CESifo WORKING PAPERS

7266
2018

September 2018

# Forensics, Elasticities and Benford's Law

*Banu Demir, Beata Javorcik*

CESifo

**Impressum:**

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
Editors: Clemens Fuest, Oliver Falck, Jasmin Gröschl
www.cesifo-group.org/wp

An electronic version of the paper may be downloaded
· from the SSRN website: www.SSRN.com
· from the RePEc website: www.RePEc.org
· from the CESifo website: www.CESifo-group.org/wp

CESifo *Working Paper No. 7266*
*Category 8: Trade Policy*

# Forensics, Elasticities and Benford's Law

## Abstract

Estimates of the trade elasticity based on actual trade policy changes are scarce, and the few that exist are all over the place. This paper offers a setting where an exogenous increase in a border tax can be used to estimate the trade elasticity. It shows theoretically and empirically that if evasion of border taxes is not taken into account, the trade elasticity is estimated with a large downward bias, leading to miscalculation of gains from trade. The paper also contributes to the literature by proposing two new methods of detecting evasion of border taxes.

JEL-Codes: F100.

Keywords: trade elasticity, tax evasion, trade financing, border taxes, Benford's law.

*Banu Demir*
*Bilkent University*
*Ankara / Turkey*
*banup@bilkent.edu.tr*

*Beata Javorcik*
*University of Oxford*
*Oxford / United Kingdom*
*beata.javorcik@economics.ox.ac.uk*

September 5, 2018
The authors would like to thank Andy Bernard, Maria Guadalupe, David Hummels, Oleg Itskhoki, Mazhar Waseem and Muhammed Ali Yildirim as well as seminar audiences at Warwick, King's College, Koc University, Free University of Amsterdam, Aarhus, Copenhagen, Nottingham and the New Economic School in Moscow for useful comments and discussions

# 1 Introduction

A very prominent and fast growing strand of the international trade literature evaluates the consequences of trade policy through the lens of a structural model of behavior of consumers and producers (see Ossa (2014); Caliendo and Parro (2015); Arkolakis et al. (2018) just to name a few examples). This approach is particularly useful when researchers are interested in the welfare consequences of policy changes, whether actual, proposed or counterfactual. However, the estimated effects depend crucially on the consistency of the estimated parameters fed into the analysis, especially on the trade elasticity. Yet, as pointed out by Goldberg and Pavcnik (2016) in their recent survey, "estimates of the trade elasticity based on *actual* trade policy changes are scarce, and the few that exist are all over the place". Moreover, much of the literature on trade elasticity does not take into account political economy of trade policy and institutions and the possibility that firms might have a behavioral response to changes in taxes. Goldberg and Pavcnik call it "a hole in the literature that future research will hopefully address".[1]

This paper offers a setting where an exogenous increase in a border tax can be used to estimate the trade elasticity. The exercise yields the estimate of 2.2, which falls above the range of typical values found by studies relying on time-series variation but below the values obtained from cross-sectional studies. More interestingly, this paper shows that in the presence of evasion the trade elasticity is estimated with a large downward bias yielding the value of only 0.4. In other words, this paper demonstrates that ignoring behavioral responses of firms to changes in taxes, such as tax evasion, will lead to biased trade elasticity estimates and hence miscalculation of gains from trade based on standard welfare formulations. Al-

[1] The trade elasticity is usually estimated either based on cross-sectional (cross-country and cross-industry) variation of trade costs other than trade policy barriers or based on time series variation stemming from exchange rate fluctuations. Studies relying on cross-sectional variation produce high estimates for the trade elasticity (around 5 or higher), while studies relying on time-series variation yield low estimates (around 1 or lower) (see a review by Hillberry and Hummels (2013) as well as studies by Baier and Bergstrand (2001); Broda and Weinstein (2006); Romalis (2007); Caliendo and Parro (2015)). Although one may argue that the former studies capture long-term effects corresponding to different steady states associated with different trade costs and the latter studies capture on the the short-run effects, Goldberg and Pavcnik (2016) point out that the differences could be simply due to very different sources of variation used.

though our study considers a particular policy shock, our theoretical model demonstrates that the downward bias will be present in any context where evasion takes place. And as shown by Ferrantino et al. (2012), tariff evasion occurs even in industrialized countries, such as the U.S.[2]

This paper makes a further contribution to the literature by proposing two new methods of detecting evasion of border taxes. The first method is based on Benford's law, which describes the distribution of first digits in economic or accounting data. The second method relies on comparing demand elasticities with respect to price and trade taxes. Both methods are applied to an unexpected policy change in Turkey and uncover evidence consistent with an increase in tax evasion after the Turkish authorities raised the tax rate applied to external financing of imports. This conclusion is confirmed using a well-established approach based on discrepancies in international trade statistics, proposed by Fisman and Wei (2004).

While focusing on a particular policy shock is interesting in its own right, given that taxes collected by Turkish Customs amounted to USD 26.8 billion, or about 18% of total tax revenues in Turkey in 2011, the paper has practical implications going beyond a particular policy episode. It suggests that Benford's law could be used by authorities to decide where to channel resources in their fight with evasion. A simple test showing a positive relationship between deviations from Benford's law and the applicable tax/tariff rate would be quite suggestive of evasion taking place and would call for further scrutiny. Such a test would could be applied to import flows using a particular mode of transport, crossing a particular checkpoint, or even being cleared by a particular customs officer.[3] The test could be performed using import transaction data that are collected by customs and hence readily available.[4]

The final contribution of this paper lies in showing theoretically the positive welfare

[2]These authors estimate that about 2 billion of U.S. tariff revenue was lost due evasion during 2002-2008.

[3]Of course, as with any statistical test, the possibility of type I and II errors should be kept in mind when interpreting the results.

[4]In that sense, this test is much more useful than the Fisman-Wei method, which relies on partner country statistics that are typically available after a long delay. Moreover, it is usually difficult to obtain partner country statistics disaggregated at the level of a particular transport mode or a border checkpoint.

implications of tax evasion in the context of a simple Armington trade model.

The unexpected policy shock exploited in this paper is the increase in the *Resource Utilization Support Fund* (RUSF) tax which took place on 13 October 2011 in response to high and persistent current account deficits. The tax rate was doubled, increasing from 3% to 6% of the transaction value.[5] The RUSF tax, in force since 1988, applies when credit is utilized to finance the cost of imported goods. Whether or not an import transaction is subject to the tax depends on the payment terms. Transactions financed through open account (OA), acceptance credit (AC), and deferred payment letter of credit (DLC) are subject to the tax.[6] Transactions financed in other ways (e.g., through cash in advance or a standard letter of credit) are not taxed. In other words, all imports for which the Turkish importer receives a trade credit are subject to the tax.[7]

We examine the effect of the policy change on evasion and estimate it using both cross-sectional and time-series variation. We use very detailed import data, including information on payment terms, to measure the exposure of a given product imported from a given source country to the RUSF tax before the policy change. We then ask whether the post-shock evasion response is systematically related to the pre-shock exposure to the tax. Put differently, our identifying assumption is that import flows which are typically purchased on credit, and thus are subject to the tax prior to the shock, will see a larger increase in evasion in the post-shock period relative to imports that tended not to utilize external financing.

In the first step, we show that the well-established "missing trade" approach, proposed by

[5]Google Trends statistics show a large spike in the number of searches involving "KKDF" or "Kaynak Kullanımını Destekleme Fonu", which is the Turkish name of the tax, in the week of 9 October 2011. The number of searches was stable in the months preceding the policy change. See Figure 1 in a working paper version of the paper available at https://cepr.org/active/publications/discussion_papers/dp.php?dpno=12798

[6]Under the OA terms, foreign credit is utilized as the Turkish importer pays the exporter only after receiving the goods. Under the AC terms, domestic credit may be utilized: a bank sets up a credit facility on behalf of the importer and provides financing for the purchase of goods. Finally, the DLC gives the importer a grace period for payment: the importer receives goods by accepting the documents and agrees to pay the bank after a fixed period of time.

[7]Although the tax can be avoided in the medium-run by not importing on credit or finding domestic suppliers of the same product, such adjustment may not be possible immediately. We will come back to this issue later in the paper.

Fisman and Wei (2004), produces evidence consistent with an increase in tax evasion after the policy change. More specifically, we find that the increase in underreporting of imports into Turkey (relative to exports figures reported by partner countries) after the policy change is systematically related to exposure to the RUSF tax before the shock. The estimates imply that import flows that came fully on credit (i.e., tax exposure equal to 100%) saw a 6% larger increase in underreporting relative to flows with no exposure to the tax prior to the shock.

In the second step, we lay out our proposed detection method based on Benford's law, which describes the distribution of leading digits in economic or accounting data and which is explained in detail in Section 3.2. The underlying premise of this method is that while Benford's law should hold in import data, it will not hold if the data have been manipulated for the purposes of tax evasion. It is because, as shown by experimental research, people do a poor job of replicating known data-generating processes, by for instance over-supplying modes or under-supplying long runs (Camerer (2003), pp. 134-138).[8] Moreover, since Benford's law is not widely known, it seems very unlikely that those manipulating numbers would seek to preserve fit to the Benford distribution.

We apply this method to Turkish import data disaggregated by firm, 6-digit Harmonised System (HS) product, source country, month and payment method.[9] For each product-country-year cell, we calculate deviation from Benford's law. Then we show that cells with greater exposure to the RUSF tax prior to the shock have greater deviations from Benford's distribution after the policy change. This finding is consistent with evasion increasing after

[8]An example given by Hill (1999) (p. 27) illustrates this point nicely: "To demonstrate this [the difficulty of fabricating numerical data successfully] to beginning students of probability, I often ask them to do the following homework assignment the first day. They are either to flip a coin 200 times and record the results or merely pretend to flip a coin and fake the results. The next day I amaze them by glancing at each student's list and correctly separating nearly all the true from the faked data. The fact in this case is that in a truly random sequence of 200 tosses it is extremely likely that a run of six heads or six tails will occur (the exact probability is somewhat complicated to calculate), but the average person trying to fake such a sequence will rarely include runs of that length."

[9]One may think of this data set as including transaction-level information aggregated to the monthly level.

the policy change.[10]

In the third part of the paper, we present a simple trade model, which predicts that the elasticity of imports with respect to trade taxes is distorted in the presence of tax evasion. We estimate the import demand equation instrumenting for price with a proxy for transport costs. The tax elasticity before the shock is found to be almost identical to the estimated price elasticity, as predicted by the model in the absence of evasion. The estimate is about 2.2, which lies in between the studies relying on time-series and cross-section variation, as discussed by Hillberry and Hummels (2013) in their review of the trade elasticity parameters used in the literature. After the shock, however, the estimated tax elasticity becomes substantially smaller (less than 0.4), which (according to the theoretical model) is consistent with an increase in tax evasion after the shock. This matters, because a biased estimate of trade elasticity leads to overestimation of welfare losses from the tax increase, as calculated based on the widely used formula proposed by Arkolakis et al. (2012).

In part four of the paper, we present a simulation exercise that shows how our theoretical model is related to the approach based on Benford's law. The simulations show that under the assumption of tax evasion the average deviation from Benford's law is higher than in the benchmark case without evasion. The difference is statistically significant.

Next we show theoretically that tax evasion unambiguously reinforces gains from trade. On the one hand, evasion lowers the relative price of foreign goods, and thus decreases the domestic expenditure share. On the other hand, it increases tax revenues by increasing the tax base. While resources wasted on evasion and underreporting tend to reduce tax revenues, lower relative price of foreign goods tends to raise them. The latter effect dominates the former, so the the overall effect is positive.

As mentioned earlier, Turkish importers can avoid being subject to the RUSF tax by ceasing to utilize trade credit. An immediate adjustment may not be possible because it

[10] Both Fisman-Wei and Benford's law methods are implemented in a difference-in-differences setting, thus capturing the change in evasion between the pre- and the post-shock period. We do not test for the presence of evasion prior to the policy change.

takes time to find alternative sources of financing, but in the medium run many importers may replace trade credit with other sources of financing. If that is the case, they will no longer have the need to engage in evasion of the RUSF tax. Therefore, the last part of the paper investigates persistence of evasion. Using all three methods, outlined above, we find that the spike in evasion observed immediately after the policy change disappears one year later, which is consistent with a delayed adjustment on the part of importers.

