PIER

PUEY UNGPHAKORN INSTITUTE
FOR ECONOMIC RESEARCH

Exchange Rate Volatility and Cross-Border Travel: Theory and Empirics

by

Wisarut Suwanprasert

August 2021

Discussion Paper

No. 158

Exchange Rate Volatility and Cross–Border Travel: Theory and Empirics*

Wisarut Suwanprasert†
Middle Tennessee State University

July 4, 2021

Abstract

I develop a search-theoretic model to study how consumers' search behavior responds to exchange rate volatility. The model offers two main predictions. First, the number of cross-border travelers is increasing in exchange rate volatility. Second, the elasticity of cross-border travel with respect to exchange rate volatility is increasing in transportation cost. I use monthly Canadian traveler data from 2005 to 2012 to test the model's predictions. The estimate suggests that when exchange rate volatility increases by one standard deviation, the number of same-day travelers increases by 1.6 percent. When exchange rate volatility is measured by implied volatilities, the estimates increase to 2.1–2.5 percent. When the data is restricted to the subperiod before the 2008 financial crisis, the estimated coefficients of exchange rate volatility and implied volatilities increase to 4 percent and 7.3–10.7 percent, respectively. This paper concludes that cross-border shopping behavior responds to both ex ante and ex post exchange rate volatilities.

Keywords: international price differences, exchange rate, exchange rate volatility, cross-border shopping, implied volatility

JEL classification numbers: F10, F14, F31.

*I thank Aaron Gamino, Ohyun Kwon, Pongsak Luangaram, Janelle Mann, Kittichai Saelee, Kanis Saengchote, and participants at the Canadian Economics Association conference for helpful comments and suggestion. Patcharaporn (Numpu) Leepipatpiboon provided research assistance. Any errors that remain are mine.

†Department of Economics and Finance, Jennings A. Jones College of Business, Middle Tennessee State University, Murfreesboro, Tennessee, USA. Email: Wisarut.Suwanprasert@mtsu.edu.

1 Introduction

Unsurprisingly, consumers are more likely to cross international borders to shop in a neighboring country when their currency has appreciated against that of the other country. The literature continues to investigate the effect of exchange rate movement on cross-border shopping, based on numerous country pairs, such as the United States–Canada (Baggs, Beaulieu, Fung, and Lapham, 2016; Baggs, Fung, and Lapham, 2018; Campbell and Lapham, 2004; Chandra, Head, and Tappata, 2014; Chen, Devereux, and Lapham, 2017), the United States–Mexico (Cabral, Mollick, and Saucedo, 2019; Gutiérrez, Sánchez-Atondo, García, Mungaray-Moctezuma, and Calderón, 2021), Switzerland–Italy (Bello, 2020), Norway–Sweden (Friberg, Steen, and Ulsaker, forthcoming), Switzerland–adjacent countries (Auer, Burstein, Lein, and Vogel, 2021), Belgium–Germany–the Netherlands (Beck, Kotz, and Natalia Zabelina, 2020), and Ukraine–Poland (Wosiek and Kata, 2019). However, none of these studies has investigated the role of exchange rate volatility.

Exchange rate volatility is a major concern whenever international trade and investments involve exchange rates. To help firms and investors mitigate risk exposure, financial markets utilize financial products such as forward contracts, futures contracts, and options. Individual consumers, on the other hand, are less likely to use currency risk management strategies. Motivated by this observation, this paper investigates how exchange rate risk affects cross-border shopping behavior.

I develop a dynamic two-country consumer-search model based on Baggs et al. (2018) and Lagos and Wright (2005). To introduce exchange rate volatility, a dynamic model in which consumers face exchange rate risk over time is necessary. However, incorporating the time dimension directly into the model of Baggs et al. (2018) eliminates the model's tractability, because the intertemporal substitution effect would cause the dynamic paths of consumption and savings to be dependent on the expected path of future exchange rates. Furthermore, the general equilibrium effect would cause price distributions to fluctuate according to the realized exchange rate. To overcome this issue, I incorporate model ingredients from Lagos and Wright (2005) into Baggs et al. (2018), resulting in an analytical equilibrium solution.

In my model, potential consumers decide whether to shop in their local market or cross the border to shop in another country's market, based on randomly drawn exogenous consumer-specific travel costs. In the spirit of Burdett and Judd (1983), after arriving at their chosen market, consumers receive a random number of price quotes drawn from the price distribution of all sellers in that market and purchase from the seller with the lowest prices available to them.. Due to a feature of Lagos and Wright (2005), the time path can be simplified to a series of repeated static periods. That is, equilibrium price distributions are in a steady state, and consumers' current decisions can be summarized by the current exchange rate.

The model provides two main predictions. First, an increase in exchange rate volatility results in a larger number of cross-border travelers in that month, if the cumulative distribution function of transportation costs is locally convex. Assuming that the distribution of transportation costs is normal, the CDF is locally convex in the range of parameters in our empirically relevant case, because the border-crossing rate in our data is around 0.8 percent. The first model prediction is intuitive. An increase in exchange rate volatility means that there are more days when consumers benefit from border-crossing and, also, more days when few consumers cross the borders. On average, the number of cross-border travelers in that month increases.

Second, the elasticity of cross-border travel with respect to exchange rate volatility is increasing in transportation costs. The intuition is that nearby consumers often cross the border and do not have to wait for days for the exchange rate to appreciate significantly. In other words, as the distance increases, the curvature of the number of travelers as a function of the exchange rate becomes more convex.

To test the model's predictions, I use monthly data on Canadians who crossed the southern border into the United States between January 2005 and December 2012. The main analysis uses the number of same-day travelers, but I also consider multi-day travelers and combined (same-day and multi-day) travelerstravelers, for robustness. I first demonstrate that the model specification used in the literature suffers from the omitted-variable bias problem, because it does not consider exchange rate volatility. I then estimate the model-implied regression using ordinary least squares (OLS) with unobservable fixed effects.

The main result is that a one-standard-deviation increase in exchange rate volatility, measured by the within-month standard deviation, increases the number of same-day travelers by 1.6 percent. When the time period is limited to the months preceding the 2008 financial crisis, the estimate rises to 4 percent. Subsequently, I estimate the coefficient of the interaction term between exchange rate volatility and distance and find a positive effect on the number of travelers. In line with the second model prediction, the decisions of distant travelers are more sensitive to volatility than are the decisions of nearby travelers. To demonstrate that the empirical findings are robust to various robustness tests, I use a specification curve proposed by Simonsohn et al. (2020) to display the range of estimates under various theoretically justified model specifications.

I then investigate how the expectation of exchange rate risk influences cross-border shopping. I use implied volatility as a measure of ex ante exchange rate volatility. Implied volatility, which is calculated from option prices using the Black-Scholes model, reflects the market's expectations for volatility in the future. I use four durations for implied volatility: one-month implied volatility, three-month implied volatility, six-month implied volatility, and one-year implied volatility. The empirical results are consistent with the main findings. When implied volatility increases by one standard deviation, the number of same-day travelers increases by 2.1–2.5 percent in the entire year coverage and 7.3–10.7 percent in the periods before the 2008 financial crisis. This implies that both ex post and ex ante exchange rate volatilities have a significant impact on cross-border shopping.

This paper connects two areas of the literature. The first area is exchange rate and border crossing. A significant number of papers in this area concentrate on cross-border shopping activity between the United States and Canada. These studies include Baggs et al. (2016), Baggs et al. (2018), Campbell and Lapham (2004), Chandra et al. (2014), and Chen et al. (2017). Other papers investigate cross-border shopping in Europe. For example, Auer et al. (2021) consider Switzerland and the neighboring; Beck et al. (2020) study travel within Belgium, Germany, and the Netherlands; Wosiek and Kata (2019) investigate travel between Ukraine and Poland; Steen et al. (2018) consider the border of Norway and Sweden; Bello (2020) considers the border of Switzerland and Italy. I expand this line of research by demonstrating that the perception of exchange rate risk can cause changes in cross-border travel, even though the exchange rate remains constant.

The second area is consumer search models and trade. A number of studies extend the consumer search model of Burdett and Judd (1983) to study firms' pricing decisions in the context of international trade. Alessandria (2009) and Alessandria and Kaboski (2011) develop theoretical models to investigate international price dispersion and deviation from the law of one price. Baggs et al. (2018) examine the pricing decisions of firms near an international border, when consumers could cross the border to search for lower prices. Suwanprasert (2019) proposes that firms' pricing strategies could explain the role of per capita income in the gravity equation. This paper contributes to the literature by using the Burdett and Judd model to examine how exchange rate risk affects consumers' benefits from cross-border shopping.

The remainder of the paper is structured as follows. Section 2 describes my model. Section 3 solves the model and states the main model predictions. Section 4 describes the data and estimation strategy. Section 5 summarizes the main empirical findings. Section 6 presents results from other variations of our main regression equations. Section 7 investigates the role played by expectations about future exchange rate volatility. Section 8 concludes.

2 Theoretical framework

This model is a hybrid of the models of Baggs et al. (2018) and Lagos and Wright (2005).

2.1 Environment

Time is discrete and continues forever. At this moment, time subscripts can be neglected, since all decisions are static. We will define time subscripts when they matter. Each time period consists of two sequential subperiods called decentralized market (DM) and centralized market (CM). The discount rate $\beta < 1$ applies after each CM.

The world consists of two countries, called Home (H) and Foreign (F). In terms of notation, producer-related variables and consumer-related variables are indexed by i and j, respectively, where $i, j = H, F$. The masses of population in Home and Foreign are L_H and L_F, respectively. The agents supply one unit of labor and earn wage w.

There are two types of goods: one indivisible good and one numeraire good. The indivisible good, henceforth called the DM good, must be purchased from decentralized markets in the first subperiod, where buyers are subject to search frictions. The numeraire good, henceforth called the CM good, can be purchased from a frictionless centralized market in the second subperiod.[1]

[1]The model focuses on cross-border shopping behavior. International trade and global supply chains can be treated

The DM good is perishable and must be consumed within the same period, while the CM good is storable.

Each country hosts one decentralized market that is accessible to consumers from both countries. The centralized market is shared by both countries. Consumers can costlessly visit the centralized market and the domestic decentralized market in their own country, but they face travel cost θ to visit the decentralized market in the other country.

Home and Foreign use different currencies, and the Foreign currency is treated as the numeraire. The exchange rate s is defined as the value of Home's currency in terms of Foreign's currency. Thus, an increase in s indicates an appreciation of Home's currency.

Let $\frac{s-\bar{s}}{\sigma_s}$ follow the cumulative distribution function $\Psi\left(\frac{s-\bar{s}}{\sigma_s}\right)$, which is defined over the set $[-\triangle, \triangle]$ for a positive value $\triangle$ and has the mean of zero and the variance of one. Let $\psi\left(\frac{s-\bar{s}}{\sigma_s}\right)$ denote the corresponding probability distribution function. Therefore, the mean and the variance of s are $\bar{s}$ and σ_s^2, respectively.

The exchange rate is realized at the beginnning of each period before the DM market takes place.

2.2 Firms' Behavior

2.2.1 The decentralized markets

The exogenous number of firms in country i is N_i. The firms have to post their prices at the beginning of the period. Let $F_i\left(p\right)$ be the cumulative distribution function of prices in the decentralized market in country i and $f_i\left(p\right)$ be a probability density function associated with $F_i\left(p\right)$. Conditional on meeting a consumer, a firm produces a DM good at the expense of non-monetary production cost c_i.

Firms in the decentralized markets are small and take the number of consumers in the markets as given; they do not recognize the effect of their price changes on the consumers' search behavior.

In each DM subperiod, consumers randomly draw the number of prices in the decentralized market that they observe. Let $\alpha_i^k \in (0,1)$ for $k \in \{1,2,...,n\}$ be the probability that a consumer observes exactly k prices in the decentralized market in country i, where $\sum\limits_{k=1}^{n} \alpha_i^k = 1$.

