogeneity by visitor origin. In order to do so, I decompose foreign visitors into U.S. visitors versus non-U.S. visitors and allow the average amount of $100 notes carried by these two types of visitors to differ. Equation 3 for $100 net demand then becomes

$$\Delta N_t^A = \Delta R_t^A D_t^R + R_t^A \Delta D_t^R + \Delta R_t^A \Delta D_t^R - I_t^{A,US} D^{I,US} - I_t^{A,non-US} D^{I,non-US} , \quad (16)$$

where $I_t^{A,US}$ and $I_t^{A,non-US}$ represent the number of U.S. and non-U.S. international travelers entering region A in period t, respectively. $D^{I,US}$ and $D^{I,non-US}$ are the average demand for $100 notes per U.S. and non-U.S. international traveler, respectively.

Then the original bivariate regression equation (Equation 7) becomes the following with

two right-hand side terms, one each for U.S. and non-U.S. visitors:

$$\left(\frac{\Delta N_t^A}{R_t^A} - \frac{\Delta N_t^B}{R_t^B}\right) - \left(\frac{\Delta N_{t-k}^A}{R_{t-k}^A} - \frac{\Delta N_{t-k}^B}{R_{t-k}^B}\right) \approx \left[\left(\frac{I_{t-k}^{A,US}}{R_{t-k}^A} - \frac{I_{t-k}^{B,US}}{R_{t-k}^B}\right) - \left(\frac{I_t^{A,US}}{R_t^A} - \frac{I_t^{B,US}}{R_t^B}\right)\right] D^{I,US} + \left[\left(\frac{I_{t-k}^{A,non-US}}{R_{t-k}^A} - \frac{I_{t-k}^{B,non-US}}{R_{t-k}^B}\right) - \left(\frac{I_t^{A,non-US}}{R_t^A} - \frac{I_t^{B,non-US}}{R_t^B}\right)\right] D^{I,non-US} . \quad (17)$$

I estimate Equation 17 using Statistics Canada's data on the number of U.S. and non-U.S. international travelers entering each region of the country. Results are shown in Table A5. There is suggestive evidence that U.S. visitors carry fewer $100 CAD notes with them, with all four quarterly comparisons showing that the estimated amount of cash carried by U.S. visitors is smaller than that for non-U.S. visitors (though the difference is not statistically significant). Taking the average of coefficients across all four quarterly comparisons, the average U.S. visitor carries $139 worth of $100 CAD notes, while the average non-U.S. foreign visitor carries $241 worth of $100 CAD notes.

Table A5: **Demand Estimates for U.S. vs. Non-U.S. Visitors**

	(1) 2019Q1–2021Q1	(2) 2019Q2–2020Q2	(3) 2019Q3–2020Q3	(4) 2019Q4–2020Q4
VARIABLES	Demand DiD	Demand DiD	Demand DiD	Demand DiD
U.S. Visitor DiD	194.3**	123.0**	119.2***	117.5**
	(71.50)	(45.51)	(29.23)	(41.28)
Non-U.S. Visitor DiD	196.2	269.9**	166.7**	332.0**
	(191.6)	(109.1)	(75.14)	(123.9)
Observations	21	21	21	21
R-squared	0.839	0.898	0.867	0.864

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

B.5 Non-pandemic Years

In the baseline results, I take advantage of the natural experiment of the pandemic-related international travel restrictions to amplify the "signal" of changes in international travelers entering Canada, as shown in Figure 4. In this section, I attempt to estimate the baseline bivariate regression in non-pandemic years between 2015 and 2019. Given that the number of foreign visitors entering Canada was fairly stable from year to year, the "signal-to-noise" ratio is low, and I would expect insignificant and inconsistent results.

