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**A Short-Run Analysis of
Exchange Rates and
International Trade with an
Application to Australia,
New Zealand, and Japan**

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Abstract

The information and communication technology (ICT) revolution of the past 3 decades has transformed the world into an integrated marketplace. Today, producers and consumers alike are able to compare the prices of local businesses and worldwide sellers. For an increasing number of tradable goods, they can take advantage of arbitrage opportunities between online and offline transactions. One of the key exogenous elements behind this arbitrage is exchange rate movements. The existing literature on exchange rates has concluded that nominal prices can be assumed to be rigid, which thus opens the door to short-term international arbitrage. However, empirical evidence of international short-term arbitrage has so far been lacking due to data constraints. In this paper, we first present a new dataset that holds records on daily international exchanges of goods, namely those sent through the international postal logistics network. We then combine this data set with daily data on international exchange rate movements to test the hypothesis of international arbitrage. Applying different econometric techniques, we show that in an environment of floating exchange rates, almost instantaneous short-term international arbitrage is indeed occurring and that it has a persistent effect. The effect seems to be particularly pronounced in the developed countries of Asia and the Pacific.

JEL Classification: F14, F31

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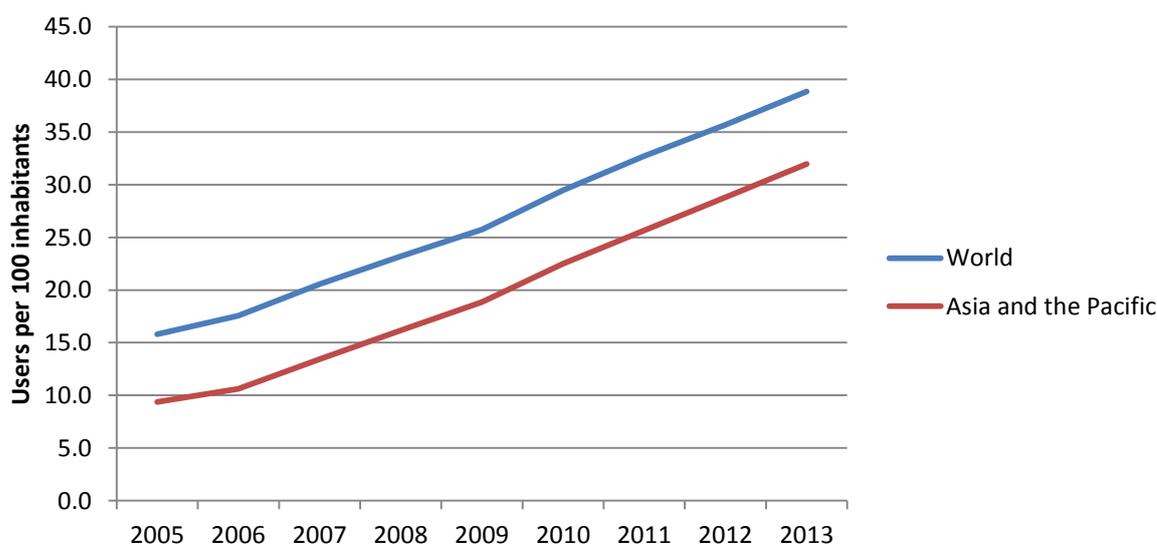
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1. INTRODUCTION

The breakthrough of the internet and the propagation of new means of communications have substantially altered international trade patterns. On the production side, the information and communication technology (ICT) revolution has made it possible to coordinate complex activities across borders, and hence, the production of goods has become increasingly unbundled and spread across a number of countries (Baldwin 2011). Unbundled production might involve entities within the same firm or collaboration with outside partners, as the ICT revolution has made it easier to find and work with suppliers of particular goods and services in the international marketplace. Similarly, today's private consumers are able to interact directly and in real time with e-retailers around the world. In the quest for the best deal, they arbitrage between the prices offered by businesses locally (either brick-and-mortar or domestic online shops) and those offered by online shops worldwide. The emergence of e-commerce has thus lowered the search costs for both producers and consumers alike, and facilitated the international matching for all three cases: between producers, between consumers, and between producers and consumers.

Figure 1 illustrates how usage of the internet by individuals has increased in the past 8 years. Asia and the Pacific outpaced the worldwide trend as usage more than tripled between 2005 and 2013. In the developed countries of Asia and the Pacific, internet usage of individuals was well above 75% in 2012, namely in Australia (82.35%), New Zealand (89.51%), and Japan (79.05%). E-commerce is developing in a very dynamic way in the region; an estimated one-third of all global e-commerce sales are carried out in the region, which amounted to over \$433 billion in 2013 according to a recent study by a consultancy firm (Emarketer 2013). The same firm estimates that the Asia and Pacific region surpassed North America in the volume of e-commerce (business-to-consumer [B2C]) spending in 2013. We therefore believe that the results of this paper are of particular importance in the context of Asia and the Pacific.

Figure 1: Individuals Using the Internet, 2005–2013



Note: The values for 2012 and 2013 are based on estimates.

Source: International Telecommunication Union. Available at <http://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx>.

Arbitrage implies that producers and consumers decide to buy abroad because of a lower price. A first condition for international arbitrage is that transport costs are not excessively high, as this would undo all possible gains. However, today for most goods, transport costs account only for a small share in the final good's price as international logistics chains are organized in a highly efficient way. One of the most efficient distribution networks is the postal network. In the postal network, the weight of distance in transportation costs is particularly low, and therefore opens the possibility for arbitrage for consumers worldwide.¹ The second condition for international arbitrage is that after accounting for shipping and handling costs, the foreign price is still lower than the domestic price. One of the key exogenous determinants of price difference between home and abroad is exchange rate movements.

Exchange rate movements have regained substantive attention during and after the recent Great Recession. As several countries have applied expansive monetary policy, macroeconomists have been repeatedly confronted with questions related to the role of monetary policy in restoring economic competitiveness. Most prominently, Japan has deliberately and openly chosen to apply an exchange rate-oriented monetary policy, which led to concerns by various countries, such as the Russia Federation, about their exporting sectors and some apprehension for commercial balance movements.² An important challenge for empirical research is in observing the short-run trade aggregates, including their fluctuations and implied volatility. Due to this key data constraint, it has been not be possible to know the short-term impacts of exchange rate swings on international trade flows. The debate on the role of expansive monetary policy for short-run gains in competitiveness has so far had little empirical foundation.