2.2.2 The centralized market

The centralized market is a perfectly competitive market where the CM good is traded frictionlessly. The firms in the CM in country i have a linear technology that converts one unit of labor into w_i units of numeraire goods. Because the price of the CM good is normalized to one, the wage w_i is the income of consumers in country i. The difference in technology is the source of income heterogeneity across countries. Firms make zero profit.

as part of production of the CM good.

2.3 Consumer Behavior

Preferences are identical across countries. Consumers' preferences are described by a utility function $U(q,x) : [0,\infty) \times [0,\infty) \to [0,\infty)$ such that

$$
\begin{aligned}
U(q,x) &= \sqrt{q} + x \\
\text{s.t.} \quad & w_j = pq + x
\end{aligned}
$$

The price of good q is p and the price of the numeraire good x is normalized to one.

Consumers in Home are allowed to travel to Foreign to search for the indivisible good. The border-crossing travel cost of each consumer, denoted by θ, is randomly drawn from a normal distribution with the mean $\overline{\theta}$ and the variance σ_θ^2. That is, $\frac{\theta-\overline{\theta}}{\sigma_\theta}$ follows the standard probability density function φ, which has the mean of zero and the variance of one. Let Φ be the corresponding cumulative distribution function.

2.4 Market-Clearing Conditions

The labor market requires that the amount of labor used in the production of DM and CM goods is equal to the total labor supply. The markets for DM and CM goods are clear. The interest rate, which affects intertemporal consumption, clears the savings market. Savings are zero in equilibrium.

3 Equilibrium

We first solve the consumer's demand, the firms' pricing strategy, and then the cross-border decision.

In a steady state, consumers always spend all of their income in the CM, because the interest rate is offset by the discount rate.[2] Therefore, the demand for CM goods is the residual from previous transactions in the DM subperiod. If a consumer purchases the DM good at price p, he has money $w - pq$ to buy the CM good, and his utility is $U\left(q, w_j - pq\right) = \sqrt{q} + \left(w_j - pq\right)$.

Consumers who see multiple prices can compare the prices and buy from the seller that offers the lowest price. For consumers who see k prices, the distribution of the minimum price follows the probability density function $k\left[1 - F(p)\right]^{k-1} f(p)$. After they pick the minimum observed price, their demand functions are as follows:

$$
\begin{aligned}
q\left(w_j, p\right) &= \frac{1}{4p^2}, \\
x\left(w_j, p\right) &= w_j - \frac{1}{4p}.
\end{aligned}
$$

[2]This is the same argument as in Lagos and Wright (2005).

Let δ_j be the fraction of consumers in country j that cross the border. The numbers of consumers in the DM markets in Home and Foreign, defined as Ω_H and Ω_F, are $\Omega_H = (1-\delta_H) L_H + \delta_F L_F$ and $\Omega_F = (1-\delta_F) L_F + \delta_H L_H$, respectively.

The profit of a firm in Foreign is

$$\begin{aligned}\pi_F(p) = &\sum_{k=1}^{n} \alpha_F^k k \left[1-F_F(p)\right]^{k-1}(p-c_F)\frac{1}{4p^2}(1-\delta_F) L_F \\ &+ \sum_{k=1}^{n} \alpha_F^k k \left[1-F_F(p)\right]^{k-1}(p-c_F)\frac{1}{4}\left(\frac{s}{p}\right)^2 \delta_H L_H.\end{aligned}$$

The profit function is the sum of the profits from selling to consumers who live in different countries and who observe different numbers of prices. The fraction α_F^k of consumers observe k prices. The probability that the price of a firm is the lowest among all k prices is $k\left[1-F_F(p)\right]^{k-1}$. The mass $\delta_H L_H$ of consumers from Home adjust the price by the exchange rate, and then each buys $\left(4(p/s)^2\right)^{-1}$ units, while the mass $(1-\delta_F) L_F$ of Foreign consumers buy $\left(4p^2\right)^{-1}$ units. The profit function can be simplified to

$$\pi_F(p) = \sum_{k=1}^{n} \alpha_F^k k \left[1-F_F(p)\right]^{k-1}(p-c_F)\left(\frac{1}{4p^2}\right)\left[(1-\delta_F) L_F + s^2 \delta_H L_H.\right] \tag{1}$$

When a consumer who observes exactly one price buys the DM goods from a firm in country i, the firm would wish it had set the price at the monopoly price, which is equal to $p_i^m = 2c_i$. The monopoly price depends on the elasticity of demand and the marginal cost, but it is independent of the exchange rate. None of the firms has the incentive to raise prices above the monopoly price.

Based on Burdett and Judd (1983), given that $\alpha_i^1 \in (0,1)$, an equilibrium must be such that (i) $F_i(p)$ is continuous with compact support $\left[p_i^{min}, p_i^m\right]$, where $p_i^{min} < p_i^m$, (ii) $\pi_i(p) = \pi_i\left(p_i^m\right)$ for all $p \in \left[p_i^{min}, p_i^m\right]$, and (ii) the equilibrium is unique.

From equation (1), we have that

$$\pi_F\left(p_F^m\right) = \alpha_F^1 \frac{1}{16c_F}\left[(1-\delta_F) L_F + s^2 \delta_H L_H\right].$$

Because $\pi_F(p) = \pi_F\left(p_F^m\right)$, the price distribution $F_F(p)$ must satisfy the functional equation

$$\sum_{k=1}^{n} \alpha_F^k k \left[1-F_F(p)\right]^{k-1}(p-c)\, p^{-2} = \alpha_F^1 \frac{1}{16c_F}. \tag{2}$$

Equation (2) pins down the unique equilibrium price distribution. Similarly, Home's price distribution must satisfy the functional equation

$$\sum_{k=1}^{n} \alpha_H^k k \left[1-F_H(p)\right]^{k-1}(p-c)\, p^{-2} = \alpha_H^1 \frac{1}{16c_H}. \tag{3}$$

The price distributions in equations (2) and (3) give the impression that the prices are sticky.

However, the model allows the prices to be fully flexible. This feature is a key message in Burdett and Judd (1983) that a flexible price model may be observationally equivalent to a sticky price model. In this paper, prices do not respond to exchange rate movements. This is in contrast to the price distributions in Baggs et al. (2018), which depends on the exchange rate.

After the price distribution is determined by the equilibrium, we can calculate the gains from attending different markets. For consumers in Home, the expected gain from crossing the border is

$$\begin{aligned} V^{cross}(s,\theta) =& \sum_{k=1}^{n} \alpha_F^k \int \left[\left(w_H + \frac{1}{2}\left(\frac{s}{p}\right)\right) k\left[1 - F_F(p)\right]^{k-1} f_F(p) \right] dp - \theta \\ =& \chi_H^F + s\Omega^F - \theta, \end{aligned}$$

where $\chi_H^F = w_H \sum_{k=1}^{n} \alpha_F^k \int k\left[1 - F_F(p)\right]^{k-1} dF_F(p)$ and $\Omega^F = \frac{1}{2} \sum_{k=1}^{n} \alpha_F^k \int \frac{k}{p}\left[1 - F_F(p)\right]^{k-1} dF_F(p)$. The expected gain is strictly increasing in exchange rate s.

For consumers in Home, the expected gain from staying in Home's market is

$$\begin{aligned} V^{stay} =& \sum_{k=1}^{n} \alpha_H^k \int \left[\left(w_H + \frac{1}{2}p^{-1}\right) k\left[1 - F_H(p)\right]^{k-1} f_H(p) \right] dp \\ =& \chi_H^H + \Omega^H, \end{aligned}$$

where $\chi_H^H = w_H \sum_{k=1}^{n} \alpha_H^k \int k\left[1 - F_H(p)\right]^{k-1} dF_H(p)$ and $\Omega^H = \frac{1}{2} \sum_{k=1}^{n} \alpha_H^k \int \frac{k}{p}\left[1 - F_H(p)\right]^{k-1} dF_H(p)$.

In each period, consumers in Home will cross the border to Foreign's DM market if the value of border crossing $V^{cross}(s,\theta)$ is larger than the value of shopping in Home's market V^{stay}. There is a travel cost θ^* such that a consumer in Home with this travel cost θ^* is indifferent between shopping in Home or crossing the border to shop in Foreign. That is, the value of border crossing $V^{cross}(s,\theta^*)$ is equal to the value of shopping in Home V^{stay}. Since the threshold must satisfy $V^{cross}(s,\theta^*) = V^{stay}$, which depends on the exchange rate, the threshold can be defined explicitely as $\theta^* = \theta^*(s)$. Consumers with travel cost $\theta < \theta^*(s)$ cross the border, and consumers with travel cost $\theta > \theta^*(s)$ stay in the local market.

The fraction of consumers who cross the border is equal to the probability that $\theta < \theta^*(s)$:

$$\delta_H(s) = \text{Prob}\left(\theta < \theta^*(s)\right) = \Phi\left(\frac{s\Omega^F - \Omega^H + \chi_H^F - \chi_H^H - \bar{\theta}}{\sigma_\theta}\right). \tag{4}$$

Equation (4) is comparable to equation (7) of Chandra et al. (2014). Both their model and this model reach the same conclusion: consumers weigh the benefits of shopping in two markets. The main difference between this model and their model is the general equilibrium effect. Because Chandra et al. (2014) use a standard Cobb-Douglas utility function across Home's and Foreign's goods, there is a substitution effect between goods across markets. In this model, the presence of search frictions eliminates the substitution effect. As a result, the price distributions in both countries are unaffected by the exchange rate.

Using equation (4), the expected number of cross-border travelers in a month is

$$\chi_H\left(\bar{s}, \sigma_s^2, \bar{\theta}, \sigma_\theta^2\right) = L_H \int \Phi\left(\frac{s\Omega^F - \Omega^H + \chi_H^F - \chi_H^H - \bar{\theta}}{\sigma_\theta}\right) \psi\left(\frac{s - \bar{s}}{\sigma_s}\right) ds. \tag{5}$$

In contrast to Chandra et al. (2014) and Baggs et al. (2018), this paper incorporates exchange rate risk into the model, while offering an analytical solution. Using equation (5), I summarize the effects of changes in the average exchange rate and the average travel cost in Lemma 1.

Lemma 1. *The number of travelers is increasing in $\bar{s}$ and decreasing in $\bar{\theta}$.*

Proof. See Appendix. □

Lemma 1 is consistent with the existing literature (e.g., Campbell and Lapham, 2004; Chandra et al., 2014; Baggs et al., 2018). When Home's currency appreciates, the price of foreign goods in the Home currency decreases, encouraging more home travelers to take advantage of the currency appreciation. Distance, which adds to the cost of cross-border travel, discourages households from crossing.

The effect of a change in the mean of exchange rates in Lemma 1 can be generalized to a change in the probability density function of the exchange rate.

Lemma 2. *If the probability density function of the exchange rate in month m_1 first-order stochastically dominates the probability density function of exchange rate in month m_2, then the number of cross-border travelers in month m_1 is larger than the number of cross-border travelers in month m_2.*

Proof. See Appendix. □

Lemma 2 generalizes the finding in the literature by allowing for changes in the probability density function of the exchange rate, while Lemma 1 only allows for a shift of the PDF.

The objective of this paper is to the effect of exchange rate volatility on the number of cross-border travelers. Proposition 1 establishes the first main model prediction.

Proposition 1. *The average number of travelers per month is increasing in exchange rate volatility if the cumulative distribution function of transportation costs is locally convex.*

Proof. See Appendix. □

To begin with, I determine if the cumulative distribution function of transportation costs is locally convex. In the empirical section, I test the model predictions using data on Canadian cross-border travelers. The same-day crossing rate, multi-day crossing rate, and cumulative crossing rate are 0.77 percent, 0.16 percent, and 0.93 percent, respectively, according to Baggs et al. (2018), who used the same dataset. As a result, in the empirically relevant parameter space, the cumulative distribution function of transportation costs is locally convex.