Our paper is related to several literatures. First, it contributes to the literature on the response of international trade to changes in trade frictions (e.g. Feenstra (1995); Baier and Bergstrand (2001); Trefler (2004); Yang (2008); Arkolakis et al. (2012); Hillberry and Hummels (2013); Felbermayr et al. (2015); Sequeira (2016); and Goldberg and Pavcnik (2016)). It is most closely related to the study by Sequeira (2016) which draws attention to the impact of evasion on estimation of trade elasticities. She obtains the trade elasticity estimate equal to 0.1 in the context of a 30 percent reduction in the average nominal tariff rate applied by Mozambique on its imports from South Africa. She finds that firms in Mozambique did not adjust the extensive or the intensive margins of imports in response to changes in nominal tariffs due to pervasive corruption and tariff evasion affecting about 80 percent of all shipments. We go beyond her study by estimating the trade elasticity both in the presence and in the absence of evasion and thus quantifying the magnitude of the evasion-induced bias.

Second, our work is related to the literature pointing out that gains from trade are affected by existing or policy-induced distortions. Early on Bhagwati (1982) argued that "directly-unproductive profit-seeking" (DUP) activities, such as tax evasion and lobbying, limit the consumption possibilities available to consumers by diverting resources from productive activities. Bhagwati and Srinivasan (1982) showed, however, that DUP activities may improve welfare if they arise as a response to a distortionary government policy. Our theoretical setting provides an example of this phenomenon. We show that tax evasion reinforces gains from trade by reducing the effective level of distortionary taxation. More recently, Khandelwal et al. (2013) demonstrate that if trade barriers are managed by inefficient institutions, trade liberalization can lead to greater-than-expected gains.

Finally, our paper is related to the literature documenting tax evasion in international trade using the "missing trade" approach (Fisman and Wei (2004); Fisman et al. (2008); Javorcik and Narciso (2008); Mishra et al. (2008); Ferrantino et al. (2012); and Javorcik and Narciso (2017)). Our paper contributes to this literature by proposing two alternative methods of detecting tax evasion in international trade, one of which could be easily implemented in practice.

The rest of the paper is structured as follows. Next section describes the institutional context and data. Section 3 presents evidence of tax evasion based on the "missing trade" approach and Benford's law. Section 4 builds a simple Armington trade model with tax evasion, which yields an empirical specification that we use to estimate the trade elasticity and detect tax evasion. It also presents a simulation exercise linking our theoretical model the Benford's law approach and derives welfare implication. The last section presents the conclusions of our study.

# 2 Institutional Context and Data

## 2.1 Institutional Context

Turkey has become increasingly involved in international trade since the early 2000s: the value of exports and imports increased five-fold between 1999 and 2013. While the country trades with more than 200 countries, about 40% of its trade is with the European Union, with whom Turkey has a customs union in manufacturing goods. Turkey's considerably low exports-to-imports ratio (about 65%) has been the main driver of its persistently large current account deficit, which has remained above 5 percent of GDP since 2006 (except in 2009).

In response to this high and persistent current account deficit, on October 13, 2011, Turkish authorities passed a law that increased the cost of import financing. The policy increased the rate of the RUSF tax (discussed in the Introduction) from 3% to 6% of the transaction value. An import transaction is subject to the RUSF tax if the importer is provided with a credit facility. In particular, the following import payment terms are subject to RUSF: open account (OA), acceptance credit (AC), and deferred payment letter of credit (DLC). Under the OA terms, foreign credit is utilized as the Turkish importer pays the exporter only after receiving the goods (usually 30 to 90 days). Under the AC terms, domestic credit is utilized: a bank sets up a credit facility on behalf of the importer and provides financing for the purchase of goods. Finally, the DLC gives the importer a grace period for payment: the importer receives goods by accepting the documents and agrees to pay the bank after a fixed period of time.[11] The RUSF applies to ordinary imports as processing imports have always been exempted from import duties and other taxation.

The Turkish law stipulates quite harsh penalties for noncompliance with the RUSF tax. Although controversial, RUSF is considered an import duty and thus subject to the customs laws and regulations, particularly with respect to penalties for noncompliance. Customs law no. 4458 provides for extensive penalties, which includes the practice of "threefold of import duties." Accordingly, RUSF that is not collected is subject to penalties of three times the underpayment. Considering that value added tax (VAT) is also assessed on the RUSF payable upon importation, the penalty amount will also include an amount for three times the underpaid VAT. Additionally, delay interest on the total amount will be assessed. As a result, penalty amounts can quickly become significant (EY (2014), p. 32.)

Doubling of the tax rate from 3% to 6% of the transaction value can potentially wipe up profit margins of some importers. They can respond to the shock in a number of ways. First, they can reduce (or even stop) imports. Second, they can switch away from importing on

[11] The following payment methods are not subject to the RUSF: cash in advance (importer pre-pays and receives the goods later); standard letter of credit (payment is guaranteed by the importer's bank provided that delivery conditions specified in the contract have been met); and documentary collection (which involves bank intermediation without payment guarantee).

trade credit.[12] However, moving away from trade credit is not trivial because it requires firms to obtain credit elsewhere. Given the unexpected nature of the tax hike, not every importer would be able to obtain credit on a short notice. Some importers may not have access to credit at all. For others, the 6% tax rate on trade credit may still be more advantageous than the cost of credit.[13] The final possibility is evasion.

It is unlikely that importers evade by misreporting the financing terms of the transaction. The Turkish Customs requires a proof of the financing terms in the form of official bank documents and obtaining official bank documents for fictitious transactions is very difficult.

A more likely scenario is the following. The export and import declarations do not mention specifics of what is being exported/imported, but only the number of the commercial invoice that has these details. The evading importer needs to obtain two invoices with the same number, with the same or different details about the products, but with different total values. When the shipment leaves the exporting country, it is accompanied by the expensive invoice, as exporters may wish to collect a VAT refund. But when the shipment enters Turkey, the cheaper invoice is attached to the import declaration. This procedure works as long as the customs authorities of the different countries do not exchange information. It is, therefore, used a lot between countries whose governments are not on particularly friendly terms. According to an employee of a trucking company located in an Eastern European country, this procedure almost never fails.

## 2.2 Data

The main dataset used in our empirical analysis is the Trade Transactions Database (TTD), a confidential dataset provided by the Turkish Statistics Institute (TUIK), which contains detailed information on Turkish firms' transactions with the rest of the world over the 2010-

[12]In the next subsection, we present evidence illustrating decline in firm-level imports purchased with trade credit.

[13]Interest rates in Turkey are high. The average deposit interest rate in the third quarter of 2011 was 8.4%.

2013 period. The data, collected by the Ministry of Customs and Trade of the Republic of Turkey, are based on the customs declarations filled in every time an international trade transaction takes place. TTD reports the quantity and the value of firm-level imports in US dollars by product, classified according to the 6-digit Harmonised System (HS), source country, date of the transaction (month and year), payment method (e.g. cash in advance, open account, letter of credit, etc.) and trade regime (ordinary and processing).[14] Import values include cost, insurance and freight (c.i.f.). We restrict the sample to the trading partners which are members of the World Trade Organization.

In the baseline analysis, we aggregate monthly trade flows into annual data to cover 24 months before and 12 months after the date of the policy change (October 2011). In particular, we construct three 12-month periods: $t = \{T-2, T-1, T\}$, where $T-2$ covers the October 2009-September 2010 period, $T-1$ covers October 2010-September 2011, and $T$ covers October 2011-September 2012.[15]

We measure the RUSF tax exposure of product $h$ from source country $c$ imported at time $t$ as:

$$Exposure_{hct} = \frac{\sum_{m \in \{OA,AC,DLC\}} M_{hcmt}}{\sum_m M_{hcmt}}, \tag{1}$$

where $M_{hcmt}$ denotes the value of imports of product $h$ from country $c$ on payment method $m$ at time $t$. The numerator gives the sum of product-country-level imports on OA, AC, and DLC terms at time $t$, which are subject to the tax, and the denominator is equal to the value of total imports during the same period. A higher value of $Exposure_{hct}$ implies a greater reliance on external financing and thus a greater exposure to the increase in the RUSF tax rate.

Although, to the best of our knowledge, the RUSF tax rate increase was unexpected, in our analysis we take a conservative approach and focus on exposure 24 months before

[14] In the data, ordinary imports account for about 85% total imports.

[15] In the last part of the paper, we will also consider the period October 2012-September 2013.

the shock (October 2009-September 2010), $Exposure_{hc,T-2}$.[16] In this way, we eliminate the possibility that some importers have adjusted their behavior in anticipation of the tax increase, though, as we argued earlier, the available evidence suggests that the policy change was unanticipated.

The tax increase mattered. As illustrated in Figure 1, the distribution of $Exposure_{hc}$ for ordinary imports (in the upper panel) shifted to the left after the increase in the RUSF rate. In particular, the average value of the share of imports with external financing decreased from about 20% to 14% after the shock. As expected, the distribution of $Exposure_{hc}$ for processing imports, which are exempt from any type of tax, remained unchanged after the shock (see the lower panel).

The tax increase also affected the magnitude of trade flows. A difference-in-differences analysis (presented in Table 1) shows that imports of firms with a greater initial reliance on external financing decreased in relative terms after the increase in the RUSF rate. The estimated effect is economically significant: a one-standard-deviation increase in the share of imports with external financing before the shock was associated with imports declining by about 5% after the policy change. No such change is visible for processing imports purchased on trade credit, as they are not subject to the tax.

# 3 Preliminary Evidence on Tax Evasion

## 3.1 "Missing trade" approach

To investigate the effect of the policy change on tax evasion, we first rely on the "missing trade" approach developed by Fisman and Wei (2004). Focusing on Turkey's imports of product $h$ from country $c$ at time $t$, we construct a variable that captures the gap between

[16] The October 2009-September 2010 period overlaps with the Great Recession, which was characterized by a major worldwide disruption of trade finance. However, the distribution of the share of Turkish imports utilizing external financing does not show a significant change during this period relative to the pre-crisis period.

the value of the flow reported by the source country $c$ and the value reported by Turkey:

$$MissingTrade_{hct} = \ln X^{c}_{hct} - \ln M^{TUR}_{hct},$$

where $\ln X^{c}_{hct}$ is logarithm of country $c$'s exports of product $h$ to Turkey as reported by $c$, and $\ln M^{TUR}_{hct}$ is the logarithm of imports of $h$ from $c$ as reported by Turkey. As export figures are reported on f.o.b. basis and import statistics include freight and insurance charges (i.e., they are reported on c.i.f. basis), we expect $MissingTrade$ to be negative. However, on average the reported exports exceeded the imports by 1.4% in 2010 and 3.3% in 2011. Implementing the "missing trade" approach to detecting evasion requires export data reported by Turkey's partner countries. We obtain annual trade data from United Nations COMTRADE database. When we focus on flows that are reported by both Turkey and a partner country, we have information on annual imports for 4,295 6-digit HS products from 98 partner countries over the 2010-2012 period. The database also reports the weight of each flow, which we use to construct unit values (value per kilogram).[17]

In the top panel of Figure 2, we plot local polynomial regressions of $MissingTrade$ in the year prior to the shock and after the shock as a function of $Exposure_{hc,T-2}$. As evident from the figure, $MissingTrade$ increases with exposure to the tax. For tax exposure of about 10 percent, the discrepancy in trade statistics is close to zero. However, for tax exposure of about 80 or more percent, trade reported by the exporting country exceeds the imports recorded by Turkey by over 10 percent. More interestingly, the $MissingTrade$ curve shifts up at all levels of $Exposure$ in the post-shock period with the upward shift being the largest for flows with the highest exposure to the tax.

The bottom panel plots local polynomial regressions of $\Delta \ln X^{c}_{hct}$ and $\Delta \ln M^{TUR}_{hct}$ as functions of $Exposure_{hc,T-2}$. As expected, regardless of the reporting partner, Turkish imports decreased with the initial share of trade subject to the tax. More importantly, the wedge

[17]Due to shipping lags, matching flows reported by the exporter and the importer at higher frequencies would be problematic. Therefore, we use annual trade data in this exercise.

between $\Delta \ln X_{hct}^{c}$ and $\Delta \ln M_{hct}^{TUR}$ is increasing with the initial exposure, which is consistent with an increase in tax evasion after the hike in the RUSF tax rate in October 2011. To test whether underreporting of imports after the policy change increases systematically with the initial exposure to the tax, we estimate the following equation:

$$MissingTrade_{hct} = \gamma_0 + \gamma_1 1\{t = T\} * Exposure_{hc,T-2} + \alpha_{ht} + \alpha_{ct} + \alpha_{hc} + \varepsilon_{hct}. \quad (2)$$

The equation controls for unobservable heterogeneity at the product-country level with $\alpha_{hc}$ fixed effects as well as for time-varying product ($\alpha_{ht}$) and country ($\alpha_{ct}$) fixed effects. Note that because $Exposure_{hc,T-2}$ is time invariant, its impact will be captured by product-country fixed effects. Standard errors are clustered at the country-4-digit product level, though the results are robust to two-way clustering at the country and HS4 levels.