In our study we investigate to what extent favorable nominal exchange rate profiles may indeed stimulate, in the short-run, exports to a given destination under floating exchange rate regimes. As a proxy for international trade flows, we use the postal parcel flows collected at dispatch by the Universal Postal Union (UPU) and combine them with daily exchange rate data. As we will show later in this paper, international parcel postal flows are highly correlated to traditional trade flows. In addition, as they originate mainly from e-commerce transactions, they are more responsive to exchange rate shocks than traditional trade, and thus are an ideal variable for the purposes of our study.

Our contribution to the current literature on exchange rates and international trade is mainly twofold. First, we present a new, so far unexploited, database which records short-run international postal flows, which we argue are an excellent proxy for short-term international trade flow movements of e-commerce and related flows. Given the large country coverage and detailed information, the database could be exploited for various research questions in international economics. Second, our study contributes to the empirical research on exchange rates and international trade by providing an important new finding: using a variety of econometric techniques we find that favorable exchange rate movements stimulate trade in the short run.

The paper is structured as follows. In the next section we discuss the current literature on exchange rates and trade as it relates to our work. The data section presents the postal and exchange rate database. We show how international postal flows are related to international trade flows and highlight the advantages and shortcomings of the database. Section 4 outlines the econometric approach by first discussing the time

¹ Recent research by Anson and Helble (2013) finds that the distance coefficient of the gravity equation is only about half the size of that of traditional trade flows.

²<http://www.bloomberg.com/news/2013-01-16/russia-says-world-is-nearing-currency-war-as-europe-joins.html>

series properties of the dataset and then explaining the methodology applied. After presenting the results of our baseline model in Section 5, we proceed by showing that the same results hold for different levels of time aggregation (weekly and monthly) and for non-seasonally adjusted series. The weekly results become even more pronounced in the estimations for some of the developed countries in Asia and the Pacific. Before concluding in Section 6, we present an alternative construction of the dependent variable based on residuals toward express flows.

2. LITERATURE REVIEW

In our research we link daily fluctuations in real international postal flows to daily movements in nominal exchange rates. Our goal is to test for consumer and producer international arbitrage in the online market for goods delivered by the international postal network. To carry out our empirical analysis we need to rely on some assumptions that are corroborated by recent literature. Our main hypothesis is that because of price stickiness and its low reaction to exchange rate movements, in other words low exchange rate pass-through, consumers/producers are able to benefit from international arbitrage. A similar hypothesis has been used by Corsetti and Dedola (2005) in their theoretical work, in which they model prices so that they only respond mildly to nominal exchange rate changes and therefore significant cross-border price differentials between countries are observed. In their model this is due to the fact that firms tend to price to the market.

The assumption of price stickiness in the context of exchange rate movements has been tested empirically in several recent studies. For example, Lunnemann and Wintz (2006) mainly focus on internet prices and show that for a subset of products in Germany, Italy, the United Kingdom, France, and the United States, the median average price change spans from 25 to 68 days. They also point out that price decreases seem to be more frequent in the internet businesses, rather than the traditional brick-and-mortar businesses. In contrast to nominal exchange rates, which are rather volatile, retail prices tend to move sluggishly. The authors conjecture that the average time span seems large enough to allow for consumer arbitrage. In their seminal contribution, Gopinath and Rigobon (2008) use monthly data on at-the-dock import and export prices for the United States and show that the trade-weighted average price duration in dollars is 12.26 months for imports and 13.77 months for exports.

More empirical attempts that highlight cross-border price differentials are found in the studies that emerged from the Billion Prices Project (BPP) at the Massachusetts Institute of Technology.³ Collecting and exploiting daily price data from large online retailers around the world, these studies have detected different pricing behavior across borders. Among others, Burstein and Gopinath (2013) find that nominal exchange rate movements do not impact domestic sales prices; in the short to medium run there seems to be a low exchange rate pass-through. Despite these rich insights, the BPP lacks daily trade flow data to complete the picture. Our dataset, once it is fully product specific, could add this important additional dimension to this seminal research.⁴

In the macroeconomic literature that deals with sticky prices and exchange rate movements, different assumptions are made regarding the pricing by producers (e.g.,

³ <http://bpp.mit.edu/>

⁴ In the near future the UPU will provide product-specific parcel data with HS classification.

Engel [2002] and Goldberg and Tille [2008]). First, several models assume producer currency pricing, in which prices are set in the producer's currency. The second option is local currency pricing, in which the producers set the price in the consumer's currency. Finally, some models assume dollar pricing, where all prices are set in dollars. Staiger and Sykes (2010) show that depending on the type of pricing applied, the effects of currency movements cannot be easily translated into trade policy equivalents as the effect hinges critically on the type of pricing applied. In a more recent paper, Gopinath and Itskhoki (2010) find evidence that for US imports, there is a large difference in the pass-through of the average good priced in dollars (25%) versus non-dollars (95%). Our dataset consists mainly of parcel flows between countries, which are generated by purchases from businesses to businesses, from businesses to consumers, or between consumers. We do not know which pricing model is predominant, but we conjecture that in these transactions all three pricing models are applied.

More broadly, our research relates to two streams of economic literature in the area of exchange rates and trade.⁵ First, our study is related to the literature on exchange rate misalignments and international trade. A key ingredient of almost all trade models are relative prices, and unsurprisingly the empirical research on the responsiveness of trade flows to changes in relative prices started more than 6 decades ago.⁶ Empirical studies on this topic typically calculate the differences between nominal and real exchange rates based on consumer price indices, and assess how the level of currency misalignment is related to trade performance. In contrast with these empirical studies, our dataset does not allow calculation of the exact level of misalignment, as we have no high-frequency data on consumer price indices. Our hypothesis, therefore, is that based on the assumption of price stickiness, any substantive short-run fluctuations of exchange rates translate into a short-run change in relative prices and the possibility of arbitrage.