To understand the intuition of Proposition 1, let consider two hypothetical months with the same average exchange rate, but where the exchange rate is more volatile in the first month. In this case, the first month has more days when the exchange rate appreciates and more days when it depreciates. On the one hand, on the days when the exchange rate appreciates, more consumers cross the border. On the other hand, on the days when the exchange rate depreciates, few consumers cross the border. When we compare the numbers of travelers in both months, the ranking is determined by whether the increase in the number of travelers on the days when the exchange rate appreciates or the decrease in the number of travelers on the days when the exchange rate depreciates is greater. The comparison depends on whether the cumulative distribution function of transportation costs is locally convex.

Proposition 1 establishes a testable hypothesis that the effect of exchange rate volatility on the number of cross-border travelers should be positive.

Motivated by the prediction of Lemma 1 that distance reduces the number of travelers, I then investigate how distance affects the elasticity of border crossing with respect to exchange rate volatility. Proposition 2 presents the second main result.

Proposition 2. *The responsiveness of the number of travelers due to exchange rate volatility is increasing in distance.*

Proof. See Appendix. □

Proposition 2 predicts that the number of border-crossing travelers in an area with longer distance is more sensitive to exchange rate volatility. Intuitively, households that live further away from a border post are less likely to cross the border. Therefore, when the exchange rate is more volatile, there are more opportunities for these households to take advantage of currency appreciation. Since the initial number of travelers from distant area is small, the change in terms of percentage change is relatively larger.

Proposition 2 leads to another testable hypothesis that the interaction term between distance and exchange rate volatility should be positive.

4 Data and Estimation Strategy

4.1 Data Source and Variable Description

The data used in this study are monthly panel data at the border-post level from January 2005 to December 2012. Since the 2008 financial crisis could have caused a structural shift in behavior, I will also consider two subsamples: the period from January 2005–September 2008 and the period from January 2005–December 2008.

I use the number of automobiles returning to Canada from the United States by port of entry in the Southern Canadian border. The dataset contains 103 land and ferry border posts that connect seven provinces in Canada and nine states in the United States. Canadian travelers are classified into two types based on their duration of stay: same-day travelers and multi-day travelers. Fewer than 1.8 percent of the observations have zero cross-border travelers.

A general concern is that the data includes travelers who cross the border for reasons other than shopping, such as tourists or workers. However, this data is commonly used in the literature, for example, Baggs et al. (2016), Baggs et al. (2018), Campbell and Lapham (2004), Chandra et al. (2014), and Chen et al. (2017). In fact, the model used in this paper can easily capture tourism and work, because they can be interpreted as different types of transactions in the DM market.

My main analysis uses the subsample of data that contain only the border posts that had a positive number of travelers in every month. The final data set consists of 94 border posts and 96 months. As a robustness check, I consider the full-sample data set and replace the variable $\log(\text{travellers})$ with $\log(1 + \text{travellers})$ to avoid the problem of undefined log of zero. I also use the inverse hyperbolic sine transformation to handle zeros.

The monthly exchange rate is the average of the daily exchange rates in the corresponding month. The exchange rate is expressed as the amount of US dollars for which one Canadian dollar can be exchanged. The exchange rate increases as the Canadian dollar appreciates. For robustness, I also use the exchange rates in the first and last days of the months, but the conclusions remain unchanged.

I use several measures of monthly exchange rate volatility. The main analysis uses the standard deviation (s.d.), variance (var.), and the coefficient of variation (c.v.) of the daily exchange rate in the corresponding month. I extend the analysis to investigate the ex ante volatility by using implied volatilities as additional measures of exchange rate volatility. The data on exchange rates and implied volatility are from Bloomberg database.

To proxy for the distance that Canadian travelers need to commute to shop across the border, the variable "distance" is the sum of the median driving distance to the closest border post and the distance from the border post to the nearest shopping center in the United States. In the estimation, the distances are demeaned so that the interaction can be interpreted as a percentage-point deviation from the mean. The data on cross-border travelers and distances are from Baggs et al. (2018).

Table 1 provides the summary statistics of main variables. Table 2 presents the correlation matrix of various measures of exchange rate volatility.

4.2 The Omitted–Variable Bias in Traditional Regressions

The traditional regression in the literature is in the form of

$$\log\left(\text{travelers}_{pt}\right) = \beta_1 \log\left(\text{FX}_t\right) + \boldsymbol{X}_{pt}\boldsymbol{\beta} + \epsilon_{pt}, \tag{6}$$

where the variable of interests is the number of population who travel through border post p in period t, the variable FX_t is the bilateral exchange rate, and $\boldsymbol{X}_{pt}$ is the set of controls which include

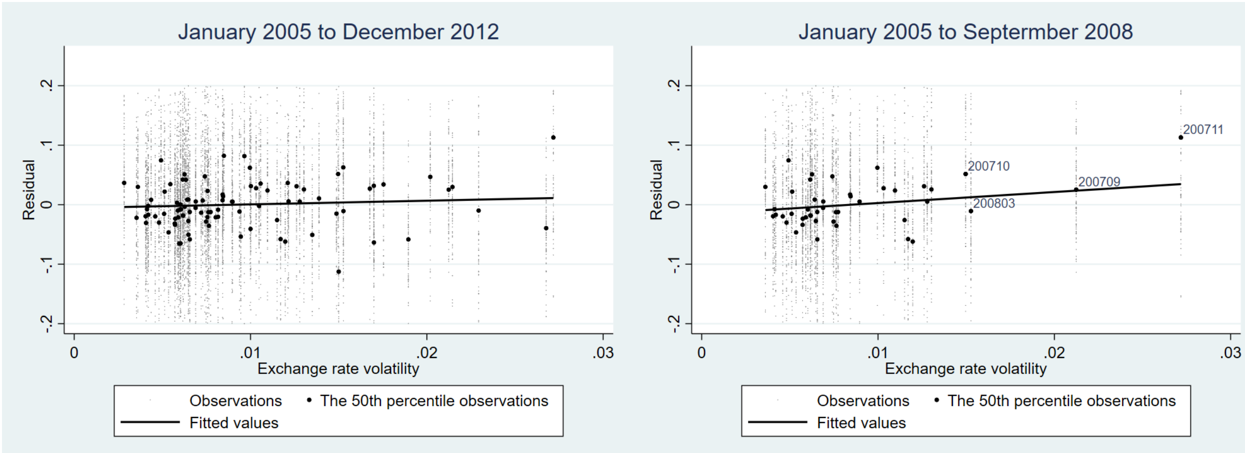

Figure 1: The scatterplots of the residuals from equation (7) and exchange rate volatility. The left plot shows all the observations from 2005–2012, and the right plot shows the observations from 2005–2008. The gray small dots represent all samples. The thick black dots represent the median samples of the residuals for each exchange rate volatility. The fitted line is the simple linear prediction of the residual, using exchange rate volatility.

distance, the tax rates in both countries, gas prices, and fixed effects.

To show the problem of an omitted variable bias, I consider a variation of equation (6), in the form of

$$\log\left(\text{travelers}_{pym}\right) = \beta_1 \log\left(\text{FX}_{ym}\right) + \gamma_{py} + \gamma_{pm} + \epsilon_{pym}, \tag{7}$$

where the time period t is described by the combination of year y and month m, travellers$_{pym}$ is the number of same-day travelers, γ_{py} is border-post-year fixed effects, and γ_{pm} is border-post-month fixed effects.

After running a regression and obtaining residuals $\widehat{\epsilon}_{pym}$, I show scatterplots of the residuals $\widehat{\epsilon}_{pym}$ from equation (7) and exchange rate volatility in Figure 1. The left scatterplot presents the combinations of observations from 2005 to 2012. To highlight the pattern, I show the median residual for each exchange rate volatility. The fitted line in Figure 1 suggests that the residual is positively correlated to exchange rate volatility.

The right figure shows the scatterplot of the residuals and exchange rate volatility when the data is restricted to the observations before the financial crisis in 2008. The slope of the fitted line in the right figure is steeper than that of the fitted line in the left figure. These two figures imply that the omitted-variable bias becomes more pronounced in the subperiod. The fitted line in the right scatterplot is not sensitive to excluding the outliers with greater exchange rate volatility.

4.3 Formal Regression Analysis

Motivated by the positive relationship in Figure 1, this paper introduces exchange rate volatility (FX volatility) as an additional explanatory variable into a variation of equation (6).

The first main regression is

$$\log\left(\text{travelers}_{pym}\right) = \beta_1 \log\left(\text{FX}_{ym}\right) + \beta_2 \log\left(\text{Distance}_p\right) + \beta_3\left(\text{FX volatility}_{ym}\right) + \boldsymbol{X}_{pym}\boldsymbol{\beta} + \epsilon_{pym}, \tag{8}$$

where travellers$_{pym}$ is the number of same-day travelers, FX_{ym} is the average bilateral exchange rate in year y and month m, Distance$_p$ is the sum of the median distance from the city to the closest border post and from the border post to the nearest shopping center in the United States, FX volatility$_{ym}$ is the standard deviation of daily exchange rates in year y and month m, and $\boldsymbol{X}_{pym}$ is the set of fixed effects.

The main dependent variable in the regression is the number of same-day travelers, which fits the story of cross-border shopping. In the next section, I also consider the numbers of multi-day travelers and combined (same-day and multi-day) travelers as alternative dependent variables.

We use three sets of fixed effects $\boldsymbol{X}_{pym}$. The first set has year fixed effects and month fixed effects. The year fixed effects capture aggregate factors that affect border-crossing behavior in all border posts but may vary across years, such as economic conditions. The month fixed effects capture the seasonal effects that persist every year. The second set of fixed effects consists of Canadian-province-year fixed effects, US-State-year fixed effects, and month fixed effects. The Canadian-province-year fixed effects absorb all variations in across province and year such as population size and tax rates. The US-State-year fixed effects capture variations across states and years, such as state-specific sale tax. The month fixed effects control for aggregate seasonal variations.

The third set of fixed effects has post-year fixed effects and post-month fixed effects. In this case, year fixed effects and month fixed effects are allowed to vary across border posts. The post-year fixed effects absorb border-post-level variation across year such as population, tax rates in US states, tax rates in Canadian provinces, distances, information frictions, etc. The post-month fixed effects absorb border-post-level seasonality. In regressions that include the post-year fixed effects, the distance variable has to be dropped. Standard deviations are clustered at the border-post level.

Subsequently, I test the model prediction in Proposition 2 that the elasticity of the number of travelers due to exchange rate volatility is increasing in transportation cost.

The second main regression is

$$\begin{aligned}\log\left(\text{travelers}_{pym}\right) =& \beta_1 \log\left(\text{FX}_{ym}\right) + \beta_2 \log\left(\text{Distance}_p\right) + \beta_3\left(\text{FX volatility}_{ym}\right) \\ &+ \beta_4\left(\text{FX volatility}_{ym}\right) \times \left(\text{Distance}_p\right) + \boldsymbol{X}_{pym}\boldsymbol{\beta} + \epsilon_{pt}.\end{aligned} \tag{9}$$

Equation (9) extends equation (8) by introducing the interaction term of exchange rate volatility and distance. Proposition 2 predicts that the coefficient of the interaction term should be positive; the longer the distance, the larger the elasticity of cross-border travel with respect to exchange rate volatility. I will estimate this equation using the same three sets of fixed effects

Because the 2008 financial crisis produced disruptions and uncertainty, and governments responded with fiscal and monetary policies, the cross-border travel behavior in the periods after the crisis may have been anomalous. Therefore, I will consider two time periods: the entire period from 2005 to 2012 and the subperiod from 2005 to 2008.

5 Main Empirical Results

This section presents estimates of equations (8) and (9) when the dependent variable is the number of same-day travelers. The benchmark case uses the observations from all time periods and the precrisis case uses the observations prior to the financial crisis.