Our coefficient of interest is $\gamma_1$ whose positive value would be consistent with an increase in tax evasion after the hike in the RUSF tax rate in October 2011. The results obtained from estimating equation (2) are presented in the first column in the upper panel of Table 2. Our coefficient of interest $\gamma_1$ is positive and statistically significant at the 5% level. It implies that increasing $Exposure$ from zero to one increases $MissingTrade$ by about 6 percent after the RUSF hike. We also investigate the channels through which evasion may take place; importers may underreport quantities and/or prices. The results presented in the second and third columns suggest that evasion tends to take place through underreporting of prices rather than quantities, though the coefficient in the quantity estimation is relatively large, albeit statistically insignificant.[18]

Table 3 reports three robustness checks. The top panel explores whether the response of "missing trade" to the initial tax exposure is non-linear. It is done by creating indicators for bins based on quartiles of $Exposure_{hc,T-2}$. The results are consistent with the patterns

[18]The relationship between "Missing trade" and $Exposure_{hc,T-2}$, which would be indicative of evasion taking place already prior to 2012, is not visible in the table. It is because product-country ($\alpha_{hc}$) fixed effects included in each specification capture the impact of $Exposure_{hc,T-2}$, and hence this variable does not enter the specification.

illustrated in Figure 2. The gap between exports reported by partner countries and imports recorded by Turkey increases little at the bottom quartile of $Exposure_{hc,T-2}$ but increases greatly for higher quartiles. In the middle panel, we assign a placebo date (October 2010 instead of October 2011) to the shock. As expected, we do not find any statistically significant effects. The bottom panel of the table shows the results from a falsification test where we construct $Exposure^{placebo}$ using processing imports which are exempt from any type of tax. As expected, the coefficient of interest $\gamma_1$ does not retain its statistical significance in the placebo specification.

## 3.2 Benford's law

Our first alternative approach to detecting evasion relies on Benford's law. Benford's law describes the distribution of first (or leading) digits in economic or accounting data.[19] The law predicts that a given leading digit d will occur with the following probability:

$$P(\text{First digit is d}) = log_{10}(1 + 1/d) \tag{3}$$

The law naturally arises when data are generated by an exponential process or independent processes are pooled together (see Figure 3 for the predicted distribution of leading digits according to the law). Deviations from Benford's distribution have been used to detect reporting irregularities in macroeconomic data (Michalski and Stoltz (2013)) and in survey data (Judge and Schechter (2009)).

We expect Benford's law to hold in our data for the following reasons. First, "second-generation" distributions, i.e., combinations of other distributions, such as, quantity×price (as in our case) conform with Benford's law (Hill (1995)). Second, distributions where mean is greater than median and skew is positive have also been shown to comply with Benford's law (Durtschi et al. (2004)). The distribution of import values in our data is positively

[19] For instance, in the number 240790, digit 2 is the leading digit.

skewed, with a mean greater than the median value.[20]

Our hypothesis is that while Benford's law should hold in import data, it will not hold if the data have been manipulated for the purposes of tax evasion. It is because people do a poor job of replicating known data-generating processes, by for instance over-supplying modes or under-supplying long runs (Camerer (2003), pp. 134-138). Additionally, since Benford's law is not widely known, it seems very unlikely that those manipulating numbers would seek to preserve fit to the Benford distribution.

We start by performing a simple $\chi^2$ test to check whether our import data conform with Benford's law. We use the data obtained from TTD aggregated to the level of 6-digit product and source country for the 12-month periods $T$ and $T-1$. We consider ordinary trade only, as processing trade is not subject to any border taxes. We construct the data by first grouping transactions by treatment status, i.e., subject to RUSF or not, for each period. Then we aggregate observations in each sub-sample at the 6-digit HS and source country level. Table 4 shows that ordinary imports that are not subject to the RUSF tax conform with the law both at $t = T$ and $t = T - 1$. However, when we consider ordinary imports subject to the RUSF tax, their distribution conforms with the law before the tax hike but not afterwards. This finding is consistent with the message from the "missing trade" exercise, which suggests that evasion in the aftermath of the policy change was rising with exposure to the tax.

Next, we use a difference-in-differences approach to test whether the distribution of Turkish imports deviated significantly from Benford's law after the policy change and whether this deviation was systematically related to the initial exposure to the tax. To do so, we follow Cho and Gaines (2007) and Judge and Schechter (2009) and use the following distance measure to capture deviations from Benford's law:

$$D = \sum_{d=1}^{9}(f_d - \hat{f}_d)^2, \tag{4}$$

[20]See Figure 5 in a working paper version of the paper available at https://cepr.org/active/publications/discussion_papers/dp.php?dpno=12798.

where $\hat{f}_d$ denotes the observed fraction of leading digit $d$ in the data, and $f_d$ fraction predicted by Benford's law. For each product-country $hc$ pair with at least 30 observations, we calculate respective frequencies, $f^d_{hct}$ to construct $D_{hct}$. The summary statistics are presented in Table 5. We estimate the following specification:

$$D_{hct} = \theta_0 + \theta_1 1\{t = T\} * Exposure_{hc,T-2} + \alpha_{ht} + \alpha_{ct} + \alpha_{hc} + e_{hct}, \quad (5)$$

which controls for product-year, country-year and product-country fixed effects. Standard errors are clustered at the country-HS4 level, though the results are robust to two-way clustering at the country and HS4 levels. We anticipate a positive estimate of $\theta_1$ which would be consistent with an increase in tax evasion after the hike in the RUSF tax rate in October 2011.

This alternative approach to detecting tax evasion yields results supporting our earlier conclusions. The results in column 1 of Table 6 show that an increase in deviation from Benford's law after the shock is positively correlated with the initial exposure to the tax. The estimates imply that going from no exposure to the tax to a full exposure (i.e., increase from 0 to 1) increases the deviation from Benford's Law by 17% relative to the mean value of $D$ at $t = T - 1$.[21]

In columns 2-3, we conduct a robustness test where we test the deviation of the joint distribution of the leading two or three digits from their respective distributions predicted by Benford law:

$$Prob(D_1 = d_1, ..., D_k = d_k) = log_{10}\left[1 + \left(\sum_{i=1}^{k} d_i * 10^{k-i}\right)^{-1}\right],$$

where $k = 1, 2, 3$; $d_1 \in \{1, 2, ..., 9\}$ and $d_2, d_3 \in \{0, 1, 2, ..., 9\}$. As in the baseline exercise,

[21] To put this figure into perspective consider a random sample with characteristics similar to an average product-country cell in our sample before the shock, that is, a collection of numbers with D = 0.0172. Now add "faked" observations which do not follow Benford's law. Instead, assume that a "faked" observation is equally likely to start with digit 1, 2, 3, etc. What is the fraction of "faked" observations required to generate the estimated increase in D due to exposure going from 0 to 1? It is about 40%.

we construct deviations of the observed distribution from the predicted distribution and re-estimate equation (5). The results are in line with the baseline findings which point to an increase in evasion after the increase in the RUSF rate in October 2011.

In the fourth column, we assign a placebo date (October 2010 instead of October 2011) and show that there is no statistically significant link between tax exposure and deviations from Benford's law. In column 5, we conduct a placebo exercise by focusing on processing trade which is not subject to any border taxes and where we would not expect to see an increase in deviation from Benford's law after the policy change. The results confirm our priors. The coefficient of interest is not statistically significant and its magnitude is very close to zero.

# 4 Estimating the Trade Elasticity in the Presence of Tax Evasion

## 4.1 Theoretical predictions

In this section, we propose an alternative approach to detecting tax evasion in international trade transactions, which relies on comparing price and tax elasticity of demand for imports. While the approach is not new in public economics (e.g., Marion and Muehlegger (2008)), it has not been used to detect tax evasion in international trade.

Compared to a standard taxation model in public economics, our setting poses an important challenge. Whether or not a transaction is subject to the RUSF tax is an endogenous decision taken by an importer. The reason is that the tax applies only when external financing is used when importing. Therefore, the importer decides whether to evade taxes, conditional on using external financing.

Consider a simple Armington model of international trade with $n + 1$ countries, indexed by $c$. We refer to Turkey as the home country ($c = 0$).[22] Goods are differentiated by country of origin. On the demand side, we assume that consumer preferences are represented by a standard CES utility function, with elasticity of substitution given by $\sigma > 1$:

$$Q = \left( \sum_{c=0}^{n} q_c^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} ; \sigma > 1$$

where $q_c$ is the quantity imported from country $c$ to the home country ($c = 0$).

International trade is subject to two types of frictions. First, there are transport costs which take the iceberg form: $t_c > 1$. Second, there are policy-induced costs which take the ad-valorem form and are borne by consumers: $\tau > 1$. Domestic trade is not subject to any frictions.

There is a continuum of consumers, indexed by $k$, in the home country, who have identical preferences over goods. When they import, consumers choose between paying immediately and delaying payment (i.e., using external financing). By paying immediately, consumer $k$ incurs a liquidity cost, $r_k > 1$ but saves $\tau$. Liquidity costs are drawn from a common and known distribution $g(r)$ with positive support on the interval $(\underline{r}, \infty)$ and a continuous cumulative distribution $G(r)$.

Consumers, who choose to delay payments, may underreport prices to evade taxes.[23] Let $p_c$ denote the true price of the good exported by country $c$, which is inclusive of transport costs.[24] Assuming perfect competition on the supply side and denoting wages in the source country by $w_c$, prices inclusive of transport costs are given by $p_c = t_c w_c$.[25] Instead of reporting the true price, a consumer may report its fraction $(1 - \alpha)p_c$, where $\alpha \in [0, 1)$. Tax evasion is subject to a cost that is proportional to the true price and quadratic in the

[22]We drop destination-country subscript for notational simplicity. Turkey is assumed to be the destination country in all derivations.

[23]This assumption is consistent with the empirical evidence presented earlier using the "missing trade" approach.

[24]This assumption is consistent with the observation that there exists no significant association between price changes after the policy shock and Turkey's initial market share in a given product-country market.

[25]This assumption implies that one unit of labor is required to produce one unit of output.

extent of evasion ($\alpha$). The latter assumption, also made by Yang (2008), can be justified on the grounds that it is more difficult to hide evidence of large scale underreporting. The evasion cost is equal to $((\gamma/2)\alpha^2)p_c$, $\gamma > 0$. With probability $\theta$, consumers are subject to a more careful inspection at the border, which will reveal the true price. If $\alpha > 0$, they pay a penalty for the undeclared amount, denoted by $f > 2(\tau - 1)$.[26]

Each consumer first decides on the method of payment. If consumer $k$ decides to pay immediately, then the cost of importing is equal to $r_k p_c$. If she delays payment by using external financing, the cost becomes $\tau p_c$, though the consumer can evade the tax by underreporting the price of the good. In the case of evasion, the expected cost of importing with external financing becomes:

$$\tau^e p_c = [1 + (1 - \alpha)(\tau - 1) + (\gamma/2)\alpha^2 + \theta\alpha f]p_c,$$

where $\tau^e$ denotes the evasion-inclusive tax rate. The first term in square brackets represents the cost due to financing tax to be paid on the declared price. The second term is the cost of evading taxes (e.g., bribes, obtaining fake documents, etc.), and the last term is the expected cost of penalties. Consumers choose $\alpha$ to minimize expected tax payments. At an interior solution, it yields:[27]

$$\alpha^* = \frac{\tau - 1 - \theta f}{\gamma}.$$

The expression implies that tax evasion increases with the tax rate ($\tau$), and it decreases with the cost of evasion ($\gamma$), probability of being inspected ($\theta$), and the fixed penalty ($f$). Let us now consider the choice of payment method. Given the cost minimizing level of evasion derived above, consumers compare the cost of liquidity ($r_k$) to the cost of external financing with evasion ($\tau^e|_{\alpha=\alpha^*}$) and choose the method that is associated with a lower expected cost.

[26] This is consistent with the institutional setup in Turkey described earlier.