Another, more recent, stream of literature has studied the relationship between exchange rate devaluations and export surges, instead of focusing on the trade balance. Bernard and Jensen (2004) study the sources of US export growth from 1987 to 1992. The authors identify changes in exchange rates and rises in foreign income as dominant sources for the export increase, while productivity increases in US plants played a relatively small role. Fang et al. (2006) investigate the effect of exchange rate depreciation on exports for 8 Asian countries. They find that depreciation encourages exports, but at the same time increases exchange rate risks, which had a negative effect on export growth in 6 of the 8 countries. Freund and Pierola (2008) identify 92 episodes of export surges with an increase in manufacturing exports of at least 6% that last for 7 years or longer. Their results indicate that export surges in developing countries are preceded by a substantive real depreciation and a reduction in exchange rate volatility. They find that 25% of export growth during the surge was generated by more entries into new export products and new markets. Haddad and Pancaro (2010) show that a real underevaluation had a positive effect on economic growth and export expansion; however, the effect was only significant for low-income countries. More specifically, in developing countries with per-capita income levels below \$2,500, an increase of 50% in real underevaluation led to a 1.7% increase in export growth. Using a gravity equation approach, Nicita (2013) estimates that exchange misalignment had a

⁵ Auboin and Ruta (2013) provide a comprehensive recent survey of the literature on the relationship between currencies and trade.

⁶ For example, Stern et al. (1976) provide a review of 130 studies that try to estimate import and export demand elasticities.

significant impact on exports and thereby produced a trade diversion effect quantifiable at about 1% of world trade.

In summary, the existing literature concurs the finding that prices are sticky, especially in the short and medium run, and that currency misalignments have often been associated with export growth in the medium run. What is lacking so far is evidence on how international exchange rate movements and international trade interact in the very short run. Our study attempts to fill this gap.

3. DATA

In this section we describe the two main databases used in our regression analysis. We start by explaining why the postal network is important for international trade and how postal flows are related to traditional trade. We then present the postal flow database sourced from data collected by the UPU as well as the exchange rate data. Finally, we describe the final dataset after merging both datasets.

3.1 The Relevance of Postal Flows in International Trade

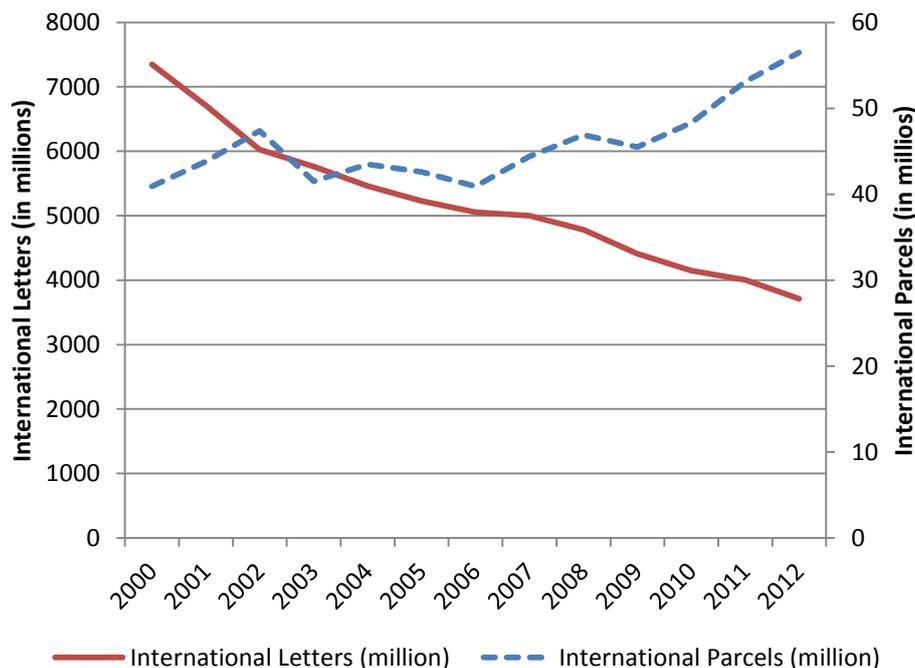
Postal and express delivery services form an integral part of world trade logistics and international supply chains. They are specialized in the delivery of relatively lightweight goods and shipments. Compared to the bulk of international trade that is transported by container, international postal exchanges are typically airborne and therefore much faster in delivery. Another interesting feature of the postal and express delivery network (in the following just called postal network) is the interconnections between operators. In the overwhelming majority of international postal exchanges, postal items are handed over from one operator to another in a well-established and standardized procedure that defines an international postal supply chain. Finally, traditional international trade in goods is predominantly made of transactions between producers (or business-to-business [B2B], especially in the case of global supply chains) or between producers and retailers (another type of B2B). In contrast, the postal network connects not only producers and retailers across borders, but also provides consumers with direct access to the international marketplace. The cross-border postal exchanges are thus between producers (B2B), producers and consumers (B2C), as well as between consumers (consumer-to-consumer [C2C]). Overall, the postal network seems to be more inclusive and better connected than the network of traditional trade flows. It is therefore not surprising that when applying a gravity equation to international postal exchanges the distance coefficient is only half of the estimate for traditional trade flows (Anson and Helble [2013]).⁷

The international postal network has gained significant importance over recent years for the delivery of physical goods for two main reasons. First, unbundled production spread across various countries requires speedy and reliable exchange of information and goods. The postal network may have lost part of its relevance in written communication (Figure 2, solid line), however, it has gained in the organization of the delivery of physical goods (Figure 2, dotted line). Benefiting from its interconnections and capillarity the postal network becomes crucial whenever certain products or components are needed urgently in a specific location. Second, the recent rise of cross-border e-commerce was made possible through an intensive use of the logistics services offered by the postal network. The use of traditional methods of exchanging goods, which rely on containers and consignment of goods, would introduce significant

⁷ For another discussion on new technologies and the weight of distance refer to Lendle et al. (2012).

delays in the delivery of goods for retailers. E-commerce platforms offer consumers the possibility to receive goods at their doorstep within a short period of time, which are two features that only postal networks can offer.