5.1 All Observations from 2005–2012

Table 3 shows the estimated coefficients from the benchmark case. The baseline regression on Column (1) supports the finding in the literature that the number of cross-border travelers increases in the exchange rate and decreases in distance. When the exchange rate appreciates by one percent, the number of same-day travelers increases by one percent. In line with the literature, this paper finds that a border post far from a US shopping center is associated with fewer cross-border travelers.

The first main result of this paper is shown in Columns (2) to (4) in Table 3. The estimates support the model prediction in Proposition 1 that exchange rate volatility has a positive impact on cross-border travel. When exchange rate volatility increases by one standard deviation, the number of same-day travelers increases by 1.62 percent. The estimates are consistent across all sets of fixed effects.

The estimates from equation (9) are presented in Columns (5) to (7). The estimates of β_3 are in the range of 1.56–1.59 percent, which is consistent with the previous estimates on Columns (2) to (4). The estimated coefficient of the interaction term is 0.0118. This implies that around the means, when distance doubles, the effect of a one standard-deviation increase in exchange rate volatility on the number of travelers is 1.18. The estimated coefficients are statistically significant, ranging from 0.54 to 1.18.

5.2 Prior to the 2008 Financial Crisis

The relationship between exchange rate volatility and cross-border travel could potentially have a structural change caused by the financial crisis in 2008. Therefore, I re-estimate the main regressions using the subsample between January 2005 and September 2008.

Table 4 presents the estimates when the observations are restricted to those from 2005–2008. The estimates are consistent with those in Table 3. The estimated coefficient of exchange rate volatility increases from 1.62 in Table 3 to 4.04 in Table 4. The estimated coefficient of the interaction term between exchange rate volatility and distance increases to the range of 0.81 and 1.55, compared to the range of 0.54 to 1.16 in Table 3. Due to the decrease in sample size, standard errors in Table 4 are larger than those in Table 3, and although the point estimates in Table 3 are larger than those in Table 3, some of them are not statistically significant.

6 Alternative Model Specifications

This section presents variations of model specifications. First, I replace same-day travel with multi-day travel and combined (same-day and overnight) travel. Second, I measure exchange rate volatility by using the variance and the coefficient of variation. Third, I use the lags of exchange rate and exchange rate volatility. Fourth, I use the whole sample, which includes border posts that have zero travelers in some months. Finally, I use a specification curve to show the range of estimates under theoretically justified model specifications.

6.1 The Number of Travelers

First, I re-estimate the model using different measures of cross-border travel. The dependent variable is changed to the number of multi-day travelers (those who do not return on the same day) and the number of combined travelers (which is the sum of the numbers of same-day travelers and multi-day travelers).

The estimates are shown in Tables 5 to 8. When the Canadian dollar appreciates by one percent, the number of multi-day travelers increases by 0.84 percent. The effect of exchange rate volatility on the number of multi-day travelers is 2.81, which is larger than the case of same-day travelers in Table 3. When the observations are restricted to the months preceding the 2008 financial crisis, the estimate increases to 8.88. The interaction term of exchange rate volatility and distance becomes statistically significant only when the fixed effects are post-year fixed effects and post-month fixed effects and the observations are from before the 2008 financial crisis.

When the dependent variable is the number of combined travel, the estimated effect of exchange rate volatility is 1.97 in the full sample and is 5.42 in the subperiod before the financial crisis. Generally, the effects in the case of same-day travel are stronger than they are in the case of multi-day travel and the estimates from the subperiod before the financial crisis are larger than the estimates from the full sample.

6.2 Alternative Measures of Exchange Rate Volatility

The empirical analysis also considers the coefficients of variation and variance as other measures of exchange rate volatility. One advantage of the coefficient of variation is that it considers the fact that the exchange rate volatility should be normalized by the mean.

I show the estimate from the full sample and the subsample before the financial crisis. In the interest of brevity, I only show the results when the fixed effects are post-year fixed effects and post-month fixed effects. Tables 9 to 12 present estimates when exchange rate volatility is measured by the variance and the coefficient of variation.

The effect of exchange rate volatility on the number of travelers is statistically positive in all model specifications. The estimates suggest that one standard deviation increase in exchange rate volatility increases the number of same-day travelers by 1.56 percent when exchange rate volatility is measured by coefficient of variation and by 1.28 percent when exchange rate volatility is measured by variance. When the observations are restricted to the pre-financial-crisis period, the estimated effect for coefficient of variation and variance increases to 4.21 percent and 6.85 percent, respectively.

The coefficient of the interaction term is statistically positive when the dependent variable is same-day travel and combined travel. The coefficient of the interaction term on multi-day travelers is positive but is not statistically different from zero. In general, the estimates in Tables 9 and 12 agree with the estimates in Tables 3 to 7.

6.3 The Lags of Exchange Rate and Exchange Rate Volatility

One might be concerned that cross-border travel could have an impact on exchange rate volatility in the same time period, and that the estimate would be biased. This possibility is unlikely to occur, because the total value of cross-border shopping transactions is relatively small in comparison to the overall capital flow between the two countries.

To address this concern, this section re-estimates the main regression by replacing exchange rate and exchange rate volatility with their lags. The new estimates are shown in Tables 13 to 15. In general, the impact of lagged exchange rate volatility is less than that of current exchange rate volatility. The estimated effect of the lag in the exchange rate is 0.98 percent. In the subperiod preceding the 2008 financial crisis, it rises to 2.32 percent. The same pattern can be seen in the numbers of multi-day and combined travelers.

6.4 Full Sample

I re-estimate the models in Tables 3 to 7 using the entire sample data that includes border posts with no travelers in some months. To handle the observations with zero travelers, the dependent variable is modified to $\log(1 + \#\text{ of travellers})$. I also use the inverse hyperbolic sine transformation for robustness. Because the results from the inverse hyperbolic sine transformation agree with those from $\log(1 + \#\text{ of travellers})$, they are not reported in the paper.

The estimates are shown in Tables 16 to 18. In general, the coefficient of exchange rate volatility decreases while the coefficient of the interaction term increases. When the dependent variable is the number of same-day travelers, the estimated effect of exchange rate volatility is 1.62 percent in the subsample data and is around 0.61 percent in the full-sample data. However, the coefficient of the interaction term, which is 0.54 in the subsample data, is 0.90 in the full-sample data.

Similarly, the effect of exchange rate volatility on the number of multi-day travelers is around 1.55 percent in the full-sample data. The coefficient of the interaction term is not statistically different from zero. The effect of exchange rate volatility on the number of combined travelers is 1.93–1.97 percent in the subsample data and around 0.94 in the full-sample data.

The estimates support the previous empirical evidence of the effect of exchange rate volatility on cross-border travel.

6.5 Specification Curve

This section tests the robustness of our empirical analysis. As proposed by Simonsohn et al. (2020), I use a specification curve to show the range of estimates for the effect of exchange rate volatility under various theoretically justified model specifications. I estimate all possible combinations of six measures of monthly exchange rates, three measures of distance, three year coverages, two border post coverages, and seven sets of fixed effects.

I consider six measures of monthly exchange rates: the average of daily exchange rates, the exchange rate on the first day of each month, the exchange rate on the last day of each month, the average of the log of daily exchange rates, the log of the exchange rate on the first day of each month, and the log of the exchange rate on the last day of each month. I use three different distance measurements. The distance variable is measured by the level of the effective distance, or the log of the effective distance, or is not included. I consider three year coverages: January 2005–December 2012, January 2005–December 2008, and January 2005–September 2008. I estimate using either the observations from all border posts or the subsample of border posts that have a positive number of travelers in every month.

Finally, I use seven sets of fixed effects: (i) year fixed effects and month fixed effects, (ii) Canadian-province-year fixed, US-State-year fixed effects, month fixed effects, (iii) Canadian-province-year fixed, US-State-year fixed effects, border-post fixed effects, month fixed effects, (iv) Canadian-province-year fixed, US-State-year fixed effects, post-month fixed effects, (v) post-year fixed effects and month fixed effects, (vi) year fixed effects and post-month fixed effects, post-year fixed effects and post-month fixed effects.

There are 756 combinations in total. However, the number of model specifications is reduced to 396, because the distance variable cannot coexist with post-level fixed effects.

The specification curve in Figure 2 summarizes the results. The estimates are sorted by magnitude, as suggested by Simonsohn et al. (2020). The model specification of each estimate is described by the combination of dots at the bottom of the graph. The upper and lower bounds for the 95% confidence intervals are depicted in the figure.

The point estimates predict that when exchange rate volatility increases by one standard deviation, the number of same-day travelers increases around 0.33–5.22 percent, with an average of 2.42 percent. When the data is restricted to the months before the 2008 financial crisis, the estimates are positive and statistically significant. The estimated effect increases to the range of 3.55–5.22 percent, with an average of 4.39 percent.

There are 33 model specifications with estimates that are not statistically significant from zero. They all use data from all years, including the years following the 2008 financial crisis. 18 of these 33 model specifications have unusually large standard errors. The standard error in these 18 model specifications is 0.0072 (in the range of 0.0068–0.0078), while the standard error in the other 363 model specifications is 0.0043.

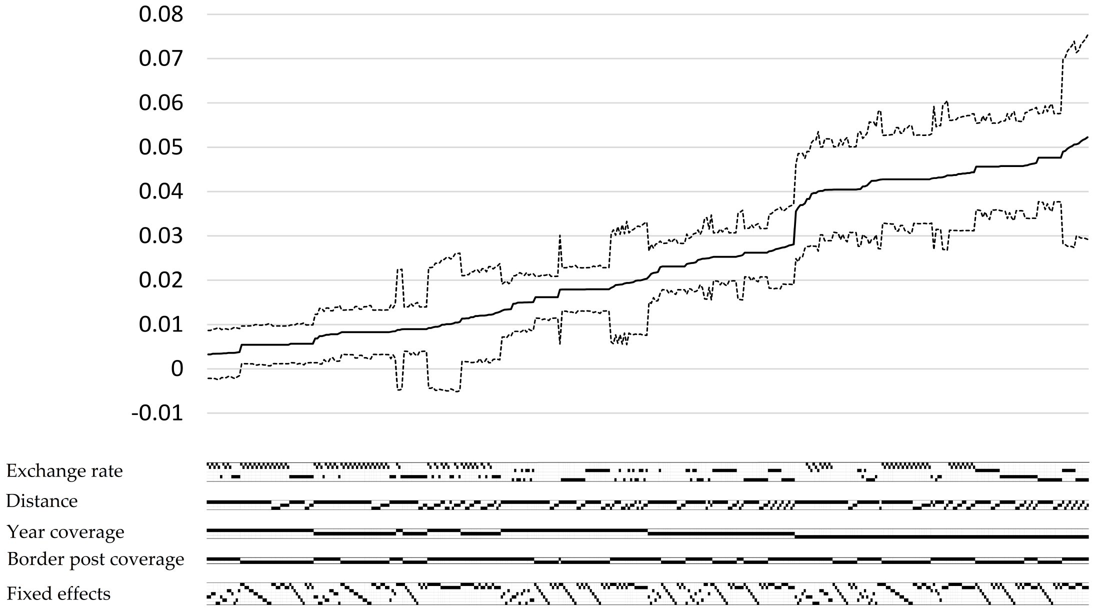

Figure 2: The specification curve presents the estimates of the coefficient of exchange rate volatility from model specifications.

7 Forward-Looking Exchange Rate Volatility

The previous sections establish empirical evidence of standard deviation, coefficient of variation, and variance. These measures of exchange rate volatility are ex post volatilities and are calculated from observed data. A natural follow-up question is how expectations about exchange rate volatility affect cross-border travel. To answer this question, this section uses implied volatilities, which are ex ante volatilities calculated from option prices using the Black-Scholes model. Implied volatilities represent the financial market's perception of the uncertainty of exchange rates over various time frames. If the option market is efficient, implied volatilities should be an efficient predictor of the future volatility of the underlying asset (Christensen and Prabhala, 1998). The analysis uses four types of implied volatility: one-month, three-month, six-month, and one-year.