[27] We consider the parameter values at which the minimization problem has an interior solution. Since $\alpha < 1$, we exclude the parameter values that satisfy $\tau - 1 > \gamma + \theta f$.

Given that consumers are heterogeneous in the cost of liquidity they are facing, we can define a marginal consumer who is indifferent between paying immediately and delaying payment s.t. $r^* = \tau^e|_{\alpha=\alpha^*} = \tau - \frac{(\tau-1-\theta f)^2}{2\gamma}$. Consumers with $r_k \in [\underline{r}, r^*]$ choose to pay immediately, and others use external financing to delay payment. Now we can establish a link between this simple model and our variable of interest in the empirical analysis, *Exposure*. The model implies the following expression for the share of imports from origin country $c$ with external financing:

$$Exposure_c = \frac{\int_{r^*}^{\infty} p_c q_c(\tau) dG(r)}{\int_{\underline{r}}^{r^*} p_c q_c(r) dG(r) + \int_{r^*}^{\infty} p_c q_c(\tau) dG(r)}, \tag{6}$$

In the expression, $q_c(\tau)$ and $q_c(r)$ denote, respectively, the quantity of imports with and without external financing from country $c$ such that

$$q_c(\tau) = y P^{\sigma-1} p_c^{-\sigma} \tau^{-\sigma} \tag{7a}$$

$$q_c(r) = y P^{\sigma-1} p_c^{-\sigma} r^{-\sigma}, \tag{7b}$$

where $y$ denotes per-capita income in Turkey, and $P$ the standard CES price index. *Exposure* depends on the policy-induced cost $\tau$ for two reasons. First, an increase in $\tau$ decreases the mass of consumers who import using external financing (extensive margin). Second, it decreases the quantity imported by consumers who continue to use external financing (intensive margin). The following result summarizes this prediction.[28]

**Result 1** *The share of imports with external financing, $Exposure_c$, declines as policy-induced trade frictions, $\tau$, increase.*

This result highlights the importance of taking the nature of the policy into account when evaluating its impact. In particular, the extent to which changes in the policy-induced tax rate $\tau$ affect imports is determined by the choices made by individual importers. Therefore,

[28] See Appendix A for the proof.

differences in the behavior of importers create a new extensive margin of adjustment, which is captured by $Exposure$.

Next, we consider the elasticity of firm imports with respect to the tax rate. Demand for imports by firms that choose to pay immediately does not depend on the tax rate. So, we focus on equation (7a) describing the behavior of firms that delay payments. Taking the logarithm of both sides of the equation and replacing $\tau$ with $\tau^e$ yield:

$$\ln q_c(\tau) = \ln\left(yP^{\sigma-1}\right) - \sigma \ln p_c - \sigma \ln \tau^e \tag{8}$$

It is easy to see that the elasticity of imports with respect to the evasion-inclusive tax rate is equal to the price elasticity, which is given by $\sigma$. However, since we never observe the evasion-inclusive tax rate, we need to derive the elasticity with respect to the policy rate, $\tau$. Using the expression for $\tau^e$, we can write the following relationship between $\ln \tau^e$ and $\ln \tau$:

$$\ln \tau^e = \ln \tau + \ln\left(1 - \frac{(\tau - 1 - \theta f)^2}{2\gamma\tau}\right)$$

Substituting this into the demand equation in (8) gives:

$$\ln q_c(\tau) = \ln\left(yP^{\sigma-1}\right) - \sigma \ln p_c - \sigma \ln \tau - \sigma \ln\left(1 - \frac{(\tau - 1 - \theta f)^2}{2\gamma\tau}\right)$$

We can use this equation to estimate the tax elasticity of imports as follows:

$$\ln q_{kc} \quad = \quad \beta_0 + \beta_1 \ln p_{kc} + \beta_2 \ln \tau + \delta_c + \delta_k + e_{kc}, \tag{9}$$

where $\delta_c$ absorbs the market specific variables $\ln\left(yP^{\sigma-1}\right)$, and $\delta_k$ controls for selection into external financing as only importers that face relatively high liquidity costs, such that $r_k > r^*$, rely on external financing and delay payment. Since we cannot observe the evasion-inclusive tax rate, $e_{kc}$ includes the term $\Xi(\tau) = -\sigma \ln\left(1 - \frac{(\tau-1-\theta f)^2}{2\gamma\tau}\right)$, which is positively correlated with the policy tax rate:

$$\frac{d\Xi}{d\tau} = \frac{\sigma}{2\left(1 - \frac{(\tau-1-\theta f)^2}{2\gamma\tau}\right)} \frac{\tau + 1 + \theta f}{\tau^2} \alpha^* > 0$$

This creates a positive bias in the estimate of $\beta_2$ as we expect $\beta_2 < 0$.

**Result 2** *The elasticity of imports with respect to the evasion-inclusive tax rate is equal to the price elasticity of demand for imports ($\epsilon$), which is given by $\sigma$. Since the evasion-inclusive tax rate is not observed, the elasticity with respect to the actual policy rate is estimated with a positive bias, $\epsilon^{\tau} > \epsilon = -\sigma$.*

Put simply, a reduction in prices should generate a response in quantities as reflected by $\sigma$. But if the reduction in prices is fake, i.e., driven by underreporting, a corresponding rise in quantities will not be observed. A smaller or perhaps no response in quantities will be registered.

## 4.2 Estimating trade elasticities

Our estimation strategy is based on an augmented version of Equation (9). We focus on ordinary imports and estimate the equation using import data disaggregated by the importing firm ($i$), product ($h$), source country ($c$), time ($t$) and financing terms ($m$):

$$\begin{aligned} \ln q_{ihcmt} &= \beta_0 + \beta_1 \ln p_{ihcmt} + \beta_2 \ln \tau_{ihcmt} + \beta_3 1\{t = T\} * \ln \tau_{ihcmt} \\ &+ \delta_{hct} + \delta_{it} + e_{ihcmt}, \end{aligned} \quad (10)$$

In the absence of evasion, i.e., $\tau^e = \tau$, the elasticity of import demand with respect to the tax rate is equal to price elasticity, which means that we would expect $\beta_1$ to be equal to $\beta_2$. In the presence of evasion, the tax elasticity is estimated with a positive bias, implying that the post-shock elasticity given by $\beta_2 + \beta_3$ would be smaller in size (absolute value) than the estimated price elasticity $\beta_1$.

In the estimation, we need to address a number of issues. First, our estimating equation is subject to the classical endogeneity bias associated with demand estimation. To address this issue, we use the distance between the importing firm and the source country as an instrument for import prices. More specifically, our instrument $\ln Distance_{ic}$ is the logarithm of the sum of the distance between the province in which the importing firm $i$ is located and Istanbul (the largest international port of Turkey) and the distance between Istanbul and country $c$. Suppose that there are two firms importing the same product from the same country through Istanbul. Our identification strategy relies on the fact that the one that is located farther away from Istanbul will pay a higher c.i.f. price as it pays a higher domestic transport cost. In other words, the instrument captures variation in transport costs, which affects the quantity demanded only through its effect on cif prices. Second, while the model does not distinguish between different products, one could expect heterogeneity across products within a country in the data. We address this issue by adding fixed effects at the source-country-6-digit-product-time level. Third, we add firm-time fixed effects to control for potential time-varying confounding factors at the firm level, as well as to account for selection into external financing.

Table 7 presents the estimation results. Our preferred specification, presented in column 2, instruments unit price with the distance between the importing firm $i$ and the exporting country. Before the shock, the tax elasticity is equal to $-2.18$ and is almost the same as the estimated price elasticity. The F-test does not reject the equality of the two coefficients. This result is in line with the theoretical predictions in the absence of evasion. After the shock, the estimated elasticity is equal to the sum of coefficients on $\ln \tau_{ihcmt}$ and $1\{t = T\} * \ln \tau_{ihcmt}$, which implies a tax elasticity of $-0.378 = -2.18 + 1.803$. This estimate is substantially smaller than the corresponding elasticity before the shock and the price elasticity. This result is consistent with tax evasion being present after the shock.

In the third column of Table 7, we include an interaction between $1\{t = T\}$ and price to check whether there was a change in the estimated price elasticity after the policy change. The coefficient on this interaction is not statistically significant, and our coefficient of interest retains its size and significance. In the final robustness check, reported in column 1 of Table 8, we show that assigning a placebo date to the shock (October 2010 instead of October 2011) does not lead to a statistically significant coefficient on the variable of interest.

The result that tax evasion creates a downward bias in trade elasticity estimates has an important implication for welfare gains from trade liberalization. Indeed, trade elasticity is one of the two sufficient statistics required to calculate welfare effects of changes in variable trade costs in a large class of trade models (Arkolakis et al. (2012)). To quantify the change in welfare implied by the estimated trade elasticity, we use their welfare formulation, which is:

$$\hat{W} = \left(\frac{\text{Share of exp. on domestic goods at } t = T}{\text{Share of exp. on domestic goods at } t = T - 1}\right)^{1/\epsilon^{\tau}}$$

In the absence of tax evasion, tax elasticity is equal to price elasticity, which is estimated to be $\epsilon^{\tau} = 2.18$. The implied welfare change is -0.6% ( $\hat{W} = (0.728/0.719)^{-1/1.218} = -0.6\%$). In the presence of tax evasion, the biased estimate of tax elasticity is $\epsilon^{\tau^e} = 0.378$, which gives the implied welfare change of -3.2% ( $\hat{W} = (0.728/0.719)^{-1/0.378} = -3.2\%$).

In other words, the upward bias in the tax elasticity estimates created by tax evasion leads to overestimation of welfare losses.

## 4.3 How persistent is evasion?

How lasting was the spike in evasion documented in our study? Two factors make us expect the spike to be short lived. First, increased evasion was unlikely to have gone unnoticed. Most probably it has attracted attention on the part of authorities, which resulted in greater scrutiny of import flows. Second, as the time went by, importers were able to legally avoid the RUSF tax by using other sources of financing to replace import trade credit.[29]

To shed light on the persistence of evasion we extend the sample by one year and repeat our estimation allowing for a differential impact of tax exposure at $T$ (the 12-month period following the shock) as well as $T + 1$ (the subsequent twelve months). As visible from tables 9, 10 and 8, corresponding to the three evasion methods considered, the spike in evasion appears to have died down at $T + 1$. Even though in most cases the estimated coefficients of interest still bear reasonably sizeable coefficients, these coefficients do not appear to be statistically significant.

This relatively rapid adjustment on the part of importers may explain why our baseline results from the elasticity approach were suggestive of there being no tax evasion prior to the RUSF tax rate increasing from 3% to 6%. Although the pattern presented in the upper panel of Figure 2 and in Figure 4 are consistent with some degree of evasion before the shock, our results suggest that its extent was very limited. The most likely reason is that a 3% tax rate was not high enough to induce a large number of firms to pay the evasion costs and risk being detected and penalized. As illustrated in the theoretical model, the extent of evasion increases in the tax rate and decreases with the cost of evasion, the probability of being detected and the penalty. And, as mentioned earlier, non-compliance with RUSF carries substantial penalties (see Section 2).

## 4.4 Theoretical framework versus Benford's law

In this section, we present a simulation exercise which shows how our theoretical model is related to the approach based on the Benford's law (see Section 3.2).

We generate trade values based on the model and examine the distribution of their first digits with and without tax evasion. To do so, we take a partial equilibrium approach and make two additional assumptions. First, to emphasize the importance of evasion, we assume

[29] A recent study by Demir et al. (2018), which considers the same shock, finds that (i) liquidity constrained importers were hit harder; and (ii) Turkish importers affected by the increase in the RUSF tax responded by increasing the number of new domestic suppliers and the value of domestic purchases.

$\underline{r} > \tau$, i.e., all importers choose to delay payment and thus $Exposure = 1$. Second, for each source country, there is a representative importer in the home country, and importers are heterogenous in their belief about the probability of being caught and convicted for tax evasion at the border. These probabilities follow a uniform distribution on the interval $\theta_k \in [0, 1]$. An importer $k$ minimizes the cost of importing by misreporting $\alpha^*(\theta_k)$ fraction of the true price, which is given by:

$$\alpha^*(\theta_k) = \frac{\tau - 1 - \theta_k f}{\gamma}.$$

Table 11 summarizes the variables and parameters used in simulations. We run 1,000 simulations and simulate 500 countries in each run. Country-level productivities, $\phi$, are assumed to have a log-normal distribution with $(\mu, \nu)$. We take the elasticity of substitution between varieties $\sigma = 4$ from Melitz and Redding (2015). We set income in the home country to 1,000,000, and the parameter governing the cost of evasion $\gamma$ to 0.125. Finally, in line with the discussion in Section 2, we assume $f = 3$, i.e., RUSF that is not collected is subject to penalties of three times the underpayment.