Figure 2: Volume of International Letters and Parcels, 2000–2012



Source: Universal Postal Union. <http://www.upu.int/en/resources/postal-statistics/about-postal-statistics.html>

Beyond freight forwarding, which is not covered by the nature of trade studied in this paper, two logistics systems compete internationally in the postal and express industry. One is an integrated model that supplies end-to-end services through the same network. The other, namely the postal one, is a model of interconnected networks with one network originating a shipment and another located abroad which ensures final delivery. Postal flows are the most universal of all trade flows in terms of geographical access by different populations to their services, for instance in rural areas and small and medium-sized towns. As these populations are being increasingly connected to mobile telephony and to internet platforms, postal platforms are likely to be increasingly used for their cross-border trade.

One might ask what types of goods are transported through postal and express networks. In a recent survey, a designated postal operator in a developed country recorded in detail the content of all parcels sent, mainly in order to facilitate and expedite the customs clearance processes.⁸ Table 1 is based on this data and contains the summary statistics of this sample of products transported by the international postal network. The 15 harmonized system (HS) chapters listed represent about 80% of all products dispatched internationally by this postal operator. The composition of the postal flows therefore reflects the content of cross-border e-commerce. As one might have expected, apparel and clothing as well as print products account for over 25% of international postal flows.

⁸ Due to confidentiality reasons the country name cannot be disclosed.

Table 1: Products Transported by International Postal Networks

HS2 Code	Description	Frequency
61	Articles of apparel and clothing accessories	0.136
49	Printed books, newspapers, pictures	0.123
85	Electrical machinery, equipment parts	0.108
95	Toys, games, and sports requisites	0.095
64	Footwear, gaiters	0.054
21	Miscellaneous edible preparations	0.049
70	Glass and glassware	0.038
33	Essential oils and resinoids	0.026
90	Optical, photographic, cinematographic, measuring, checking	0.026
84	Nuclear reactors, boilers, machinery, and mechanical appliances	0.026
62	Articles of apparel and clothing accessories	0.025
87	Vehicles other than railway or tramway rolling stock	0.023
71	Natural/cultured pearls, precious stones	0.023
92	Musical instruments; parts and accessories	0.022
42	Articles of leather; saddlery and harness	0.020

HS = harmonized system.

Note: Outward statistics from a sample of customs declarations.

Source: Authors' compilation.

Another question to ask is how these postal international exchanges are correlated with international trade flows in the same product groups. In order to answer this question we correlate the monthly volumes of the dispatches in these 15 HS chapters with the corresponding monthly value of trade in these chapters as reported by national customs authorities. (We need to aggregate our daily postal data to monthly flows, since trade data is only available at monthly frequency.) When correlating the monthly trade flows corresponding to the top 50% and 75% HS2 codes present in our parcel data, we observe a strong statistical relationship (R^2 of 68% and 73%) as reported in Table 2. The correlation stays significant even when controlling by fixed effects.

Given this strong correlation, it is not surprising that the international postal exchanges are assumed to reflect the evolution of global trade volumes. Postal and express delivery figures are often seen as a leading indicator of the evolution of international trade and closely monitored by participants in financial markets (such as the Dow Jones Transportation Average), but rather neglected by trade economists.⁹

⁹ The Dow Jones Transportation Average records the economic performance of the 20 largest US logistics providers and is available at: <http://www.djaverages.com/?go=transportation-overview>.

Table 2: Correlation between Parcel Dispatches and Export Comtrade Data

Dependent Variable	Exports	Exports	Exports	Exports	Exports	Exports
	Top 50% HS2	Top 50% HS2	Top 50% HS2	Top 75% HS2	Top 75% HS2	Top 75% HS2
log parcel dispatches	0.887***	0.032***	0.710***	0.898***	0.024***	0.655***
	(-0.013)	(-0.007)	(-0.020)	(-0.011)	(-0.005)	(-0.018)
R ²	0.345	0.345	0.675	0.395	0.395	0.725
Importer-time FE	No	No	Yes	No	No	Yes
Exporter-time FE	No	No	Yes	No	No	Yes
Importer-Exporter FE	No	Yes	No	No	Yes	No
Number of observations	110,628	110,628	110,433	118,882	118,882	118,670

HS = harmonized system, FE = fixed effects.

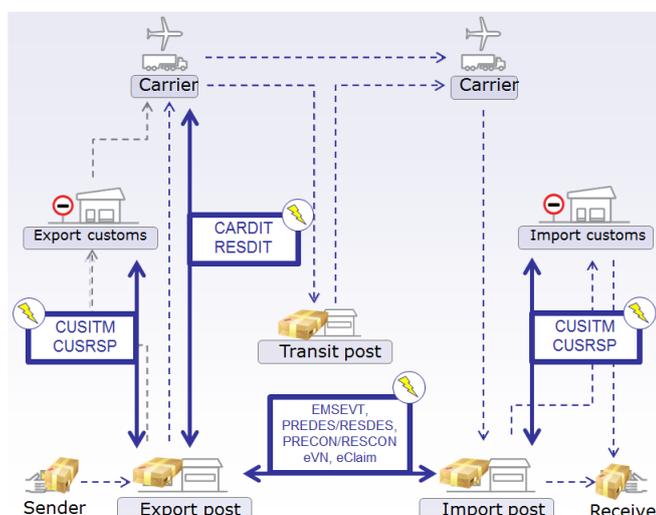
Note: Standard errors are in parentheses, with ***, **, and * denoting statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

3.2 International Postal Flow Data

The postal data used in this study is based on entries in the electronic data interchange (EDI) system of the UPU, which is a real-time messaging system used to organize cross-border postal operations at the international level. In the EDI system, every postal item that is dispatched internationally is scanned and tracked at several stages of the international postal process until it reaches its final destination. For a visual overview of the messaging system refer to Figure 3.

Figure 3: Electronic Data Interchange Messaging System



Source: Universal Postal Union. <http://www.upu.int/>

The EDI system has been conceived to ensure traceability of every postal shipment from origin to destination, and to improve the quality of international postal services through greater operational efficiency along the postal supply chain. It is also meant to

enhance the interconnection between postal operators according to agreed international standards.