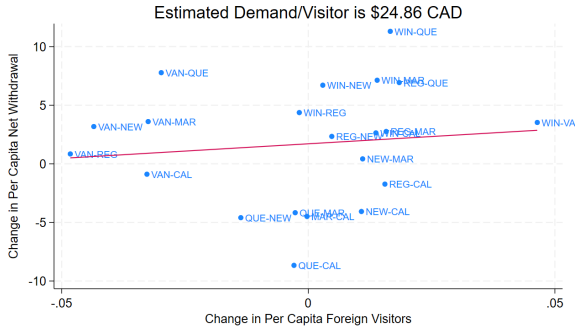
An example of results for Q3 comparisons is shown in Table A6 and Figure 9. As expected, the estimated value of $100 notes carried per foreign visitor varies tremendously, from a low of -$1058 to a high of $324, and three out of four quarterly comparisons are insignificant. These results demonstrate that the natural experiment of pandemic-related international travel restrictions is necessary to obtain reliable and consistent estimates.

Table A6: **Non-pandemic Q3 Estimates**

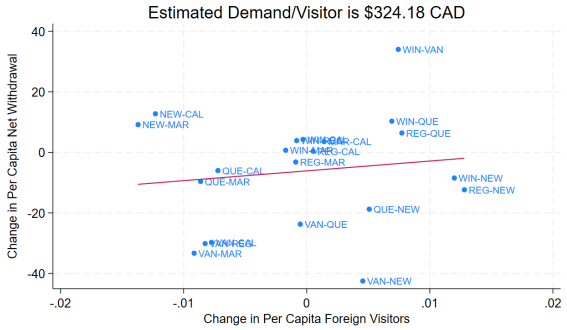
	(1)	(2)	(3)	(4)
	2015Q2–2016Q2	2016Q2–2017Q2	2017Q2–2018Q2	2018Q2–2019Q2
VARIABLES	Demand DiD	Demand DiD	Demand DiD	Demand DiD
Visitor DiD	24.86	324.2	-1,058***	-161.7
	(48.14)	(540.7)	(223.1)	(322.1)
Observations	21	21	21	21
R-squared	0.014	0.019	0.542	0.013

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

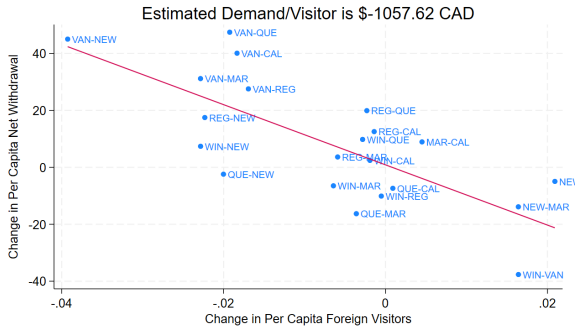
Figure 9: **Non-pandemic Estimates of Demand of $100 Notes per Foreign Visitor**



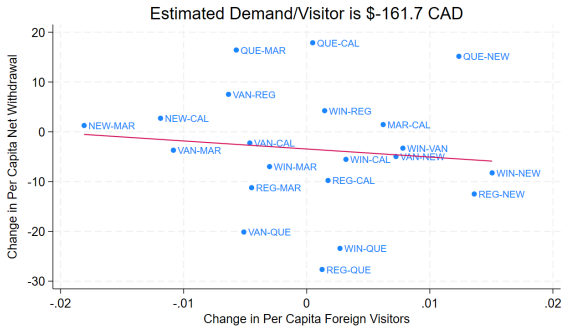
(a) 2015Q3 vs. 2016Q3



(b) 2016Q3 vs. 2017Q3



(c) 2017Q3 vs. 2018Q3



(d) 2018Q3 vs. 2019Q3

The vertical axis in each figure represents the difference-in-differences in per capita net withdrawal of $100 notes for a region pair between two quarters, and the horizontal axis represents the difference-in-differences in per capita foreign visitors entering each of the two regions between two quarters. Each dot represents a region pair (excluding pairs with Ontario). The red line represents the linear fit, with its slope equal to the estimated demand per foreign visitor in terms of $100 notes. Source: Bank of Canada, Statistics Canada, author's calculations.