We consider four scenarios: no evasion with low tax rate ($\tau = 1.03$), no evasion with high tax rate ($\tau = 1.06$), evasion with low tax rate ($\tau = 1.03$), and evasion with high tax rate ($\tau = 1.06$). In the absence of evasion, trade values are generated according to the following expression:

$$x_c(\tau) \quad = \quad yP^{\sigma-1}p_c^{1-\sigma}\tau^{1-\sigma};$$

In the presence of evasion, it becomes:

$$x_c(\tau, \theta_k) \quad = \quad yP^{\sigma-1}p_c^{1-\sigma}(\tau^e)^{-\sigma}\tau(1 - \alpha^*(\tau, \theta_k)).$$

Figure 5 shows deviations from Benford's law, based on the distance formula in equation

(4), under the four cases listed above. As a benchmark, Panel A shows deviations from Benford's law without tax evasion. The average deviation is equal to 0.0029, and the distribution is not affected by the tax rate. Panel B shows the distribution of deviations under the assumption $\tau = 1.03$ with and without tax evasion. Under evasion, the average deviation is significantly higher than the benchmark case without evasion.[30] Panel C compares the distribution of deviations from Benford's law with and without evasion under the high tax scenario ($\tau = 1.06$). The average deviation under evasion is equal to 0.0033, and it is statistically different from the average deviation without evasion as well as the average deviation with evasion under $\tau = 1.03$.

In sum, our theoretical approach framework is consistent with Benford's law. And the simulations illustrate that deviations from the law will increase in the tax rate in the presence of evasion.

## 4.5 Welfare

We have just shown that identifying the trade elasticity from variation in import taxes is challenging in the presence of evasion. Evasion also affects the welfare calculations through two other channels: (i) it changes the actual tax rate paid, and (ii) it affects the domestic expenditure share. Here we illustrate this in the context of our simple Armington trade model. Although resources spent on evading taxes are wasted, tariff revenues are assumed to be redistributed to consumers as a lump-sum transfer. Tax-inclusive expenditures on goods imported by Turkey from country $c$ in the presence of evasion are given by:

$$x_c^e = Y_0 P_0^{\sigma-1} p_c^{1-\sigma} \int_0^1 \tau^e(\theta_k)^{1-\sigma} dG(\theta_k), \tag{11}$$

where $Y_0 = y_0 L_0$ is total income in Turkey, and $G(\theta_k)$ is the cumulative distribution function of $\theta_k$.[31] Then, we can write total expenditures in the home country as the sum of expenditures

[30] The difference is 0.00011 with a standard deviation of 0.00003.

[31] We allow each importer to import from every source country.

on domestically produced goods and imports:

$$X_0^e = \sum_{c=0}^{n} x_c^e = x_0^e + \sum_{c=1}^{n} x_c^e$$

where $x_0^e = Y_0^e P_0^{e\sigma-1} p_0^{1-\sigma}$. Government revenues from taxes on foreign goods are given by:

$$T_0^e = \Gamma(\tau)(\tau - 1) \sum_{c=1}^{n} \frac{x_c}{\tau} = \Gamma(\tau) T_0 \tag{12}$$

where $x_c$ and $T_0$ denote the value of expenditures on imports from country $c$ and total tax revenues, respectively, in the absence of evasion. $\Gamma(\tau)$ is given by:

$$\int_0^1 (1 - \alpha^*(\theta_k)) \left(1 - \frac{\gamma}{2\tau}(\alpha^*(\theta_k))^2\right)^{-\sigma} dG(\theta_k) \tag{13}$$

The second term inside the integral is equal to $\left(\frac{\tau^e(\theta_k)}{\tau}\right)^{-\sigma}$, and since $\tau^e(\theta_k) \leq \tau$ by construction, it is greater than one. Since tax revenues are redistributed to consumers in a lump-sum fashion, expenditures are financed by labor income and tax revenues:

$$X_0^e = w_0 L_0 + T_0^e = X_0 + T_0(\Gamma(\tau) - 1),$$

where $X_0$ denotes the sum of expenditures on domestically produced goods and imports in the absence of evasion. Using the following relationship between tax revenues and total expenditures in the absence of evasion:

$$T_0 = \frac{(\tau - 1)}{\tau}(1 - \lambda_0) X_0,$$

where $\lambda_0 = x_0/X_0$ is the share of consumer expenditures on domestically produced goods in the home country, we can re-write total expenditures in the presence of evasion as:

$$X_0^e = X_0 \left[1 + \frac{(\tau - 1)}{\tau}(1 - \lambda_0)(\Gamma(\tau) - 1)\right]$$

Per capita welfare can be written as:

$$W_0 = \frac{X_0}{P_0 L_0} \tag{14}$$

So, the relative welfare in the presence of tax evasion is given by:

$$\frac{W_0^e}{W_0} = \frac{X_0^e}{X_0}\frac{P_0}{P_0^e} = \frac{X_0^e}{X_0}\left(\frac{w_0^{1-\sigma}/\lambda_0}{w_0^{1-\sigma}/\lambda_0^e}\right)^{1/(1-\sigma)}$$

The second equality follows as $\lambda_0 = (w_0/P_0)^{1-\sigma}$.[32] We obtain:

$$\frac{W_0^e}{W_0} = \underbrace{\left(\frac{\lambda_0^e}{\lambda_0}\right)^{1/(1-\sigma)}}_{>1}\left[1 + \frac{(\tau - 1)}{\tau}(1 - \lambda_0)(\Gamma(\tau) - 1)\right]$$

Appendix B shows that the term in square parentheses is also greater than one as $\Gamma(\tau) > 1$. This implies evasion unambiguously reinforces gains from trade. On the one hand, evasion lowers the relative price of foreign goods, and thus decreases the domestic expenditure share. On the other hand, it increases tax revenues by increasing the tax base. While resources wasted on evasion and underreporting tend to reduce tax revenues, lower relative price of foreign goods tends to raise them. The latter effect dominates the former, so the the overall

[32]To see this, note that $x_c/x_0 = (p_c/p_0)^{1-\sigma}(\tau^e)^{1-\sigma}$, where $c \neq 0$. So, we have

$$\begin{aligned} X_0 &= x_0 w_0^{\sigma-1}(w_0^{1-\sigma} + \sum_{c=1}^{n}(p_c\tau)^{1-\sigma}) \\ &= x_0 w_0^{\sigma-1}P_0^{1-\sigma} \end{aligned}$$

$$\implies \lambda_0 = \frac{x_0}{X_0} = \left(\frac{w_0}{P_0}\right)^{1-\sigma}$$

effect is positive.

## 5 Conclusions

A fast growing literature uses quantitative methods to evaluate welfare implications of trade policies. Estimates of the trade elasticity are a key ingredient in these studies, and yet very few of these estimates are based on actual policy changes. This paper contributes to the literature by offering a setting where an exogenous increase in a border tax can be used to estimate the trade elasticity. Our estimate of 2.18 lies in between the estimates commonly found in time-series studies and those coming from the cross-sectional exercises. We further show that the trade elasticity estimate is heavily biased in the presence of tax evasion, which may partially explain why studies relying on data from countries with different levels of evasion produce different estimates.

Our other contribution lies in proposing two novel methods of detecting tax evasion in international trade. The first method uses deviations from Benford's law and could be easily implemented by customs offices that wish to combat corruption and evasion. The second method relies on comparing price and trade cost elasticity of import demand. We apply both methods to an unexpected policy change that increased the cost of import financing in Turkey and show that both methods produce evidence consistent with an increase in tax evasion after the shock. A standard approach based on "missing trade" confirms this conclusion.

## References

**Arkolakis, Costas, Arnaud Costinot, and Andres Rodriguez-Clare**, "New Trade Models, Same Old Gains?," *American Economic Review*, February 2012, *102* (1), 94–130.

_ , **Natalia Ramondo, Andrs Rodrguez-Clare, and Stephen Yeaple**, "Innovation and Production in the Global Economy," *American Economic Review*, August 2018, *108* (8), 2128–73.

**Baier, Scott L. and Jeffrey H. Bergstrand**, "The growth of world trade: tariffs, transport costs, and income similarity," *Journal of International Economics*, 2001, *53* (1), 1 – 27.

**Bhagwati, Jagdish N.**, "Directly-unproductive, profit-seeking activities: welfare-theoretic synthesis and generalization," *Journal of Political Economy*, October 1982, *90.*

_ **and T. N. Srinivasan**, "The welfare consequences of directly-unproductive profit-seeking (DUP) lobbying activities : Price versus quantity distortions," *Journal of International Economics*, August 1982, *13* (1-2), 33–44.

**Broda, Christian and David E. Weinstein**, "Globalization and the Gains From Variety," *The Quarterly Journal of Economics*, 2006, *121* (2), 541–585.

**Caliendo, Lorenzo and Fernando Parro**, "Estimates of the Trade and Welfare Effects of NAFTA," *The Review of Economic Studies*, 2015, *82* (1), 1–44.

**Camerer, C.**, *Behavioral Game Theory : Experiments in Strategic Interaction*, New Age International, 2003.

**Cho, Wendy K Tam and Brian J Gaines**, "Breaking the (Benford) Law," *The American Statistician*, 2007, *61* (3), 218–223.

**Demir, Banu, Beata Javorcik, Tomasz Michalski, and Evren Ors**, "Financial Constraints and Propagation of Shocks in Production Networks," Mimeo, Department of Economics, University of Oxford 2018.

**Durtschi, Cindy, William Hillison, and Carl Pacini**, "Effective Use of Benford's Law to Assist in Detecting Fraud in Accounting Data," *Journal of Forensic Accounting*, 2004, *4*.

**EY**, "TradeWatch, March 2014," 2014. http://www.ey.com/Publication/vwLUAssets/EY-tradewatch-vol13-issue1/$FILE/EY-tradewatch-Vol13-Issue1.pdf.

**Feenstra, Robert C.**, "Chapter 30 Estimating the effects of trade policy," in "," Vol. 3 of *Handbook of International Economics*, Elsevier, 1995, pp. 1553 – 1595.

**Felbermayr, Gabriel, Benjamin Jung, and Mario Larch**, "The welfare consequences of import tariffs: A quantitative perspective," *Journal of International Economics*, 2015, *97* (2), 295–309.

**Ferrantino, Michael J., Xuepeng Liu, and Zhi Wang**, "Evasion behaviors of exporters and importers: Evidence from the U.S.China trade data discrepancy," *Journal of International Economics*, 2012, *86* (1), 141–157.

**Fisman, Raymond and Shang-Jin Wei**, "Tax Rates and Tax Evasion: Evidence from "Missing Imports in China," *Journal of Political Economy*, April 2004, *112* (2), 471–500.

**_ , Peter Moustakerski, and Shang-Jin Wei**, "Outsourcing Tariff Evasion: A New Explanation for Entrept Trade," *The Review of Economics and Statistics*, 2008, *90* (3), 587–592.

**Goldberg, Pinelopi K. and Nina Pavcnik**, "The Effects of Trade Policy," NBER Working Papers 21957, National Bureau of Economic Research, Inc February 2016.

**Hill, Theodore P.**, "A Statistical Derivation of the Significant-Digit LawDetecting Problems in Survey Data Using Benfords Law," *Statistical Science*, 1995, *4*.

_ , "The Difficulty of Faking Data," *CHANCE*, 1999, *12* (3), 27–31.

**Hillberry, Russell and David Hummels**, *Trade Elasticity Parameters for a Computable General Equilibrium Model*, Vol. 1 of *Handbook of Computable General Equilibrium Modeling*, Elsevier,

**Javorcik, Beata S. and Gaia Narciso**, "Differentiated products and evasion of import tariffs," *Journal of International Economics*, December 2008, *76* (2), 208–222.

_ **and** _ , "WTO accession and tariff evasion," *Journal of Development Economics*, 2017, *125*, 59 – 71.

**Judge, George and Laura Schechter**, "Detecting Problems in Survey Data Using Benfords Law," *Journal of Human Resources*, 2009, *44* (1).

**Khandelwal, Amit K., Peter K. Schott, and Shang-Jin Wei**, "Trade Liberalization and Embedded Institutional Reform: Evidence from Chinese Exporters," *American Economic Review*, October 2013, *103* (6), 2169–95.