For our research question, we are interested in the daily volume of bilateral postal exchanges. We have therefore aggregated the detailed data for each message and constructed a database containing daily information on the volume of international bilateral dispatches. Our aggregation covers the three types of international postal items: first, international letter-post items (including not only letters but also items weighting up to 2 kilograms [kg] each); second, international parcel post items (up to 30 kg each); and third, international express mail service items belonging to what is called EMS, the fastest international postal service covering both documents and packages (up to 30 kg each). For each day from 1 October 2010 to 31 December 2012, we calculated the weight and amount (in terms of number of items) by mail class that every postal operator sent to its partners. As specified in Table 3, our postal data of aggregated EDI messages covers entries from 185 countries (postal operators) for a total of 14,148 country pairs (corridors). In total, we count 2,224,416 non-zero entries.

Table 3: Postal Data Overview

Number of countries	185
Number of currencies	144
Number of corridors	14,148
Time span	1 October 2010–31 Dec 2012
Number of records	7,822,404
Number of zero observations	5,597,988

Source: Authors' Calculations.

The daily aggregated data of postal exchanges presents several statistical challenges. First of all, postal flows are not uniformly distributed during the week, as reported in Table 4. In addition, some countries do not have daily postal flows, and dispatches are only sporadic. This is mainly due to logistical reasons and factors relating to market size. Secondly, there are many zero records (around 70% of the sample) as we illustrate in Table 4. The zeroes come from two different sources. On the one hand, postal flows are scarce during weekends, accounting for 30% of the zeros. On the other hand, in some country pairs exchanges are few or non-existent. The zero trade flows are similar to the trade literature, and relate to the fact that the world trade matrix tends to be sparsely populated.

Table 4: Daily Deviations in International Parcel Dispatches (%)

Day	Average deviation	Standard deviation	Minimum deviation	Maximum deviation
Tuesday	0.363	0.350	-0.782	1.998
Wednesday	0.458	0.398	-0.633	2.351
Thursday	0.449	0.407	-0.678	2.315
Friday	0.437	0.479	-0.647	3.550
Saturday	-0.035	0.372	-0.931	2.996
Sunday	-0.640	0.115	-0.962	-0.303

Note: Percentage deviations are calculated using Monday as the benchmark.

Source: Authors' calculations.

3.3 Exchange Rate Data

We retrieved daily exchange rates from Bloomberg and collected 144 spot prices toward the US dollar in direct quote.¹⁰ The direct quote allows us to have homogeneous quotes in terms of US dollars. We computed the bilateral exchange rates by dividing, for a given country-pair, their respective spot prices. An increase of the new computed exchange rates is considered as a depreciation in the exporting country. The spot prices are those at the close of the London exchange market. We chose London to simplify the collection of data and because of the importance of this stock exchange platform. As a corollary, we use the business calendar of the London Stock Exchange, which implies that we do not observe exchange rates during weekends. For the sake of simplicity we assume the latter to be equal to the ones of the preceding Friday. The spot prices for the 14,148 corridors were computed by dividing each country relative spot price with respect to the US dollar. The daily data spans from 1 October 2010 to 31 December 2012.

3.4 Sample Data

For our study, we have eliminated all countries with exchange rate regimes that are either pegged or managed. The reason is that in most managed or pegged exchange rate regimes, the consumer is unable to undertake international arbitrage, as small deviations from the targeted exchange rate are immediately corrected. Our study thus only includes fully floating exchange rates, according to the de facto classification of the International Monetary Fund (IMF). In addition, in order for international consumer arbitrage to happen, countries need to be internationally integrated and to have a high share of the population with internet access. In our sample we count 26 countries (most of them are countries with high per capita incomes) with de facto floating exchange rates according to the IMF classification in August 2012 (see Table 5). After excluding all bilateral pairs which use the same currency (e.g., postal flows among eurozone countries), we count a total number of 406 corridors with an average of 814 observations each (Table 6). Another important feature of this sample restriction is that most of the remaining economies are developed countries.

¹⁰ <http://www.bloomberg.com/>.

Table 5: Free-Floating Countries

Country	ISO 2 Country Code	ISO Currency Code
Austria	AT	EUR
Australia	AU	AUD
Canada	CA	CAD
Chile	CL	CLP
Cyprus	CY	EUR
Czech Republic	CZ	CZK
Germany	DE	EUR
Estonia	EE	EUR
Spain	ES	EUR
Finland	FI	EUR
France	FR	EUR
United Kingdom	GB	GBP
Greece	GR	EUR
Ireland	IE	EUR
Israel	IL	ILS
Italy	IT	EUR
Japan	JP	JPY
Malta	MT	EUR
Netherlands	NL	EUR
New Zealand	NZ	NZD
Poland	PL	PLN
Portugal	PT	EUR
Sweden	SE	SEK
Slovenia	SI	EUR
Slovakia	SK	EUR
United States	US	USD

Source: Authors' tabulation.

Table 6: Floating Sample Overview

Number of countries	26
Number of corridors	406
Time span	1 October 2010–31 December 2012
Average number of observations per corridor	815

Source: Authors' tabulation.

4. A DYNAMIC MODEL FOR TESTING INTERNATIONAL ARBITRAGE

Our sample consists of a large number of time series observations of international postal exchanges and exchange rates (more than 2 years on a daily basis) and a large number of groups (406 corridors). The main objective of our econometric analysis is to test the hypothesis of short-run international arbitrage. Traditionally, such a problem would have been tackled using either of the two following procedures: First, one can run separate regressions for each group and analyze the distribution of the estimated coefficients across groups. The key result would then be the mean of the estimates, which is called the mean group estimator and which yields a consistent estimate of the average of the parameters. However, the estimation does not take into account that some parameters may be identical across groups. The second econometric approach

would be to estimate pooled estimators, such as the fixed or random effects estimators. Using this approach the intercepts are allowed to differ across groups while it is assumed that all other coefficients and error variance are identical. Pesaran et al. (1999) have developed an intermediate approach which we argue is the most appropriate for our setup, as it allows intercepts, short-run coefficients, and error variances to differ across groups, but the long-run coefficients are assumed to be the same. Pesaran's Vector Error Correction (VEC) is specifically designed for dealing with panels with large time and group dimensions, where one needs to distinguish short-run effects from equilibrium effects. We therefore specify the model in a way that identifies the impact of transitory short-run shocks and of permanent equilibrium shocks. We discuss the specification in the section below where we also define the dependent variable as a seasonal adjusted version of postal flows.