The estimates are shown in Tables 19 to 26. Although the correlations between implied volatilities and ex post volatiliies (s.d., c.v., and variance) shown in Table 2 are in the range of 0.34–0.69, the new estimates confirm the findings in the previous sections.

The coefficients of one-month, three-month, six-month, and one-year implied volatilities are 0.021, 0.023, 0.024, and 0.025, respectively. On average, when an implied volatility increases by one standard deviation, the number of same-day travelers increases by 2.1–2.5 percent. One interesting observation is that the coefficient of implied volatility is weakly increasing in the time frame duration. The estimated effect increases to the range of 7.3–10.5 percent when the observations are restricted to the months before the 2008 financial crisis.

When distance doubles, the effect of one standard-deviation increase in exchange rate volatility on the number of cross-border travelers increases by 0.81–1.1 percent in the benchmark case and by 3.00–4.21 percent in the observations before the financial crisis.

The coefficients are larger when the dependent variable is the number of multi-day travelers. The coefficients of one-month, three-month, six-month, and one-year implied volatilities are 0.038, 0.039, 0.040, and 0.041, respectively. When an implied volatility increases by one standard deviation, the number of multi-day travelers increases by 3.8–4.1 percent.

These empirical results suggest that ex ante exchange rate volatility could explain the variations in cross-border travel. In general, ex ante exchange rate volatility has a greater impact than ex post exchange rate volatility. We conclude that consumers are forward-looking; they respond to the expected future exchange rate volatility as well as current exchange rate volatility.

8 Conclusion

This paper analyzes how exchange rate volatility affects cross-border travel. I extend a consumer search model based on Baggs et al. (2018) and Lagos and Wright (2005) to study consumers' search behavior. The first model prediction is that the number of cross-border travelers is increasing in exchange rate volatility, if the cumulative density function of travel cost is locally convex. The second model prediction is that the number of cross-border travelers is more sensitive to exchange rate fluctuations in a city where customers face high travel costs.

This paper tests the model predictions by using the monthly data of Canadian travelers who crossed the southern international border into the United States between 2005 and 2012. The empirical evidence supports the model predictions. On average, when exchange rate volatility increases by one standard deviation, the number of same-day travelers increases by 1.6 percent. The estimate is larger when the data is restricted to the subperiod before the 2008 financial crisis. Travelers who live far away are more sensitive to exchange rate fluctuations than are those who live nearby.

This paper suggests a line of research on the effect of exchange rate volatility on cross-border consumers's search behavior. Future work may extend this paper by using the data from other country pairs or detailed data on consumers and firms' pricing strategies.

References

[1] Alessandria, George. 2009. “Consumer Search, Price Dispersion, and International Relative Price Fluctuations.” *International Economic Review* 50 (3): 803–829.

[2] Alessandria, George and Joseph P. Kaboski. 2011. "Pricing-to-Market and the Failure of Absolute PPP." *American Economic Journal: Macroeconomics*, 3(1): 91–127.

[3] Asplund, Marcus, Richard Friberg, and Fredrik Wilander. 2007. “Demand and Distance: Evidence on Cross-Border Shopping.” *Journal of Public Economics* 91 (1): 141–157.

[4] Auer, Raphael, Ariel Burstein, Sarah Lein, and Jonathan Vogel. 2021. “Unequal Expenditure Switching: Evidence from the 2015 Swiss Franc Appreciation.” Unpublished Manuscript.

[5] Baggs, Jen, Eugene Beaulieu, Loretta Fung, and Beverly Lapham. 2016. “Firm Dynamics in Retail Trade: The Response of Canadian Retailers to Exchange Rate Shocks.” *Review of International Economics* 24 (3): 635–666.

[6] Baggs, Jen, Loretta Fung, and Beverly Lapham. 2018. “Exchange Rates, Cross-border Travel, and Retailers: Theory and Empirics.” *Journal of International Economics* 115: 59–79.

[7] Beck, Guenter W., Hans-Helmut Kotz, and Natalia Zabelina. 2020. “Price Gaps at the Border: Evidence from Multi-country Household Scanner Data.” *Journal of International Economics* 127: 1033–1068.

[8] Bello, Piera. 2020. “Exchange Rate Effects on Cross-border Commuting: Evidence from the Swiss–Italian Border.” *Journal of Economic Geography* 20 (4): 969–1001.

[9] Burdett, Kenneth, and Kenneth L. Judd. 1983. “Equilibrium Price Dispersion.” *Econometrica* 51 (4): 955–969.

[10] Cabral, René, André Varella Mollick, and Eduardo Saucedo. 2019. “Northbound Border Crossings from Mexico to the U.S. and the Peso/Dollar Exchange Rate.” *Research in Transportation Business & Management* 33: 1004–1023.

[11] Campbell, Jeffrey R., and Beverly Lapham. 2004. “Real Exchange Rate Fluctuations and the Dynamics of Retail Trade Industries on the U. S.-Canada Border.” *American Economic Review* 94 (4): 1194–1206.

[12] Chandra, Ambarish, Keith Head, and Mariano Tappata. 2014. “The Economics of Cross-Border Travel.” *The Review of Economics and Statistics* 96 (4): 648–661.

[13] Chen, Zhe, Michael B. Devereux, and Beverly Lapham. 2017. “The Canadian Border and the US Dollar: The Impact of Exchange Rate Changes on US Retailers.” *Canadian Journal of Economics/Revue canadienne d’économique* 50 (5): 1525–1555.

[14] Christensen, B. J., and N. R. Prabhala. 1998. "The Relation between Implied and Realized Volatility." *Journal of Financial Economics* 50 (2): 125–150.

[15] Ferris, J. Stephen. 2000. "The Determinants of Cross Border Shopping: Implications for Tax Revenues and Institutional Change" *National Tax Journal* 53 (4.1): 801–824.

[16] Gutiérrez, Manuel, Alejandro Sánchez-Atondo, Leonel García, Alejandro Mungaray-Moctezuma, and Julio Calderón. 2021. "Understanding Cross-Border Mobility in Medium-Small Mexico-U.S. Binational regions. Mexicali-Imperial Valley case study." *Transportation Research Interdisciplinary Perspectives* 9: 1003–1024.

[17] Lagos, Ricardo, and Randall Wright. 2005. "A Unified Framework for Monetary Theory and Policy Analysis." *Journal of Political Economy* 113 (3): 463–484.

[18] Simonsohn, Uri, Joseph P. Simmons, and Leif D. Nelson. 2020. "Specification curve analysis." *Nature Human Behaviour* 4 (11): 1208–1214.

[19] Friberg, Richard, Frode Steen, and Simen A. Ulsaker. "Hump-Shaped Cross-Price Effects and the Extensive Margin in Cross-Border Shopping." *American Economic Journal: Microeconomics*, forthcoming.

[20] Suwanprasert, Wisarut. 2019. "Endogenous Markup, Per Capita Income and Population Size in the Gravity Equation." *The B.E. Journal of Theoretical Economics* 19 (2).

[21] Wosiek, Małgorzata, and Ryszard Kata. 2019. "Trade at the Polish-Ukrainian Borderland–Selected Economic Aspects." *The Polish Statistician* 64 (2): 44–63.

Appendix I: Mathematical Proofs

Proof of Lemma 1

Lemma. *The number of travelers is increasing in $\bar{s}$ and decreasing in $\bar{\theta}$.*

Proof. Equation (5) states that the number of travelers is

$$\chi_H\left(\bar{s},\sigma_s^2,\bar{\theta},\sigma_\theta^2\right) = L_H \int \Phi\left(\frac{s\Omega^F - \Omega^H + \chi_H^F - \chi_H^H - \bar{\theta}}{\sigma_\theta}\right)\psi\left(\frac{s-\bar{s}}{\sigma_s}\right)ds.$$

1. The number of travelers is increasing in $\bar{s}$.

To prove this statement, I will show that if $\bar{s}_1 > \bar{s}_2$, then $\chi_H\left(\bar{s}_1,\sigma_s^2,\bar{\theta},\sigma_\theta^2\right) > \chi_H\left(\bar{s}_2,\sigma_s^2,\bar{\theta},\sigma_\theta^2\right)$.

Suppose that $\bar{s}_1 > \bar{s}_2$. Consider cumulative distribution functions $\Psi_1(s) = \Psi\left(\frac{s-\bar{s}_1}{\sigma_s}\right)$ and $\Psi_2(s) = \Psi\left(\frac{s-\bar{s}_2}{\sigma_s}\right)$. Because $\bar{s}_1 > \bar{s}_2$, $\Psi_1(s)$ first-order stochastically dominates $\Psi_2(s)$. Since $\Phi\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\bar{\theta}}{\sigma_\theta}\right)$ is a strictly increasing function in s, first-order stochastic dominance implies that

$$\int \Phi\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\overline{\theta}}{\sigma_\theta}\right)d\Psi_1\left(s\right)>\int \Phi\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\overline{\theta}}{\sigma_\theta}\right)d\Psi_2\left(s\right).$$

This leads to $\chi_H\left(\overline{s}_1,\sigma_s^2,\overline{\theta},\sigma_\theta^2\right)>\chi_H\left(\overline{s}_2,\sigma_s^2,\overline{\theta},\sigma_\theta^2\right)$. Therefore, the number of travelers is increasing in $\overline{s}$.

2. The number of travelers is decreasing in $\overline{\theta}$.

To prove this statement, I will show that if $\overline{\theta}_1>\overline{\theta}_2$, then $\chi_H\left(\overline{s},\sigma_s^2,\overline{\theta}_1,\sigma_\theta^2\right)>\chi_H\left(\overline{s},\sigma_s^2,\overline{\theta}_2,\sigma_\theta^2\right)$.

Suppose that $\overline{\theta}_1>\overline{\theta}_2$. Then the fractions of consumers who cross the border must satisfy

$$\Phi\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\overline{\theta}_1}{\sigma_\theta}\right)<\Phi\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\overline{\theta}_2}{\sigma_\theta}\right).$$

Therefore,

$$\int \Phi\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\overline{\theta}_1}{\sigma_\theta}\right)d\Psi\left(s\right)<\int \Phi\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\overline{\theta}_2}{\sigma_\theta}\right)d\Psi\left(s\right).$$

This leads to $\chi_H\left(\overline{s},\sigma_s^2,\overline{\theta}_1,\sigma_\theta^2\right)>\chi_H\left(\overline{s},\sigma_s^2,\overline{\theta}_2,\sigma_\theta^2\right)$. Therefore, the number of travelers is decreasing in $\overline{\theta}$. □

Proof of Lemma 2.

Lemma. *If the probability density function of exchange rate in month m_1 first-order stochastically dominates the probability density function of exchange rate in month m_2, then the number of cross-border travelers in month m_1 is larger than the number of cross-border travelers in month m_2.*

Proof. Suppose that the cumulative distribution function of the exchange rate in month m_1, defined as $\Psi_1\left(s\right)$, first-order stochastically dominates the cumulative distribution function in month m_2, defined as $\Psi_2\left(s\right)$. Since $\Phi\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\overline{\theta}}{\sigma_\theta}\right)$ is a strictly increasing function in s, first-order stochastic dominance implies that

$$\int \Phi\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\overline{\theta}}{\sigma_\theta}\right)d\Psi_1\left(s\right)>\int \Phi\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\overline{\theta}}{\sigma_\theta}\right)d\Psi_2\left(s\right).$$

Therefore, the number of cross-border travelers in month m_1 is larger than the number of cross-border travelers in month m_2. □

Proof of Proposition 1.