**Marion, Justin and Erich Muehlegger**, "Measuring Illegal Activity and the Effects of Regulatory Innovation: Tax Evasion and the Dyeing of Untaxed Diesel," *Journal of Political Economy*, 2008, *116* (4), 633–666.

**Melitz, Marc and Stephen Redding**, "New Trade Models, New Welfare Implications," *American Economic Review*, 2015, *105* (3), 1105–46.

**Michalski, Tomasz and Gilles Stoltz**, "Do Countries Falsify Economic Data Strategically? Some Evidence That They Might," *The Review of Economics and Statistics*, May 2013, *95* (2), 591–616.

**Mishra, Prachi, Arvind Subramanian, and Petia Topalova**, "Tariffs, enforcement, and customs evasion: Evidence from India," *Journal of Public Economics*, 2008, *92* (1011), 1907 – 1925.

**Ossa, Ralph**, "Trade Wars and Trade Talks with Data," *The American Economic Review*, 2014, *104* (12), 4104–4146.

**Romalis, John**, "NAFTA's and CUSFTA's Impact on International Trade," *The Review of Economics and Statistics*, 2007, *89* (3), 416–435.

**Sequeira, Sandra**, "Corruption, Trade Costs, and Gains from Tariff Liberalization: Evidence from Southern Africa," *American Economic Review*, October 2016, *106* (10), 3029–3063.

**Trefler, Daniel**, "The Long and Short of the Canada-U. S. Free Trade Agreement," *American Economic Review*, September 2004, *94* (4), 870–895.

**Yang, Dean**, "Can Enforcement Backfire? Crime Displacement in the Context of Customs Reform in the Philippines," *The Review of Economics and Statistics*, February 2008, *90* (1), 1–14.

# Appendices

## A Proof of Result 1

It is easier to derive $\frac{d(1/Exposure)}{d\tau}$, where country subscript is dropped to simplify notation. It is equal to

$$
\begin{aligned}
\frac{d(1/Exposure)}{d\tau} &= \frac{q(r^*)g(r^*)\frac{dr^*}{d\tau}\int_{r^*}^{\infty} q(\tau)dG(r) - \int_{\underline{r}}^{r^*} q(r)dG(r)\left(\int_{r^*}^{\infty} \frac{dq(\tau)}{d\tau}dG(r) - q(r^*)g(r^*)\frac{dr^*}{d\tau}\right)}{\left(\int_{r^*}^{\infty} q(\tau)dG(r)\right)^2} \\
&\propto q(r^*)g(r^*)\frac{dr^*}{d\tau}\int_{r^*}^{\infty} q(\tau)dG(r) - \int_{\underline{r}}^{r^*} q(r)dG(r) \\
&\times \left(\int_{r^*}^{\infty} yP^{\sigma-1}p_c^{-\sigma}(-\sigma)(\tau^e)^{-\sigma-1}\frac{d\tau^e}{d\tau}dG(r) - q(r^*)g(r^*)\frac{dr^*}{d\tau}\right) \\
&= q(r^*)g(r^*)\frac{dr^*}{d\tau}\int_{r^*}^{\infty} q(\tau)dG(r) - \int_{\underline{r}}^{r^*} q(r)dG(r)\int_{r^*}^{\infty} q(\tau)\frac{-\sigma}{\tau^e}\frac{d\tau^e}{d\tau}dG(r) \\
&= q(r^*)g(r^*)\frac{dr^*}{d\tau}\left(\int_{r^*}^{\infty} q(\tau)dG(r) + \int_{\underline{r}}^{r^*} q(r)dG(r)\right) + \frac{\sigma}{\tau^e}\frac{d\tau^e}{d\tau}\int_{\underline{r}}^{r^*} q(r)dG(r)
\end{aligned}
$$

where $\frac{dr^*}{d\tau} = \frac{d\tau^e}{d\tau} = 1 - \frac{\tau-1-\theta f}{\gamma} = 1 - \alpha^* > 0$. The last equality follows from the fact that $q(r^*) = q(\tau^e)$. Therefore, $\frac{d(1/Exposure)}{d\tau} > 0 \implies \frac{d(Exposure)}{d\tau} < 0$.

## B Proof of the welfare result

Here, we aim to show that the term below in square parentheses is also greater than one:

$$
\frac{W_0^e}{W_0} = \underbrace{\left(\frac{\lambda_0^e}{\lambda_0}\right)^{1/(1-\sigma)}}_{>1}\left[1 + \frac{(\tau-1)}{\tau}(1-\lambda_0)(\Gamma(\tau)-1)\right]
$$

To do so, it is sufficient to show that $\Gamma(\tau) > 1$ as $\tau > 1$ and $\lambda_0 < 1$. As explained in the text, $\Gamma(\tau)$ can also be written as:

$$
\int_0^1 (1-\alpha^*(\theta_k))\left(\frac{\tau^e(\theta_k)}{\tau}\right)^{-\sigma} dG(\theta_k)
$$

Since $\sigma > 1$, the following inequality holds:

$$\begin{aligned}\Gamma(\tau) &> \int_0^1 (1-\alpha^*(\theta_k)) \left(\frac{\tau^e(\theta_k)}{\tau}\right)^{-1} dG(\theta_k) \\ &= \int_0^1 (1-\alpha^*(\theta_k)) \frac{\tau}{\tau^e(\theta_k)} dG(\theta_k) \\ &\geq \int_0^1 (1-\alpha^*(\theta_k)) dG(\theta_k)\end{aligned}$$

The last inequality follows as $\tau \geq \tau^e(\theta_k)$ by construction. Otherwise, it would not be profitable to evade taxes.

The integral in the last line can be evaluated to obtain:

$$\left(1-\frac{\tau-1}{\gamma}\right)\theta_k\bigg|_{\theta_k=1} + \frac{f}{2\gamma}\theta_k^2\bigg|_{\theta_k=1} = 1 + \frac{f-2(\tau-1)}{2\gamma} > 1$$

as $f - 2(\tau - 1)$ by assumption. This completes the proof.

# C Tables and Figures

Table 1: **Firm-level Imports before and after the Shock**

| | Baseline | Pre-existing trends | Processing imports |
|---|---|---|---|
| | (1) | (2) | (3) |
| $1\{t = T\} * Exposure_{i,T-2}$ | **-0.119**$^{**}$ | **-0.151**$^{**}$ | -0.104 |
| | (0.0530) | (0.0665) | (0.0847) |
| $1\{t = T-1\} * Exposure_{i,T-2}$ | | -0.0666 | |
| | | (0.0640) | |
| N | 45818 | 45818 | 8549 |
| $R^2$ | 0.888 | 0.888 | 0.910 |
| Fixed effects | s(i)xt,i | s(i)xt,i | s(i)xt,i |

*Notes:* This table shows the results from estimating the following regression:

$$\ln M_{it} = \delta_0 + \delta_1 1\{t = T\} * Exposure_{i,T-2} + \alpha_{s(i),t} + \alpha_i + e_{it}$$

where the dependent variable is the logarithm of the value of imports by firm $i$ at time $t = \{T-2, T-1, T\}$, and $Exposure_{i,T-2}$ is share of firm-level imports with external financing at time $t = T-2$. $1\{t = T\}$ is a dummy variable that takes on the value one for the October 2011-September 2012 period (after the increase in RUSF rate), and zero otherwise. The specification controls for time-varying factors common to a given 4-digit NACE industry ($\alpha_{s(i),t}$) and firm fixed effects ($\alpha_i$). $^{*}$, $^{**}$, $^{***}$ represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors (in parentheses) are clustered at the the 4-digit NACE industry where firm $i$ operates.

Table 2: **Evidence of Evasion: "Missing trade" approach**

| | (1) | (2) | (3) |
|---|---|---|---|
| $MissingTrade$ in | Value | Quantity | Price |
| $1\{t = T\} * Exposure_{hc,T-2}$ | **0.062**$^{**}$ | 0.022 | **0.040**$^{*}$ |
| | (0.028) | (0.035) | (0.020) |
| N | 70089 | 70089 | 70089 |
| $R^2$ | 0.812 | 0.787 | 0.711 |

*Notes:* This table shows the results from estimating specification in equation (2). $MissingTrade_{hct}$ in terms of value is defined as the difference in the value of exports of product $h$ to Turkey reported by country $c$ and imports of $h$ from $c$ reported by Turkey. $MissingTrade$ in terms of quantity is defined similarly using weight, while $MissingTrade$ in terms of prices is defined in terms of value per kg. $Exposure_{hc,T-2}$ is share of product-country-level imports with external financing at time $t = T - 2$. $1\{t = T\}$ is a dummy variable that takes on the value one in 2012, and zero otherwise. $t = T - 2$. All columns include country-time, product-time, and country-product fixed effects. $^{*}, ^{**}, ^{***}$ represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors (in parentheses) are clustered at the source country-HS4 level.

Table 3: **Evidence of Evasion: Robustness checks for "missing trade" approach**

| | (1) | (2) | (3) |
|---|---|---|---|
| *MissingTrade* in | Value | Quantity | Price |
| | | Panel A: Non-parametric estimates | |
| $1\{t = T\}$∗Bin 2 | **0.0546**$^{**}$ | 0.040 | 0.014 |
| | (0.021) | (0.026) | (0.015) |
| $1\{t = T\}$∗Bin 3 | **0.072**$^{***}$ | 0.026 | **0.047**$^{***}$ |
| | (0.021) | (0.026) | (0.015) |
| $1\{t = T\}$∗Bin 4 | **0.0683**$^{***}$ | 0.020 | **0.048**$^{***}$ |
| | (0.022) | (0.027) | (0.015) |
| N | 70089 | 70089 | 70089 |
| $R^2$ | 0.812 | 0.787 | 0.711 |
| F-stat. $\beta_{Bin2} = \beta_{Bin3}$ | 1.003 | 0.414 | **5.723**$^{**}$ |
| F-stat. $\beta_{Bin2} = \beta_{Bin4}$ | 0.484 | 0.659 | **5.727**$^{**}$ |
| F-stat. $\beta_{Bin3} = \beta_{Bin4}$ | 1.003 | 0.414 | **5.723**$^{**}$ |
| | | Panel B: Assigning a placebo date (October 2010) to the shock | |
| $1\{t = T - 1\} * Exposure_{hc,T-2}$ | 0.0053 | -0.0157 | 0.0210 |
| | (0.030) | (0.038) | (0.024) |
| N | 46726 | 46726 | 46726 |
| $R^2$ | 0.872 | 0.853 | 0.796 |
| | | Panel C: Using placebo exposure based on processing imports | |
| $1\{t = T\} * Exposure^{placebo}_{hc,T-2}$ | 0.028 | 0.000 | 0.027 |
| | (0.030) | (0.037) | (0.020) |
| N | 23913 | 23913 | 23913 |
| $R^2$ | 0.858 | 0.838 | 0.761 |

*Notes:* In Panel A, bins are constructed based on quartiles of $Exposure_{hc,T-2}$, where Bin 1 is a dummy variable that denotes the first quartile and forms the base group in Panel A. Bin 2, Bin 3, and Bin 4 are defined analogously. Panel B restricts the sample to 2010-2011 and assigns a placebo date (October 2010) to the shock. $1\{t = T - 1\}$ is a dummy variable that takes on the value one in 2011, and zero otherwise. In Panel C, $Exposure^{placebo}_{hc,T-2}$ is share of product-country-level *processing* imports with external financing at time $t = T - 2$. All columns include country-time, product-time, and country-product fixed effects. See the notes for Table 2 for the definitions of the other variables. $^{*}$, $^{**}$, $^{***}$ represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors (in parentheses) are clustered at the source country-HS4 level.

Table 4: **Testing Conformity with Benford's law**

| Ordinary imports | Not subject to RUSF | | Subject to RUSF | |
|---|---|---|---|---|
| | Before | After | Before | After |
| Test statistic | 12.718 | 9.021 | 9.887 | **22.301**$^{***}$ |
| No. of obs | 56168 | 56168 | 26431 | 26431 |

*Notes:* Table shows $\chi^2$ goodness-of-fit test statistic values for the observed data. The underlying data are constructed by first grouping transactions by treatment status, i.e., subject to RUSF or not, in each period and then aggregating observations in each sub-sample at the 6-digit HS and source country level. Test statistic is calculated as $N \sum_{d=1}^{9} \frac{(f_d - \hat{f}_d)^2}{f_d}$, where $\hat{f}_d$ is the fraction of digit $d$ in the data and $f_d$ is the fraction predicted by Benford's law. The test statistic converges to a $\chi^2$ distribution with eight degrees of freedom as $N \to \infty$. The corresponding 5% and 1% critical values are 15.5, and 20.1.