Before discussing our econometric model we define our dependent variable. As discussed in Section 3, postal dispatches show seasonal patterns specific to each corridor. This is mainly due to logistics, as every network has its own, purely seasonal effects. For every country pair ij , our dependent variable is the residuals between postal flows and a regression of first-difference de-trended postal flows with day-of-the-week dummies. Our dependent variable is the residuals of the regression on day-of-the-week dummies. As a result the adjusted dependent variable does not contain seasonal components.¹¹ We choose the dummy variable technique because of the deterministic type of seasonality exhibited in postal networks.

In order to determine whether there is consumer arbitrage in the short run (i.e., whether parcel flows move together with exchange rate movements), we need to establish a dynamic model. The main idea is that because of price stickiness, short-run nominal exchange movements may shift consumer expenditure from domestic markets (online or offline) to foreign online retailers. The underlying assumptions are that consumers' adjustment expenditure costs are low, because the internet makes price comparisons easier, and that transport costs are low because of the postal network. As stated above, we model the dynamics between exchange rates and parcel flows with the help of the Pesaran et al. (1999) Pooled Mean Group (PMG) estimator, which is an extension of the VEC to panels with two-high dimensions. Stacking up the time series for a given country pair, ij , the PMG estimator focuses on the equation:

$$\begin{aligned}\Delta \ln EXP_{ij} &= (\xi(\theta)_{ij})\phi_{ij} + \sum_{s=1}^p \Delta \ln EXP_{ij,-p} \lambda_{ijp} + \sum_{s=1}^p \Delta \ln FX_{ij,-p} \delta_{ijp} + u_{ij}L_T + \dot{\omega}_{ij} \quad (1) \\ \xi(\theta)_{ij} &= \ln EXP_{ij,-1} - \theta \ln FX_{ij,-1} \quad ij = 1, \dots, N; t = 1, \dots, T\end{aligned}$$

The dependent variable is $\ln EXP_{ij}$, the percentage change of parcels dispatched from country i to country j . $\ln FX_{ij}$ is the exchange rate and $\ln EXP_{ij,-p}$ and $\ln FX_{ij,-p}$ are the p lags of the percentage change in parcels and in exchange rates. $\dot{\omega}_{ij}$ is the error term assumed to be Gaussian for every panel.

The interpretation of model (1) is very appealing. On one hand, it assumes that there is an underlying equilibrium relationship $(\xi(\theta)_{ij})$ with the same parameter θ for every panel. The equilibrium relationship refers to how will parcel flows change following a

¹¹When not seasonally adjusted, the relationship with the exchange rates seems stronger. However, this might be mainly due to confounding deterministic effects. Our approach is more conservative.

permanent nominal depreciation. The parameter θ can be interpreted as the elasticity of parcel flows with respect to the exchange rate. On the other hand, the speed of returning to the equilibrium or error correction term (ϕ_{ij}) is country pair specific. This allows for more flexibility; the average of ϕ_{ij} can be seen as the percentage time, in days, that it takes to be back at the equilibrium after a shock to the system. We allow the short-run parameters, λ_{ijp} and δ_{ijp} , to be specific to each corridor. This controls for the fact that for some country pairs short-run movements can be more important. The parameters can be viewed as the response to a 1% daily depreciation that is not sustained. In addition, our specification allows for a time invariant, (1_T being a vector of ones), corridor fixed effects u_{ij} . The most important coefficients are θ and the average of the ϕ_{ij} . θ is seen as the elasticity of dispatched parcels from country i to country j following a sustained 1% depreciation of country j currency. A significant and negative average of ϕ_{ij} is a necessary condition for the existence of the equilibrium relationship. We discuss the estimation of equation (1) in Section 5.

5. ESTIMATION RESULTS

We examined the exchange rate dynamics and the question of international consumer arbitrage for the sample of countries classified by the IMF as having a free floating exchange rate regime. This way we can assume that for these markets, exchange rates are exogenous to monetary policy. We emphasize the fact that the corresponding sample contains mostly well-integrated economies with a large percentage of the population having internet access. The inference only applies to countries with similar characteristics. The baseline results are discussed in Section 5.1 while we provide alternative specifications in Section 5.2. Section 5.3 looks at the case of Australia, New Zealand, and Japan.

5.1 Baseline Regression Results

In Table 7 we show the result for the PMG estimation of model (1). We present four models with different lag structures. The number of difference lags represents the order of the underlying VAR model. Our dependent variables are the seasonally adjusted dispatched parcels. We estimate model (1) by profiled maximum likelihood with a custom modified version of Pesaran's Stata command, `xtpmg`.¹² The short-run and error correction coefficients displayed are the average of the corridor-specific coefficients. For the four specifications, the system exhibits very few short-run dynamics. This might be due to the fact that exchange rate depreciations are transmitted very quickly into the internet market. When a consumer makes a decision to buy online, they will look at their budget and at the price of the good. The search cost they face is very low because it is fairly simple to compare prices online. With low expenditure adjustment cost and price stickiness the nominal exchange rate will trigger the arbitrage to balance the online market.

The absence of short-run dynamics may also indicate that transitory shocks have little impact on exports—what is needed is a sustained change for at least a few days. The error correction coefficient is negative and close to 1 indicating a fast return to the

¹² The custom command is available from the authors upon request. It is mainly based on Pesaran's command, but with a few improvements in the likelihood part of the algorithm.

equilibrium. The equilibrium relationship suggests that a 1% depreciation will increase postal flows by 0.5%–0.6%. We notice that the effect is persistent. Since the elasticities are statistically different from unity, this suggests that either there is incomplete exchange rate pass-through or that goods in foreign parcels are imperfect substitutes to domestic goods. Furthermore the general results do not depend on the lag structure.