Proposition. *The average number of travelers per month is increasing in exchange rate volatility if the cumulative distribution function of transportation costs is locally convex.*

Proof. Equation (5) states that the number of travelers is

$$\chi_H\left(\bar{s},\sigma_s^2,\bar{\theta},\sigma_\theta^2\right) = L_H \int \Phi\left(\frac{s\Omega^F - \Omega^H + \chi_H^F - \chi_H^H - \bar{\theta}}{\sigma_\theta}\right)\psi\left(\frac{s-\bar{s}}{\sigma_s}\right)ds.$$

Suppose that $\sigma_{s1} > \sigma_{s2}$. Consider cumulative distribution functions $\Psi_1(s) = \Psi\left(\frac{s-\bar{s}}{\sigma_{s1}}\right)$ and $\Psi_2(s) = \Psi\left(\frac{s-\bar{s}}{\sigma_{s2}}\right)$. Because $\sigma_{s1} > \sigma_{s2}$, $\Psi_1(s)$ is a mean-preserving spread of $\Psi_2(s)$. In other words, $\Psi_2(s)$ second-order stochastically dominates $\Psi_1(s)$. If $\Phi\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\bar{\theta}}{\sigma_\theta}\right)$ is convex in the domain of Ψ_1 and Ψ_2, then

$$\int \Phi\left(\frac{s\Omega^F - \Omega^H + \chi_H^F - \chi_H^H - \bar{\theta}}{\sigma_\theta}\right)d\Psi_1(s) > \int \Phi\left(\frac{s\Omega^F - \Omega^H + \chi_H^F - \chi_H^H - \bar{\theta}}{\sigma_\theta}\right)d\Psi_2(s).$$

Therefore, the number of travelers is increasing in exchange rate volatility.

Note that we can assume the domain of Ψ so that the distribution function $\Phi\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\bar{\theta}}{\sigma_\theta}\right)$ is convex for all s in the domain. □

Proof of Proposition 2.

Proposition. *The responsiveness of the number of travelers due to exchange rate volatility is increasing in distance.*

Proof. The convexity of the number of travelers can be measured by

$$CRRA = \frac{s\frac{\partial^2\Phi}{\partial s^2}}{\frac{\partial\Phi}{\partial s}} = \frac{s\frac{\partial\phi}{\partial S}\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\bar{\theta}}{\sigma_\theta}\right)L_H\left(\frac{\Omega^F}{\sigma_\theta}\right)^2}{\phi\left(\frac{s\Omega^F-\Omega^H+\chi_H^F-\chi_H^H-\bar{\theta}}{\sigma_\theta}\right)\frac{\Omega^F L_H}{\sigma_\theta}} = -s\left(\frac{s\Omega^F - \Omega^H + \chi_H^F - \chi_H^H - \bar{\theta}}{\sigma_\theta}\right) > 0.$$

Therefore, the partial derivative is $\frac{\partial CRRA}{\partial\bar{\theta}} = \frac{s}{\sigma_\theta}$, which is always positive. In other words, the the number of travelers is more convex in s as $\bar{\theta}$ increases. The responsiveness of the number of travelers due to exchange rate volatility is increasing in transportation cost. □

Appendix II: Tables

Table 1: Summary Statistics

Variable	# of observations	Mean	Std. Dev.	Min	Max
The number of travelers					
same-day	9,024	21313.5	46159.2	14	382999
multi-day	9,024	9664.9	21536.6	2	223518
combined	9,024	30978.4	63362.9	29	495144
Exchange rate					
CADUSA	9,024	0.931	0.075	0.773	1.052
CADUSA_SD	9,024	0.010	0.006	0.003	0.048
Implied Volatility					
1-month	9,024	10.312	3.831	4.913	25.014
3-month	9,024	10.334	3.458	5.607	22.701
6-month	9,024	10.446	3.291	5.936	21.318
1-year	9,024	10.572	3.168	5.935	20.251
Distance					
Effective Distance	9,024	127.542	87.563	1.390	441.170

Table 2: Correlation matrix

	S.D.	C.V.	VAR.	Imp Vol 1-month	Imp Vol 3-month	Imp Vol 6-month	Imp Vol 1-year
S.D.	1.000						
C.V.	0.990	1.000					
VAR.	0.923	0.932	1.000				
Imp Vol 1-month	0.658	0.685	0.514	1.000			
Imp Vol 3-month	0.591	0.612	0.431	0.983	1.000		
Imp Vol 6-month	0.543	0.560	0.380	0.956	0.993	1.000	
Imp Vol 1-year	0.503	0.516	0.342	0.922	0.974	0.994	1.000

Table 3: The effects on the number of same-day travelers – observations from 2005–2012.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Same-day	Same-day	Same-day	Same-day	Same-day	Same-day	Same-day
log(CADUSA)	1.003***	1.088***	1.088***	1.088***	1.088***	1.088***	1.088***
	(0.067)	(0.072)	(0.072)	(0.080)	(0.072)	(0.072)	(0.080)
log(distance)	-1.129***	-1.129***	-1.050***		-1.129***	-1.050***	
	(0.129)	(0.129)	(0.211)		(0.129)	(0.211)	
CADUSA_SD		0.0162***	0.0162***	0.0162***	0.0156***	0.0159***	0.0159***
		(0.00237)	(0.00238)	(0.00264)	(0.00229)	(0.00223)	(0.00246)
log(distance)					0.0118***	0.00619**	0.00543***
×CADUSA_SD					(0.00344)	(0.00293)	(0.00174)
Fixed Effects	Year FEs Month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs
Observations	9,024	9,024	9,024	9,024	9,024	9,024	9,024
Adjusted R^2	0.405	0.405	0.652	0.995	0.405	0.652	0.995

Note: Standard errors in parentheses are clustered at the border post level. Regressions in columns (1), (2), and (5) include year fixed effects and month fixed effects. Regressions in columns (3) and (6) include Canadian-province-year fixed effects, US-state-year fixed effects, and month fixed effects. Regressions in columns (4) and (7) include Post-Year FEs ad Post-month FEs. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 4: The effects on the number of same-day travelers – observations from 2005–2008.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Same-day	Same-day	Same-day	Same-day	Same-day	Same-day	Same-day
log(CADUSA)	1.469***	1.068***	1.068***	1.068***	1.068***	1.068***	1.068***
	(0.109)	(0.092)	(0.092)	(0.112)	(0.092)	(0.092)	(0.112)
log(distance)	-1.120***	-1.120***	-0.980***		-1.117***	-0.978***	
	(0.129)	(0.129)	(0.207)		(0.129)	(0.206)	
CADUSA_SD		0.0404***	0.0404***	0.0404***	0.0397***	0.0401***	0.0398***
		(0.00485)	(0.00488)	(0.00593)	(0.00492)	(0.00477)	(0.00587)
log(distance)					0.0155*	0.00817	0.0146***
×CADUSA_SD					(0.00911)	(0.00555)	(0.00556)
Fixed Effects	Year FEs Month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs
Observations	4,230	4,230	4,230	4,230	4,230	4,230	4,230
Adjusted R^2	0.408	0.408	0.667	0.995	0.408	0.667	0.995

Note: Standard errors in parentheses are clustered at the border post level. Regressions in columns (1), (2), and (5) include year fixed effects and month fixed effects. Regressions in columns (3) and (6) include Canadian-province-year fixed effects, US-state-year fixed effects, and month fixed effects. Regressions in columns (4) and (7) include Post-Year FEs ad Post-month FEs. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 5: The effects on the number of multi-day travelers – observations from 2005–2012.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Multi-day	Multi-day	Multi-day	Multi-day	Multi-day	Multi-day	Multi-day
log(CADUSA)	0.837***	0.985***	0.985***	0.985***	0.985***	0.985***	0.985***
	(0.084)	(0.094)	(0.094)	(0.104)	(0.094)	(0.094)	(0.104)
log(distance)	-0.905***	-0.905***	-1.026***		-0.905***	-1.026***	
	(0.135)	(0.135)	(0.270)		(0.135)	(0.270)	
CADUSA_SD		0.0281***	0.0281***	0.0281***	0.0280***	0.0282***	0.0280***
		(0.00304)	(0.00306)	(0.00339)	(0.00299)	(0.00310)	(0.00330)
log(distance)					0.00264	-0.000990	0.00317
×CADUSA_SD					(0.00414)	(0.00426)	(0.00204)
Fixed Effects	Year FEs Month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs
Observations	9,024	9,024	9,024	9,024	9,024	9,024	9,024
Adjusted R^2	0.253	0.253	0.435	0.992	0.253	0.435	0.992

Note: Standard errors in parentheses are clustered at the border post level. Regressions in columns (1), (2), and (5) include year fixed effects and month fixed effects. Regressions in columns (3) and (6) include Canadian-province-year fixed effects, US-state-year fixed effects, and month fixed effects. Regressions in columns (4) and (7) include Post-Year FEs ad Post-month FEs. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 6: The effects on the number of multi-day travelers – observations from 2005–2008.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Multi-day	Multi-day	Multi-day	Multi-day	Multi-day	Multi-day	Multi-day
log(CADUSA)	1.602***	0.721***	0.721***	0.721***	0.721***	0.721***	0.721***
	(0.162)	(0.164)	(0.165)	(0.200)	(0.164)	(0.165)	(0.200)
log(distance)	-0.908***	-0.908***	-1.015***		-0.904***	-1.013***	
	(0.132)	(0.132)	(0.273)		(0.132)	(0.273)	
CADUSA_SD		0.0888***	0.0888***	0.0888***	0.0881***	0.0884***	0.0880***
		(0.00741)	(0.00746)	(0.00905)	(0.00738)	(0.00738)	(0.00899)
log(distance) ×CADUSA_SD					0.0150	0.00916	0.0181***
					(0.00964)	(0.00723)	(0.00619)
Fixed Effects	Year FEs Month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs
Observations	4,230	4,230	4,230	4,230	4,230	4,230	4,230
Adjusted R^2	0.262	0.262	0.429	0.992	0.262	0.429	0.992

Note: Standard errors in parentheses are clustered at the border post level. Regressions in columns (1), (2), and (5) include year fixed effects and month fixed effects. Regressions in columns (3) and (6) include Canadian-province-year fixed effects, US-state-year fixed effects, and month fixed effects. Regressions in columns (4) and (7) include Post-Year FEs ad Post-month FEs . *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 7: The effects on the number of combined travelers – observations from 2005–2012.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Combined	Combined	Combined	Combined	Combined	Combined	Combined
log(CADUSA)	0.953***	1.057***	1.057***	1.057***	1.057***	1.057***	1.057***
	(0.060)	(0.066)	(0.067)	(0.074)	(0.066)	(0.067)	(0.074)
log(distance)	-1.037***	-1.037***	-1.025***		-1.037***	-1.025***	
	(0.118)	(0.118)	(0.218)		(0.118)	(0.218)	
CADUSA_SD		0.0197***	0.0197***	0.0197***	0.0193***	0.0196***	0.0195***
		(0.00238)	(0.00240)	(0.00266)	(0.00224)	(0.00228)	(0.00247)
log(distance)					0.00956***	0.00388	0.00564***
×CADUSA_SD					(0.00334)	(0.00303)	(0.00177)
Fixed Effects	Year FEs Month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs
Observations	9,024	9,024	9,024	9,024	9,024	9,024	9,024
Adjusted R^2	0.380	0.380	0.586	0.996	0.380	0.586	0.996