Table 5: **Summary Statistics for Deviations from Benford's law**

| | $t = T - 2$ | $t = T - 1$ | $t = T$ |
|---|---|---|---|
| D | | | |
| Mean | 0.0176 | 0.0172 | 0.0178 |
| Median | 0.0122 | 0.0120 | 0.0123 |
| Std | 0.0195 | 0.0191 | 0.0200 |
| No. of obs. per $hc$ | | | |
| Mean | 120.1 | 131.2 | 130.9 |
| Median | 65 | 67 | 67 |
| Std | 182.1 | 219.1 | 219.5 |

*Notes:* Table shows summary statistics for the test statistic constructed for deviations from Benford's law for each product-country pair in the data with at least 30 observations. It is defined as

$$D = \sum_{d=1}^{9} (f_d - \hat{f}_d)^2;$$

Table 6: **Evidence of Evasion: Using Benford's law**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | Baseline | First two digits | First three digits | Placebo date | Processing |
| $1\{t = T\} * Exposure_{hc,T-2}$ | **0.00286**$^{***}$ | **0.000694**$^{*}$ | **0.000376**$^{***}$ | | 0.0000811 |
| | (0.00107) | (0.000374) | (0.000110) | | (0.000719) |
| $1\{t = T-1\} * Exposure_{hc,T-2}$ | | | | 0.0000620 | |
| | | | | | (0.00138) |
| N | 26369 | 26369 | 26369 | 17820 | 12468 |
| $R^2$ | 0.766 | 0.882 | 0.955 | 0.817 | 0.798 |

*Notes:* This table shows the results from estimating specification in equation (5). In all columns (except columns 2-3) the dependent variable is $D_{hct}$, which measures for each $hc$-pair the deviation of observed distribution from Benford's law defined as:

$$D_{hct} = \sum_{d=1}^{9}(f_{hct}^d - \hat{f}_{hct}^d)^2.$$

In columns 3-4, the dependent variable measures the deviations of the joint distribution of the leading $k$ digits from the predicted distribution by Benford law which is given by:

$$Prob(D_1 = d_1, ..., D_k = d_k) = log_{10}\left[1 + \left(\sum_{i=1}^{k} d_i * 10^{k-i}\right)^{-1}\right],$$

where $k = 1, 2, 3$. $Exposure_{hc,T-2}$ is share of product-country-level imports with external financing at time $t = T-2$. $1\{t = T\}$ is a dummy variable that takes on the value one for the October 2011-September 2012 period, and zero otherwise. $1\{t = T+1\}$ is a dummy variable that takes on the value one for the October 2012-September 2013 period, and zero otherwise. Column 4 restricts the sample to October 2009-September 2011 and assigns a placebo date (October 2010) to the shock. Column 5 is based on the sample of processing imports. All columns include country-time, product-time, and country-product fixed effects. $^{*}$, $^{**}$, $^{***}$ represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors (in parentheses) are clustered at the source country-HS4 level.

Table 7: **Evidence of Evasion: Comparing elasticities**

| | OLS | IV | IV |
|---|---|---|---|
| | (1) | (2) | (3) |
| $\ln p_{ihcmt}$ | -1.163*** | -2.065*** | -1.937*** |
| | (0.00729) | (0.412) | (0.389) |
| $\ln \tau_{mt}$ | -2.545*** | -2.181*** | -2.296*** |
| | (0.464) | (0.691) | (0.655) |
| $1\{t = T\} * \ln \tau_{mt}$ | **2.008*** | **1.803*** | **2.026*** |
| | (0.456) | (0.640) | (0.720) |
| $1\{t = T\} * \ln p_{ihcmt}$ | | | -0.325 |
| | | | (0.599) |
| N | 875034 | 875034 | 875034 |
| $R^2$ | 0.841 | | |
| F-stat. $\beta_1 = \beta_2$ | 8.903*** | 0.0144 | 0.154 |
| KP test stat | | 14.08 | |
| CD test stat | | | 11.94 |

*Notes:* This table shows the results from estimating specification in equation (10). Dependent variable is the logarithm of the quantity of product $h$ imported by firm $i$ from country $c$ on financing term $m$ at time $t$. $\ln p_{ihcmt}$ denotes the logarithm of the c.i.f. price. $1\{t = T\}$ is a dummy variable that takes on the value one for the October 2011-September 2012 period, and zero otherwise. $\tau_{mt}$ denotes one plus the RUSF rate. In columns 2-3, $\ln p_{ihcmt}$ is instrumented with $\ln Distance_{ic}$ which is the logarithm of the sum of distance between the province where firm $i$ is located and Istanbul (the largest international port of Turkey) and the distance between country $c$ and Istanbul. In column (3), $1\{t = T\} * \ln p_{ihcmt}$ is instrumented with $1\{t = T\} * \ln Distance_{ic}$. KP and CG denote Kleibergen-Paap and Cragg-Donald test statistics, respectively. All columns include country-product-time and firm-time fixed effects. $^{*}, ^{**}, ^{***}$ represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors (in parentheses) are clustered at the source country-HS4 level.

Table 8: **Comparing Elasticities: Additional results**

| | Placebo | Extended sample |
|---|---|---|
| | IV | IV |
| | (1) | (2) |
| $\ln p_{ihcmt}$ | -2.270*** | -2.157*** |
| | (0.455) | (0.434) |
| $\ln \tau_{mt}$ | -2.008*** | -2.398*** |
| | (0.653) | (0.574) |
| $1\{t = T-1\} * \ln \tau_{mt}$ | -0.578 | |
| | (0.901) | |
| $1\{t = T\} * \ln \tau_{mt}$ | | **1.455*** |
| | | (0.526) |
| $1\{t = T+1\} * \ln \tau_{mt}$ | | 1.012 |
| | | (0.620) |
| N | 576315 | 1153807 |
| $R^2$ | 0.737 | 0.757 |
| F-stat. $\beta_1 = \beta_2$ | 0.0883 | 0.0727 |
| KP test stat | 13.81 | 13.01 |

*Notes:* This table shows the results from estimating an augmented version of equation (10). Column 1 restricts the sample to the October 2009-September 2011 period, and column 2 extends it to September 2013. Dependent variable is the logarithm of the quantity of product $h$ imported by firm $i$ from country $c$ on financing term $m$ at time $t$. $\ln p_{ihcmt}$ denotes the logarithm of the c.i.f. price. $1\{t = T-1\}$, $1\{t = T\}$, and $1\{t = T+1\}$ are dummy variables indicating the October 2010-September 2011, October 2011-September 2012, and October 2012-September 2013 periods, respectively. $\tau_{mt}$ denotes one plus the RUSF rate. In both columns, $\ln p_{ihcmt}$ is instrumented with $\ln Distance_{ic}$ which is the logarithm of the sum of distance between the province where $i$ is located and Istanbul (the largest international port of Turkey) and the distance between country $c$ and Istanbul. KP denotes Kleibergen-Paap test statistic. All columns include country-product-time and firm-time fixed effects. $^{*}$, $^{**}$, $^{***}$ represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors (in parentheses) are clustered at the source country-HS4 level.

Table 9: **Extended Sample: "Missing trade" approach**

| | (1) | (2) | (3) |
|---|---|---|---|
| $MissingTrade$ in | Value | Quantity | Price |
| $1\{t = T\} * Exposure_{hc,T-2}$ | **0.0612**$^{**}$ | 0.0195 | **0.0417**$^{**}$ |
| | (0.027) | (0.034) | (0.020) |
| $1\{t = T+1\} * Exposure_{hc,T-2}$ | 0.0219 | 0.0463 | -0.0244 |
| | (0.042) | (0.054) | (0.032) |
| N | 81873 | 81873 | 81873 |
| $R^2$ | 0.805 | 0.779 | 0.698 |

*Notes:* This table shows the results from estimating an augmented version of equation (2). $MissingTrade_{hct}$ in terms of value is defined as the difference in the value of exports of product $h$ to Turkey reported by country $c$ and imports of $h$ from $c$ reported by Turkey. $MissingTrade$ in terms of quantity is defined similarly using weight, while $MissingTrade$ in terms of prices is defined in terms of value per kg. $Exposure_{hc,T-2}$ is share of product-country-level imports with external financing at time $t = T-2$. $1\{t = T\}$ is a dummy variable that takes on the value one in 2012, and zero otherwise. $t = T-2$. $1\{t = T+1\}$ is a dummy variable that takes on the value one in 2013, and zero otherwise. All columns include country-time, product-time, and country-product fixed effects. Robust standard errors (in parentheses) are clustered at the source country-HS4 level.

Table 10: **Extended Sample: Using Benford's law**

| | (1) |
|---|---|
| $1\{t=T\} * Exposure_{hc,T-2}$ | **0.00324**$^{**}$ |
| | (0.00127) |
| $1\{t=T+1\} * Exposure_{hc,T-2}$ | 0.00289 |
| | (0.00202) |
| N | 34505 |
| $R^2$ | 0.737 |
| Fixed effects | hxt,cxt,hxc |

*Notes:* This table shows the results from estimating an augmented version of equation (5) using an extended sample that covers the 12-month period $T+1$. The dependent variable is $D_{hct}$, which measures for each $hc$-pair the deviation of observed distribution from Benford's law defined as:

$$D_{hct} = \sum_{d=1}^{9} (f^d_{hct} - \hat{f}^d_{hct})^2.$$

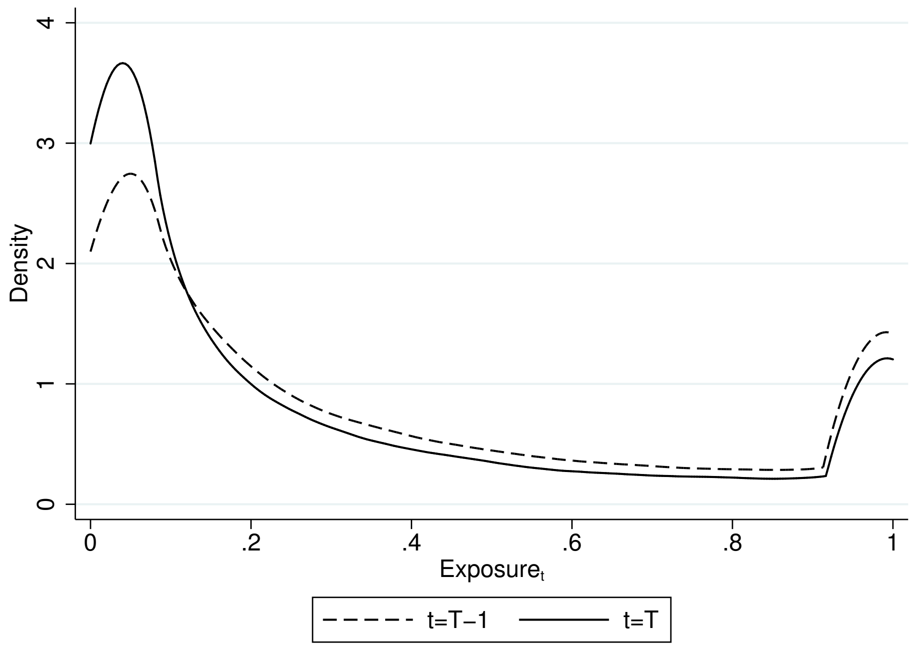
$Exposure_{hc,T-2}$ is share of product-country-level imports with external financing at time $t = T-2$. $1\{t = T\}$ is a dummy variable that takes on the value one for the October 2011-September 2012 period, and zero otherwise. $1\{t = T+1\}$ is a dummy variable that takes on the value one for the October 2012-September 2013 period, and zero otherwise. $^{*}$, $^{**}$, $^{***}$ represent significance at the 10, 5, and 1 percent levels, respectively. All columns include country-time, product-time, and country-product fixed effects. Robust standard errors (in parentheses) are clustered at the source country-HS4 level.