Table 7: Dynamic Model for Exchange Rates and Parcel Dispatches, Daily Frequency

Dependent Variable $\Delta \ln EXP$	PMG Estimates	PMG Estimates	PMG Estimates	PMG Estimates
Equilibrium relationship				
$1.\ln FX$	-0.600*** (0.092)	-0.626*** (0.102)	-0.636*** (0.104)	-0.494*** (0.105)
Short-run dynamics (average)				
$1.\Delta \ln FX$	2.601 (6.706)	1.407 (3.465)	1.111 (1.466)	-0.864 (4.433)
$2.\Delta \ln FX$		1.614 (1.238)	-0.721 (1.674)	-6.050 (4.539)
$3.\Delta \ln FX$			0.873 (1.844)	-0.412 (3.773)
$4.\Delta \ln FX$				-3.477 (2.638)
$1.\Delta \ln EXP$	-0.044 (0.095)	-0.127*** (0.048)	-0.045 (0.037)	0.270*** (0.082)
$2.\Delta \ln EXP$		-0.030 (0.030)	-0.032 (0.033)	0.208* (0.110)
$3.\Delta \ln EXP$			0.003 (0.022)	0.167*** (0.059)
$4.\Delta \ln EXP$				0.204*** (0.075)
Error correction	-0.779*** (0.088)	-0.714*** (0.044)	-0.762*** (0.033)	-1.049*** (0.086)
Constant	1.233*** (0.124)	1.427 (0.164)	1.615*** (0.138)	2.065*** (0.214)
Number of observations	106491	85875	67969	55663

PMG = pooled mean group.

Note: Standard errors are in parentheses, with ***, **, and * denoting statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

5.2 Robustness Checks

As an alternative to introducing corridor-specific, day-of-the-week dummies, one may aggregate the data on the weekly level. The weekly aggregation takes the log of the sum of postal dispatches in a week on the left-hand side of equation (1) and the log of the average of the daily exchange rates. Table 8 shows the results for the estimation of model (1) with weekly data. The conclusion is similar to before, where there are little short-run dynamics but a strong equilibrium relationship. A sustained 1% depreciation will increase exported parcels by roughly 1% to a given destination.¹³ A similar conclusion is obtained in Table 9 where we use monthly aggregated data. In this case the 1% depreciation leads to a 0.6% increase in parcels dispatched.

Table 8: Pooled Mean Group Estimation Results with Weekly Data

Dependent Variable $\Delta \ln EXP$	Pooled Mean Group Estimates
Equilibrium relationship $I.\ln FX$	-0.978*** (0.083)
Short-run dynamics (average) $I.\Delta \ln FX$	-0.562 (0.381)
$I.\Delta \ln EXP$	-0.050*** (0.009)
Error correction	-0.599*** (0.048)
Constant	1.597*** (0.129)
Number of observations	39272

Note: Standard errors are in parentheses, with ***, **, and * denoting statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

Table 9: Pooled Mean Group Estimation Results with Monthly Data

Dependent Variable $\Delta \ln EXP$	Pooled Mean Group Estimates
Equilibrium relationship $I.\ln FX$	-0.597*** (0.108)
Short-run dynamics (average) $I.\Delta \ln FX$	-0.629 (0.737)
$I.\Delta \ln EXP$	0.038** (0.015)
Error correction	-0.696*** (0.020)
Constant	2.725*** (0.127)
Number of observations	9471

Note: Standard errors are in parentheses, with ***, **, and * denoting statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

¹³ The result is the same when specific month-corridor dummies are included.

Eventually we try a different approach for the definition of our dependent variable. In fact, the database contains information about express dispatches which are related to some extent to international parcels with a few differences. The express service is more expensive than the international parcels. It exhibits higher transport costs for a faster service. On the other hand, express flows are highly correlated with international parcels. This is due to the fact that they reflect similar seasonal patterns and also changes in demand due to changes in taste toward a given origin. Moreover, express flows are less sensitive to exchange rate movements because of high transport costs. Therefore, a way of controlling for seasonal patterns and changes in demand is to first regress parcel flows on express flows. This way we control for seasonal patterns while taking into account demand changes that are unrelated to exchange rates.

Table 10: Pooled Mean Group Estimation Results with Express Flow Residuals

Dependent Variable	PMG	PMG	PMG
$\Delta \ln EXP$	Estimates	Estimates	Estimates
Equilibrium relationship			
$I.\ln FX$	-0.530*** (0.078)	-0.619*** (0.101)	-0.601*** (0.106)
Short-run dynamics (average)			
$I.\Delta \ln FX$	-2.204 (2.209)	6.879 (5.119)	0.191 (2.534)
$II.\Delta \ln FX$		-0.637 (3.728)	-2.556 (7.223)
$III.\Delta \ln FX$		7.614 (5.902)	2.752 (5.178)
$IV.\Delta \ln FX$			-24.840 (24.732)
$I.\Delta \ln EXP$	-0.021 (0.073)	-0.153** (0.067)	0.039 (0.114)
$II.\Delta \ln EXP$		-0.159** (0.065)	-0.128 (0.082)
$III.\Delta \ln EXP$		-0.070* (0.038)	-0.086 (0.154)
$IV.\Delta \ln EXP$			-0.193 (0.165)
Error correction	-1.001*** (0.320)	-0.686*** (0.081)	-0.678*** (0.068)
Constant	-0.119 (0.319)	-0.562** (0.233)	0.005 (0.281)
Number of observations	68951	48799	41252

PMG = pooled mean group.

Note: Standard errors are in parentheses, with ***, **, and * denoting statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

In Table 10 we present the results where the dependent variable is the residual of the regression between international parcel dispatches and express dispatches. Once again, the results are roughly the same as before. The error correction coefficient is negative and close to unity, indicating a fast return to the equilibrium. A sustained 1% depreciation leads to an increase of exports of about 0.6%.