Note: Standard errors in parentheses are clustered at the border post level. Regressions in columns (1), (2), and (5) include year fixed effects and month fixed effects. Regressions in columns (3) and (6) include Canadian-province-year fixed effects, US-state-year fixed effects, and month fixed effects. Regressions in columns (4) and (7) include Post-Year FEs ad Post-month FEs . *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 8: The effects on the number of combined travelers – observations from 2005–2008.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Combined	Combined	Combined	Combined	Combined	Combined	Combined
log(CADUSA)	1.493***	0.955***	0.955***	0.955***	0.955***	0.955***	0.955***
	(0.113)	(0.094)	(0.095)	(0.115)	(0.094)	(0.095)	(0.115)
log(distance)	-1.034***	-1.034***	-0.968***		-1.030***	-0.966***	
	(0.118)	(0.118)	(0.215)		(0.118)	(0.215)	
CADUSA_SD		0.0542***	0.0542***	0.0542***	0.0535***	0.0539***	0.0534***
		(0.00469)	(0.00472)	(0.00573)	(0.00467)	(0.00457)	(0.00569)
log(distance)					0.0158*	0.00743	0.0176***
$\times$CADUSA_SD					(0.00889)	(0.00570)	(0.00552)
Fixed Effects	Year FEs Month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs
Observations	4,230	4,230	4,230	4,230	4,230	4,230	4,230
Adjusted R^2	0.391	0.391	0.599	0.996	0.391	0.599	0.996

Note: Standard errors in parentheses are clustered at the border post level. Regressions in columns (1), (2), and (5) include year fixed effects and month fixed effects. Regressions in columns (3) and (6) include Canadian-province-year fixed effects, US-state-year fixed effects, and month fixed effects. Regressions in columns (4) and (7) include Post-Year FEs ad Post-month FEs . *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 9: Coefficient of variation as a measure of exchange rate volatility – observations from 2005–2012.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same-day	Same-day	Multi-day	Multi-day	Combined	Combined
log(CADUSA)	1.116***	1.116***	1.035***	1.035***	1.091***	1.091***
	(0.082)	(0.082)	(0.109)	(0.109)	(0.077)	(0.077)
CADUSA_CV	0.0156***	0.0154***	0.0274***	0.0273***	0.0191***	0.0189***
	(0.00264)	(0.00248)	(0.00339)	(0.00333)	(0.00265)	(0.00249)
log(distance)		0.00441**		0.00194		0.00457***
×CADUSA_CV		(0.00177)		(0.00195)		(0.00171)
Fixed Effects	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs
Observations	9,024	9,024	9,024	9,024	9,024	9,024
Adjusted R^2	0.995	0.995	0.992	0.992	0.996	0.996

Note: Standard errors in parentheses are clustered at the border post level. The dependent variable in each column is indicated in the second row of the table. All regressions include post-year fixed effects and post-month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 10: Coefficient of variation as a measure of exchange rate volatility – observations from 2005–2008.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same-day	Same-day	Multi-day	Multi-day	Combined	Combined
log(CADUSA)	1.144***	1.144***	0.864***	0.864***	1.050***	1.050***
	(0.114)	(0.114)	(0.198)	(0.198)	(0.118)	(0.118)
CADUSA_CV	0.0421***	0.0414***	0.0959***	0.0950***	0.0575***	0.0566***
	(0.00640)	(0.00634)	(0.00983)	(0.00976)	(0.00620)	(0.00617)
log(distance)		0.0155**		0.0198***		0.0189***
×CADUSA_CV		(0.00620)		(0.00674)		(0.00605)
Fixed Effects	Post-Year FEs	Post-Year FEs	Post-Year FEs	Post-Year FEs	Post-Year FEs	Post-Year FEs
	Post-month FEs	Post-month FEs	Post-month FEs	Post-month FEs	Post-month FEs	Post-month FEs
Observations	4,230	4,230	4,230	4,230	4,230	4,230
Adjusted R^2	0.995	0.995	0.992	0.992	0.996	0.996

Note: Standard errors in parentheses are clustered at the border post level. The dependent variable in each column is indicated in the second row of the table. All regressions include post-year fixed effects and post-month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 11: Variance as a measure of exchange rate volatility – observations from 2005–2012.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same-day	Same-day	Multi-day	Multi-day	Combined	Combined
log(CADUSA)	1.080***	1.080***	0.951***	0.951***	1.043***	1.043***
	(0.079)	(0.079)	(0.105)	(0.105)	(0.073)	(0.073)
Variance	0.0128***	0.0127***	0.0192***	0.0191***	0.0151***	0.0150***
	(0.00192)	(0.00181)	(0.00289)	(0.00283)	(0.00196)	(0.00184)
log(distance)		0.00313**		0.00188		0.00346***
$\times$Variance		(0.00133)		(0.00163)		(0.00127)
Fixed Effects	Post-Year FEs	Post-Year FEs	Post-Year FEs	Post-Year FEs	Post-Year FEs	Post-Year FEs
	Post-month FEs	Post-month FEs	Post-month FEs	Post-month FEs	Post-month FEs	Post-month FEs
Observations	9,024	9,024	9,024	9,024	9,024	9,024
Adjusted R^2	0.995	0.995	0.992	0.992	0.996	0.996

Note: Standard errors in parentheses are clustered at the border post level. The dependent variable in each column is indicated in the second row of the table. All regressions include post-year fixed effects and post-month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 12: Variance as a measure of exchange rate volatility – observations from 2005–2008.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same-day	Same-day	Multi-day	Multi-day	Combined	Combined
log(CADUSA)	1.015***	1.015***	0.743***	0.743***	0.927***	0.927***
	(0.112)	(0.112)	(0.200)	(0.200)	(0.114)	(0.114)
Variance	0.0685***	0.0675***	0.130***	0.129***	0.0855***	0.0843***
	(0.00896)	(0.00884)	(0.0146)	(0.0145)	(0.00859)	(0.00852)
log(distance)		0.0223***		0.0259***		0.0261***
$\times$Variance		(0.00824)		(0.00956)		(0.00827)
Fixed Effects	Post-Year FEs	Post-Year FEs	Post-Year FEs	Post-Year FEs	Post-Year FEs	Post-Year FEs
	Post-month FEs	Post-month FEs	Post-month FEs	Post-month FEs	Post-month FEs	Post-month FEs
Observations	4,230	4,230	4,230	4,230	4,230	4,230
Adjusted R^2	0.995	0.995	0.992	0.992	0.996	0.996

Note: Standard errors in parentheses are clustered at the border post level. The dependent variable in each column is indicated in the second row of the table. All regressions include post-year fixed effects and post-month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 13: The effects on the number of same-day travelers–using the lag of exchange rate volatility.

	All time periods				Before the 2008 financial crisis			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Same-day	Same-day	Same-day	Same-day	Same-day	Same-day	Same-day	Same-day
log(CADUSA)	1.158***	1.158***	1.158***	1.158***	1.329***	1.329***	1.329***	1.329***
	(0.0786)	(0.0877)	(0.0786)	(0.0877)	(0.106)	(0.130)	(0.106)	(0.130)
log(distance)	-1.129***		-1.129***		-1.120***		-1.116***	
	(0.129)		(0.129)		(0.129)		(0.128)	
CADUSA_SD	0.00982***	0.00982***	0.00928***	0.00953***	0.0232***	0.0232***	0.0224***	0.0225***
	(0.00278)	(0.00311)	(0.00263)	(0.00290)	(0.00448)	(0.00551)	(0.00471)	(0.00552)
log(distance) ×CADUSA_SD			0.0118***	0.00634***			0.0180**	0.0145***
			(0.00425)	(0.00189)			(0.00903)	(0.00477)
Fixed Effects	Year FEs Month FEs	Post-Year FEs Post-month FEs	Year FEs Month FEs	Post-Year FEs Post-month FEs	Year FEs Month FEs	Post-Year FEs Post-month FEs	Year FEs Month FEs	Post-Year FEs Post-month FEs
Observations	8,930	8,930	8,930	8,930	4,136	4,136	4,136	4,136
Adjusted R^2	0.405	0.995	0.405	0.995	0.408	0.995	0.408	0.995

Note: Standard errors in parentheses are clustered at the border post level. Regressions in columns (1), (3), (5), and (7) include year fixed effects and month fixed effects. Regressions in columns (2), (4), (6), and (8) include Post-Year FEs ad Post-month FEs. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 14: The effects on the number of multi-day travelers–using the lag of exchange rate volatility.

	All time periods				Before the 2008 financial crisis			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Multi-day	Multi-day	Multi-day	Multi-day	Multi-day	Multi-day	Multi-day	Multi-day
log(CADUSA)	1.065***	1.065***	1.065***	1.065***	1.695***	1.695***	1.695***	1.695***
	(0.101)	(0.112)	(0.101)	(0.112)	(0.150)	(0.185)	(0.150)	(0.185)
log(distance)	-0.905***		-0.905***		-0.907***		-0.904***	
	(0.135)		(0.135)		(0.132)		(0.132)	
CADUSA_SD	0.0162***	0.0162***	0.0161***	0.0161***	0.0186***	0.0186**	0.0179***	0.0178**
	(0.00314)	(0.00351)	(0.00308)	(0.00342)	(0.00667)	(0.00820)	(0.00660)	(0.00819)
log(distance)			0.00286	0.00266			0.0134	0.0173**
×CADUSA_SD			(0.00352)	(0.00212)			(0.00988)	(0.00764)
Fixed Effects	Year FEs	Post-Year FEs	Year FEs	Post-Year FEs	Year FEs	Post-Year FEs	Year FEs	Post-Year FEs
	Month FEs	Post-month FEs	Month FEs	Post-month FEs	Month FEs	Post-month FEs	Month FEs	Post-month FEs
Observations	8,930	8,930	8,930	8,930	4,136	4,136	4,136	4,136
Adjusted R^2	0.253	0.992	0.252	0.992	0.260	0.991	0.260	0.991

Note: Standard errors in parentheses are clustered at the border post level. Regressions in columns (1), (3), (5), and (7) include year fixed effects and month fixed effects. Regressions in columns (2), (4), (6), and (8) include Post-Year FEs ad Post-month FEs. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 15: The effects on the number of combined travelers–using the lag of exchange rate volatility.

	All time periods				Before the 2008 financial crisis			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Combined	Combined	Combined	Combined	Combined	Combined	Combined	Combined
log(CADUSA)	1.131***	1.131***	1.131***	1.131***	1.443***	1.443***	1.443***	1.443***
	(0.0728)	(0.0813)	(0.0728)	(0.0813)	(0.101)	(0.124)	(0.101)	(0.124)
log(distance)	-1.037***		-1.037***		-1.033***		-1.030***	
	(0.118)		(0.118)		(0.118)		(0.118)	
CADUSA_SD	0.0111***	0.0111***	0.0107***	0.0108***	0.0207***	0.0207***	0.0201***	0.0199***
	(0.00256)	(0.00286)	(0.00238)	(0.00265)	(0.00384)	(0.00472)	(0.00388)	(0.00481)
log(distance)			0.00902**	0.00600***			0.0143*	0.0171***
$\times$CADUSA_SD			(0.00372)	(0.00185)			(0.00828)	(0.00514)
Fixed Effects	Year FEs	Post-Year FEs	Year FEs	Post-Year FEs	Year FEs	Post-Year FEs	Year FEs	Post-Year FEs
	Month FEs	Post-month FEs	Month FEs	Post-month FEs	Month FEs	Post-month FEs	Month FEs	Post-month FEs
Observations	8,930	8,930	8,930	8,930	4,136	4,136	4,136	4,136
Adjusted R^2	0.380	0.996	0.380	0.996	0.390	0.996	0.390	0.996

Note: Standard errors in parentheses are clustered at the border post level. Regressions in columns (1), (3), (5), and (7) include year fixed effects and month fixed effects. Regressions in columns (2), (4), (6), and (8) include Post-Year FEs ad Post-month FEs. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 16: The effects on the number of same-day travelers – All border posts and all years.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same-day	Same-day	Same-day	Same-day	Same-day	Same-day
log(CADUSA)	0.995***	0.995***	0.995***	0.995***	0.995***	0.995***
	(0.076)	(0.076)	(0.076)	(0.076)	(0.084)	(0.084)
log(distance)	-1.041***	-1.051***	-0.723**	-0.729**		
	(0.133)	(0.134)	(0.314)	(0.314)		
CADUSA_SD	0.00604**	0.00607**	0.00604**	0.00606**	0.00604*	0.00606*
	(0.00297)	(0.00285)	(0.00299)	(0.00288)	(0.00331)	(0.00318)
log(distance) $\times$CADUSA_SD		0.00904***		0.00513*		0.00593*
		(0.00332)		(0.00270)		(0.00353)
Fixed Effects	Year FEs Month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs
Observations	9,888	9,888	9,888	9,888	9,888	9,888
Adjusted R^2	0.272	0.272	0.424	0.424	0.991	0.991