Table 11: **List of Parameters Used in Simulations**

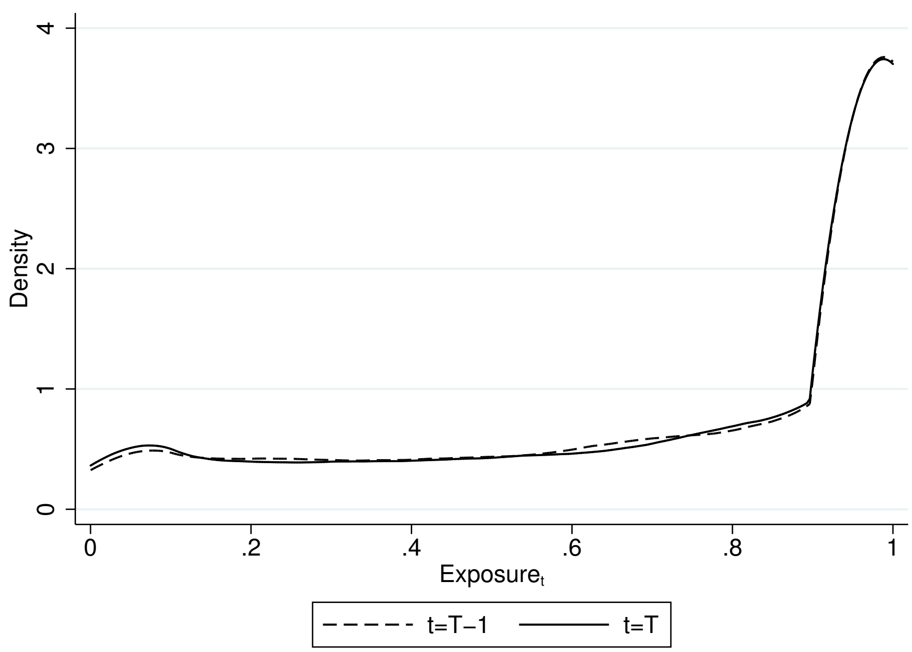
| | Variable | Parametrization | Parameter values | Source |
|---|---|---|---|---|
| Country-level productivity | $\phi$ | $\phi$ ∼Log-normal | $\mu = 0.05, \nu = 0.5$ | - |
| Income in the home country | $Y_0$ | - | 1,000,000 | - |
| Elasticity of substitution | $\sigma$ | - | 4 | Melitz and Redding (2015) |
| Number of countries | $n$ | - | 500 | - |
| Evasion cost parameter | $\gamma$ | - | 0.125 | - |
| Evasion penalties | $f$ | $3 * \tau$ | - | Turkish Customs law no. 4458 |
| Probability of being inspected | $\theta$ | $\theta \sim U[0,1]$ | - | - |

*Notes:* This table summarizes the variables and parameters used in simulations in Section 4.4.

Figure 1: Distribution of Share of Imports with External Financing ($Exposure_{hc}$)



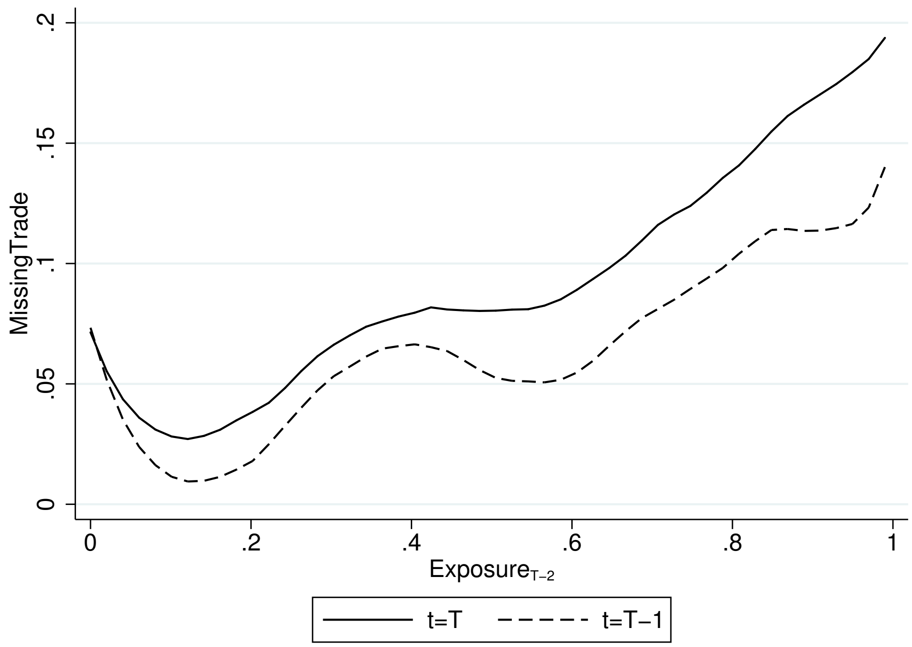

Panel A: Ordinary imports



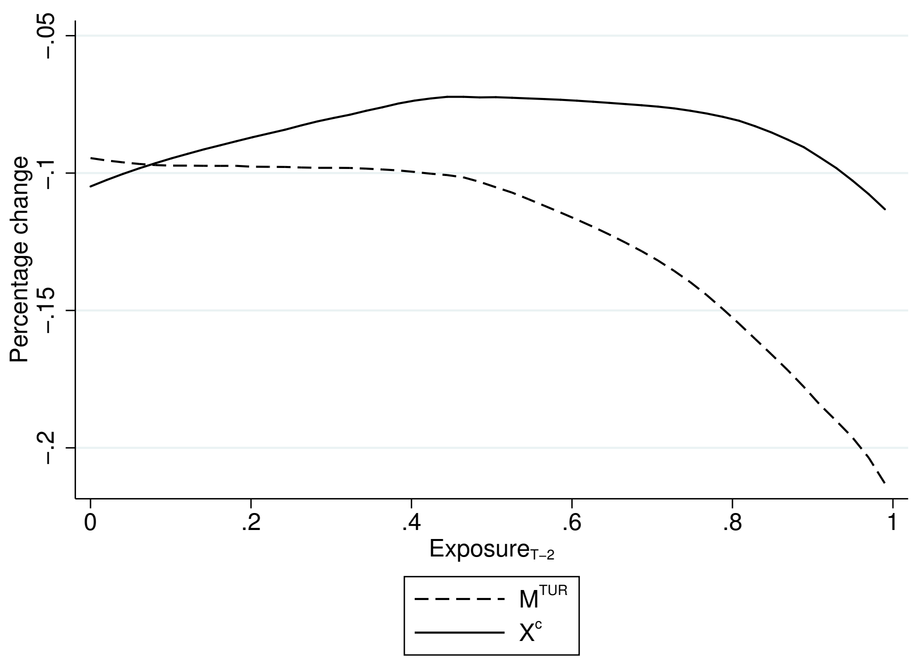

Panel B: Processing imports

*Notes:* This figure illustrates the distribution of the share of imports with external financing 12 months before and after the increase in the RUSF rate in October 2011. It covers 4,700 6-digit HS products imported from 150 source countries, or 75,000 country-product pairs.

Figure 2: Missing Trade and Exposure to RUSF



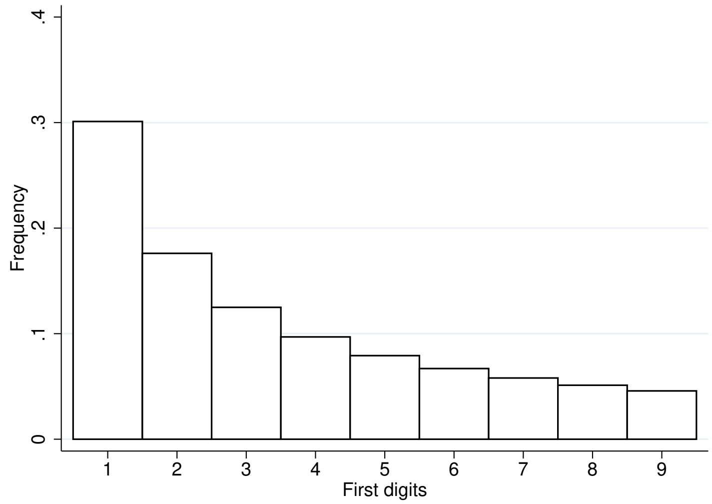

Panel A: Missing trade




Panel B: Change in imports

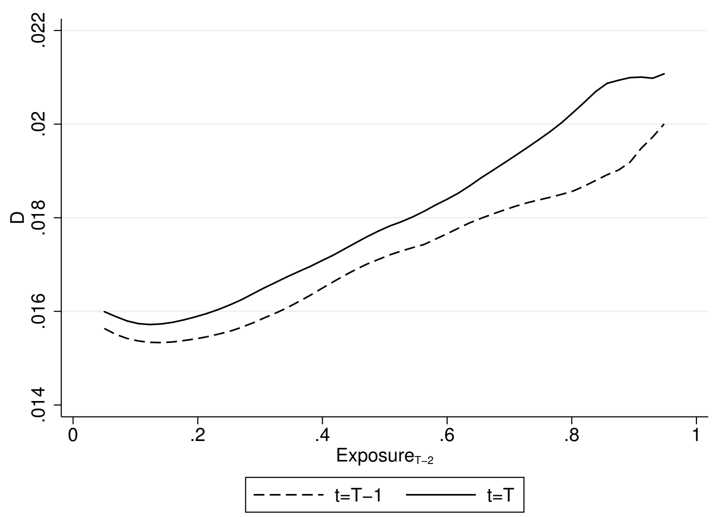
*Notes:* Panel A shows a local polynomial regression of $MissingTrade$ as a function of $Exposure$, which is defined as the share of imports with external financing at time $t = T - 2$. Panel B repeats the exercise for the change in Turkish imports.

Figure 3: Benford's Distribution of First Digits



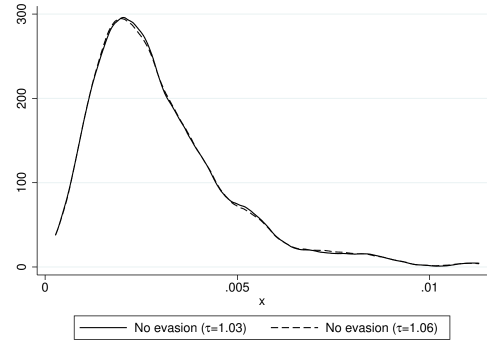

*Notes:* The figure shows the distribution of the leading first digits as predicted by Benford's law: $P(\text{First digit is d}) = log_{10}(1 + 1/d)$.

Figure 4: Deviations from Benford's law and exposure

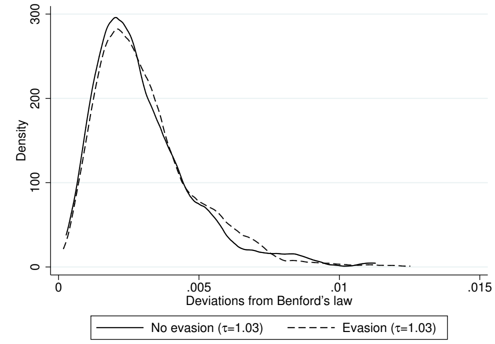



*Notes:* The figures show local polynomial regressions of Turkish imports reported by the source country and Turkey as functions of *Exposure*, which is defined as the share of imports with external financing at time $t = T - 2$.

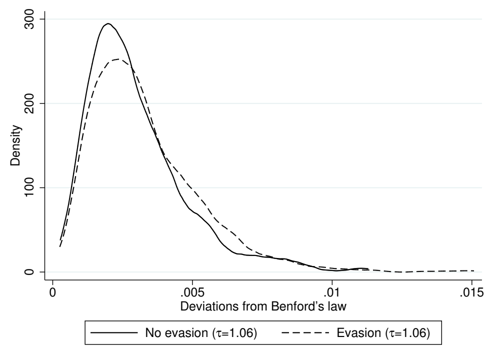
Figure 5: Deviations from Benford's Law in Simulated Data



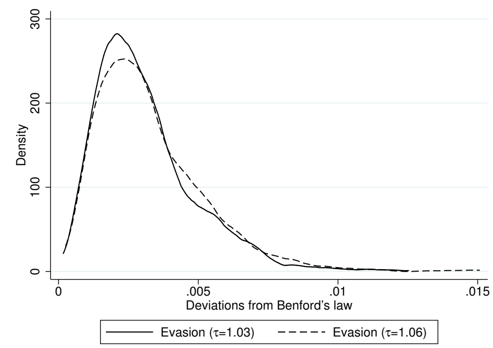

Panel A: Low vs. high tax rate without evasion




Panel B: With and without evasion under low tax rate




Panel C: With and without evasion under high tax rate




Panel D: Low vs. high tax rate with evasion

*Notes:* These figures show deviations from Benford's law, using the formula in (4), in simulated data for trade values based on the model. See the text for details.