5.3 The Case of Australia, New Zealand, and Japan

As mentioned in the introduction, e-commerce is developing in a particularly dynamic way in Asia and the Pacific. Three countries in our sample are located in this region, namely Australia, Japan, and New Zealand. Due to their high use of the internet (over 75%), e-commerce has developed rapidly in all 3 countries. In this section, we therefore test whether our estimation results equally hold for these countries.

In all 3 countries, surveys have been recently conducted on the trends of e-commerce, including on volumes of cross-border e-commerce. According to a recent study by the Australian Bureau of Statistics (2013), Australian consumers purchased goods worth A\$6.23 billion from overseas online shops, versus \$A4.55 billion from domestic online retailers in the financial year 2011–2012. It also estimated that in 2012, the average online shopper spent more than \$A2000, of which an estimated \$A1150 was spent on international purchases.

For the case of New Zealand it is estimated that over 40% of all online purchases are cross border, according to a study commissioned by the Bank of New Zealand (2013). In addition, they are growing faster than domestic online purchases. Recent data indicates that online purchases from foreign e-retailers were 24% higher in December 2013 compared to December 2012, whereas domestic e-commerce sales only increased by 7% over the same time period. The Bank of New Zealand (2013) believes that the strong New Zealand dollar is an important factor behind the increase in international retailers' share of New Zealand online spending. The most popular countries to shop online for New Zealanders were the US (30%), the UK (18%), Australia (15%), and the European Union (16%). It seems that a common language is thus an important driver of international e-commerce (which corroborates the results by Anson and Helble [2013] in their gravity model).

In 2013, the Japanese Ministry of Economy, Trade, and Industry conducted a survey on e-commerce for the financial year 2012, including the cross-border e-commerce flows between Japan, the US, and the People's Republic of China (PRC). It found that the volume of domestic e-commerce (B2C) had expanded by 12.5% in 2012 to a total of ¥9.5 trillion. In contrast to Australia, the amount of cross-border e-commerce (only purchases from the PRC and the US were taken into account) was relatively small, at ¥15.5 billion. Interestingly, the volume of US consumers' purchases from Japanese and PRC retailers was almost 5 times larger and amounted to ¥75.7 billion. The relatively small amount of cross-border online purchases by Japanese consumers might be largely explained by the fact that few websites outside Japan have their websites translated into Japanese.

The 3 countries in our sample thus offer an interesting mix. Australia and New Zealand seem to be very active in cross-border online shopping, whereas Japan, also due to its large domestic market, is at a rather low level. Table 11 shows the results when we include a dummy for the 3 countries in our estimations. The dummy becomes unity whenever one of the 3 countries is a destination of a parcel flow. Column (1) lists the results when we re-run the baseline regression with daily data, and in column (2) is the regression outcome with weekly data. The results in column (1) indicate that for the daily flows, consumers benefit from international arbitrage in the 3 countries in a similar

way as in the rest of the sample. The dummy coefficient is not statistically significant. When we aggregate to weekly flows (column [2]), the dummy variable becomes strongly statistically significant and is positive. This means that the 3 countries show an even stronger reaction to favorable exchange rate movements compared to the other countries in the sample. In conclusion, international arbitrage in online purchases seem to occur in the 3 Asia and Pacific countries at least to the same extent or even stronger than in the rest of our sample.

Table 11: Dynamic Model for Exchange Rates and Parcel Dispatches: The Case of Asia and the Pacific

Dependent variable	(1)	(2)
	PMG Estimates	PMG Estimates
$\Delta \ln EXP$		
Equilibrium relationship		
$I.\ln FX$	-0.586*** (0.104)	-0.978*** (0.083)
$I.\ln FX$ Asia	-0.064 (0.223)	-0.644*** (0.175)
Short-run dynamics (aver.)		
$I.\Delta \ln FX$	2.566 (6.691)	-0.587 (0.379)
$I.\Delta \ln EXP$	-0.042 (0.009)	-0.050*** (0.009)
Error correction	-0.764*** (0.076)	-0.589*** (0.059)
Constant	1.247*** (0.124)	1.709*** (0.128)
Number of observations	106491	39272

PMG = pooled mean group.

Note: Standard errors are in parentheses, with ***, **, and * denoting statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

6. CONCLUSIONS

For the first time, we use a high-frequency international exchange data set to assess the question of international consumer arbitrage in the online market. Postal flows form an integral part of international trade and the scale economies of its network allow consumer to face low transport costs. This, coupled with price rigidity and low search costs, allows for international arbitrage. Combining daily postal flows with daily exchange rate movements, we find that exchange rate movements do indeed matter for bilateral trade flows in the short run. A currency appreciation triggers an increase of postal inflows by a magnitude of 0.5 percentage points. The effect is very similar for the developed countries of Asia and the Pacific included in our sample.

Future extensions of this research are to include countries with active monetary policy. A sampling strategy could be to exclude only partners sharing a common currency anchor. In the near future, systematic information on customs declarations, including value, quantity, and good category for each international postal shipment, will be generated across countries. Forthcoming access to this customs declaration data will enable the analysis of consumer arbitrage at the most disaggregated HS-6 level, and estimates of exchange rate elasticities for each individual good. This could lead to a

new classification of goods between those subject to international arbitrage and others with relatively inelastic reactions to exchange rate variations, namely “proximity goods”, a new category of implicitly non-tradable goods. These goods would benefit from some sort of preference for proximity consumption due to specific characteristics, such as high transportation costs or the availability of local after-sale service.

To conclude, international e-commerce is reshaping consumer and producer behavior worldwide. The most dynamic world region is Asia and the Pacific, where more and more online transactions are undertaken cross border. One reason might be that international e-commerce constitutes an important part of international supply chains, which are widespread throughout Asia. It therefore seems that the time is ripe for economic science to start tracking and analyzing today and tomorrow’s consumption and production patterns related to international e-commerce in a systematic way. As pointed out repeatedly by leading trade economists, trade policies need to adapt to the realities of the 21st century’s trade dominated by international supply chains. Yet, international supply chains are still poorly understood. We hope that our research sheds new light on today’s international e-commerce, and that in the future, the database presented in this paper can be used in various ways to further our understanding of today’s trade patterns.

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