Note: Standard errors in parentheses are clustered at the border post level.. Regressions in columns (1) to (6) include Canadian-province-year fixed effects, US-state-year fixed effects, month fixed effects, and border-post fixed effects. Regressions in columns (7) to (9) include Canadian-province-year fixed effects, US-state-year fixed effects, and month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 17: The effects on the number of multi-day travelers – All border posts and all years.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Multi-day	Multi-day	Multi-day	Multi-day	Multi-day	Multi-day
log(CADUSA)	0.844***	0.844***	0.844***	0.844***	0.844***	0.844***
	(0.103)	(0.103)	(0.103)	(0.103)	(0.114)	(0.114)
log(distance)	-0.719***	-0.724***	-0.643*	-0.642*		
	(0.213)	(0.213)	(0.380)	(0.380)		
CADUSA_SD	0.0155***	0.0155***	0.0155***	0.0155***	0.0155***	0.0155***
	(0.00295)	(0.00284)	(0.00297)	(0.00299)	(0.00330)	(0.00316)
log(distance) $\times$CADUSA_SD		0.00480		-0.000511		0.00558*
		(0.00327)		(0.00319)		(0.00293)
Fixed Effects	Year FEs Month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs
Observations	9,888	9,888	9,888	9,888	9,888	9,888
Adjusted R^2	0.130	0.130	0.328	0.328	0.987	0.987

Note: Standard errors in parentheses are clustered at the border post level. Regressions in columns (1) to (6) include Canadian-province-year fixed effects, US-state-year fixed effects, month fixed effects, and border-post fixed effects. Regressions in columns (7) to (9) include Canadian-province-year fixed effects, US-state-year fixed effects, and month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 18: The effects on the number of combined travelers – All border posts and all years.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Combined	Combined	Combined	Combined	Combined	Combined
log(CADUSA)	0.963***	0.963***	0.963***	0.963***	0.963***	0.963***
	(0.071)	(0.071)	(0.072)	(0.072)	(0.080)	(0.080)
log(distance)	-0.950***	-0.959***	-0.736**	-0.741**		
	(0.130)	(0.131)	(0.301)	(0.301)		
CADUSA_SD	0.00941***	0.00943***	0.00941***	0.00942***	0.00941***	0.00943***
	(0.00282)	(0.00268)	(0.00284)	(0.00274)	(0.00315)	(0.00300)
log(distance) $\times$CADUSA_SD		0.00803**		0.00386		0.00618*
		(0.00330)		(0.00271)		(0.00353)
Fixed Effects	Year FEs Month FEs	Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	CAN-prov-Year FEs US-state-Year FEs Month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs
Observations	9,888	9,888	9,888	9,888	9,888	9,888
Adjusted R^2	0.275	0.275	0.441	0.441	0.992	0.992

Note: Standard errors in parentheses are clustered at the border post level. Regressions in columns (1) to (6) include Canadian-province-year fixed effects, US-state-year fixed effects, month fixed effects, and border-post fixed effects. Regressions in columns (7) to (9) include Canadian-province-year fixed effects, US-state-year fixed effects, and month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 19: One-month implied volatility as a measure of exchange rate volatility – observations from 2005–2012.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same-day	Same-day	Multi-day	Multi-day	Combined	Combined
log(CADUSA)	1.158***	1.158***	1.108***	1.108***	1.123***	1.123***
	(0.091)	(0.091)	(0.119)	(0.119)	(0.086)	(0.086)
Implied_Volatility	0.0214***	0.0210***	0.0375***	0.0373***	0.0236***	0.0232***
	(0.00494)	(0.00463)	(0.00575)	(0.00553)	(0.00477)	(0.00441)
log(distance)		0.00808**		0.00528		0.00846***
×Implied_Volatility		(0.00329)		(0.00330)		(0.00321)
Fixed Effects	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs
Observations	9,024	9,024	9,024	9,024	9,024	9,024
Adjusted R^2	0.995	0.995	0.992	0.992	0.996	0.996

Note: Standard errors in parentheses are clustered at the border post level. The dependent variable in each column is indicated in the second row of the table. All regressions include post-year fixed effects and post-month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 20: One-month implied volatility as a measure of exchange rate volatility – observations from 2005–2008.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same-day	Same-day	Multi-day	Multi-day	Combined	Combined
log(CADUSA)	0.756***	0.756***	0.314	0.314	0.624***	0.624***
	(0.126)	(0.126)	(0.205)	(0.205)	(0.109)	(0.109)
Implied_Volatility	0.0748***	0.0734***	0.135***	0.134***	0.0911***	0.0895***
	(0.0142)	(0.0137)	(0.0210)	(0.0206)	(0.0134)	(0.0128)
log(distance)		0.0300***		0.0342***		0.0340***
×Implied_Volatility		(0.00870)		(0.0122)		(0.00949)
Fixed Effects	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs
Observations	4,230	4,230	4,230	4,230	4,230	4,230
Adjusted R^2	0.995	0.995	0.992	0.992	0.996	0.996

Note: Standard errors in parentheses are clustered at the border post level. The dependent variable in each column is indicated in the second row of the table. All regressions include post-year fixed effects and post-month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 21: Three-month implied volatility as a measure of exchange rate volatility – observations from 2005–2012.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same-day	Same-day	Multi-day	Multi-day	Combined	Combined
log(CADUSA)	1.141***	1.141***	1.071***	1.071***	1.100***	1.100***
	(0.089)	(0.089)	(0.116)	(0.116)	(0.083)	(0.083)
Implied_Volatility	0.0232***	0.0227***	0.0394***	0.0391***	0.0247***	0.0243***
	(0.00538)	(0.00502)	(0.00635)	(0.00611)	(0.00514)	(0.00474)
log(distance)		0.00955***		0.00606		0.00967***
×Implied_Volatility		(0.00360)		(0.00374)		(0.00352)
Fixed Effects	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs
Observations	9,024	9,024	9,024	9,024	9,024	9,024
Adjusted R^2	0.995	0.995	0.992	0.992	0.996	0.996

Note: Standard errors in parentheses are clustered at the border post level. The dependent variable in each column is indicated in the second row of the table. All regressions include post-year fixed effects and post-month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 22: Three-month implied volatility as a measure of exchange rate volatility – observations from 2005–2008.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same-day	Same-day	Multi-day	Multi-day	Combined	Combined
log(CADUSA)	0.699***	0.699***	0.235	0.235	0.566***	0.566***
	(0.127)	(0.127)	(0.205)	(0.205)	(0.108)	(0.108)
Implied_Volatility	0.0885***	0.0869***	0.157***	0.155***	0.106***	0.105***
	(0.0159)	(0.0151)	(0.0232)	(0.0228)	(0.0148)	(0.0141)
log(distance)		0.0339***		0.0376***		0.0379***
×Implied_Volatility		(0.00970)		(0.0135)		(0.0105)
Fixed Effects	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs
Observations	4,230	4,230	4,230	4,230	4,230	4,230
Adjusted R^2	0.995	0.995	0.992	0.992	0.996	0.996

Note: Standard errors in parentheses are clustered at the border post level. The dependent variable in each column is indicated in the second row of the table. All regressions include post-year fixed effects and post-month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 23: Six-month implied volatility as a measure of exchange rate volatility – observations from 2005–2012.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same-day	Same-day	Multi-day	Multi-day	Combined	Combined
log(CADUSA)	1.132***	1.132***	1.049***	1.049***	1.086***	1.086***
	(0.089)	(0.089)	(0.115)	(0.115)	(0.083)	(0.083)
Implied_Volatility	0.0242***	0.0238***	0.0400***	0.0397***	0.0251***	0.0247***
	(0.00576)	(0.00538)	(0.00685)	(0.00661)	(0.00545)	(0.00504)
log(distance)		0.0104***		0.00629		0.0102***
×Implied_Volatility		(0.00383)		(0.00404)		(0.00374)
Fixed Effects	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs
Observations	9,024	9,024	9,024	9,024	9,024	9,024
Adjusted R^2	0.995	0.995	0.992	0.992	0.996	0.996

Note: Standard errors in parentheses are clustered at the border post level. The dependent variable in each column is indicated in the second row of the table. All regressions include post-year fixed effects and post-month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 24: Six-month implied volatility as a measure of exchange rate volatility – observations from 2005–2008.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same-day	Same-day	Multi-day	Multi-day	Combined	Combined
log(CADUSA)	0.688***	0.688***	0.278	0.278	0.575***	0.575***
	(0.125)	(0.125)	(0.201)	(0.201)	(0.107)	(0.107)
Implied_Volatility	0.101***	0.0994***	0.171***	0.170***	0.119***	0.117***
	(0.0173)	(0.0164)	(0.0255)	(0.0251)	(0.0159)	(0.0150)
log(distance)		0.0385***		0.0415***		0.0424***
×Implied_Volatility		(0.0109)		(0.0150)		(0.0117)
Fixed Effects	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs
Observations	4,230	4,230	4,230	4,230	4,230	4,230
Adjusted R^2	0.995	0.995	0.992	0.992	0.996	0.996

Note: Standard errors in parentheses are clustered at the border post level. The dependent variable in each column is indicated in the second row of the table. All regressions include post-year fixed effects and post-month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 25: One-year implied volatility as a measure of exchange rate volatility – observations from 2005–2012.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same-day	Same-day	Multi-day	Multi-day	Combined	Combined
log(CADUSA)	1.127***	1.127***	1.039***	1.039***	1.079***	1.079***
	(0.089)	(0.089)	(0.114)	(0.114)	(0.082)	(0.082)
Implied_Volatility	0.0253***	0.0248***	0.0414***	0.0411***	0.0259***	0.0254***
	(0.00611)	(0.00570)	(0.00733)	(0.00708)	(0.00575)	(0.00532)
log(distance)		0.0110***		0.00664		0.0108***
$\times$Implied_Volatility		(0.00405)		(0.00431)		(0.00395)
Fixed Effects	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs
Observations	9,024	9,024	9,024	9,024	9,024	9,024
Adjusted R^2	0.995	0.995	0.992	0.992	0.996	0.996

Note: Standard errors in parentheses are clustered at the border post level. The dependent variable in each column is indicated in the second row of the table. All regressions include post-year fixed effects and post-month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.

Table 26: One-year implied volatility as a measure of exchange rate volatility – observations from 2005–2008.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same-day	Same-day	Multi-day	Multi-day	Combined	Combined
log(CADUSA)	0.717***	0.717***	0.347*	0.347*	0.618***	0.618***
	(0.124)	(0.124)	(0.197)	(0.197)	(0.106)	(0.106)
Implied_Volatility	0.107***	0.105***	0.179***	0.177***	0.125***	0.123***
	(0.0183)	(0.0173)	(0.0269)	(0.0264)	(0.0167)	(0.0157)
log(distance)		0.0421***		0.0447***		0.0460***
×Implied_Volatility		(0.0119)		(0.0162)		(0.0126)
Fixed Effects	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs	Post-Year FEs Post-month FEs
Observations	4,230	4,230	4,230	4,230	4,230	4,230
Adjusted R^2	0.995	0.995	0.992	0.992	0.996	0.996

Note: Standard errors in parentheses are clustered at the border post level. The dependent variable in each column is indicated in the second row of the table. All regressions include post-year fixed effects and post-month fixed effects. *,**, and *** indicate the significance level of 0.10, 0.05, and 0.01, respectively.