Trade Policy Changes, Tax Evasion and Benford's Law*

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Abstract

This paper draws attention to import duty evasion as a margin through which firms adjust to changes in trade policy. This margin is different from the other forms of adjustment, as it can be employed very fast and thus it may constitute the initial reaction to the shock before a slower adjustment through the other channels take place. The study also proposes a new method of detecting tax evasion in international trade, based on deviations from Benford's law. It applies the method in the context of an unexpected policy change in Turkey that increased the cost of import financing. The results are consistent with an immediate increase in tax evasion in the affected import flows, which dies down a year later. A standard approach to detecting tariff evasion, based on "missing trade", confirms these conclusions.

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1 Introduction

One of the key questions in international trade is how firms adjust to changes in trade policy. The literature has demonstrated theoretically and empirically that the adjustment can take place through firm entry and exit, reallocation of market shares driven by differences in firm productivities and changes to the product portfolio.[1] This paper draws attention to another margin of adjustment—evasion of import duties in response to increases in border taxes. This margin is different from the other forms of adjustment, as it can be employed very fast and thus it may constitute the initial reaction to the shock before a slower adjustment through the other channels take place. Understanding and acknowledging the existence of this margin matters, as any analysis of the consequences of short-run trade policy changes that fails to take into account changes in evasion is likely to present a distorted picture of reality.[2]

By its very nature tax evasion is difficult to detect as the parties involved have every incentive to conceal their lack of compliance with the tax law. Despite the great importance of tax evasion to public policy choices, it remains elusive and difficult to detect through a statistical analysis. This paper contributes to the literature by proposing a new method of detecting tax evasion in the context of border taxes. The proposed method is based on Benford's law, which describes the distribution of first digits in economic or accounting data. This method is applied to an unexpected policy change in Turkey that increased the tax rate applicable to some import flows. The analysis uncovers evidence consistent with an increase in tax evasion after the policy shock. This conclusion is confirmed using a well-established approach based on discrepancies in international trade statistics, proposed by Fisman and Wei (2004).

[1] See Pavcnik (2002); Melitz (2003); Bernard et al. (2010); Eckel and Neary (2010); Bernard et al. (2011); Mayer et al. (2014)

[2] Import duty evasion is not limited to developing countries. Just to give an example, multiple press releases pertaining to cigarette smuggling can be found on the website of HM Revenue and Customs in the UK. See http://www.mynewsdesk.com/uk/hm-revenue-customs-hmrc/latest_news/tag/cigarette-smuggling.

The exogenous 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.[3] The tax rate was doubled, increasing from 3% to 6% of the transaction value. 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.[4] 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.[5]

The proposed detection method, based on Benford's law that describes the distribution of leading digits, is explained in detail in Section 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 oversupplying modes or under-supplying long runs (Camerer (2003), pp. 134-138).[6] Moreover, since Benford's law is not widely known, it seems very unlikely that those manipulating

[3]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.

[4]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.

[5]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.

[6]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."

numbers would seek to preserve fit to the Benford distribution.

To strengthen our argument that it is reasonable to expect Benford's law to hold in international trade data, we use simulations to show that trade values generated by a standard international trade model comply with Benford's law in the absence of tax evasion and that evasion leads to significant deviations from the law. Then, we show that Turkish export figures conform with the law. Unlike importers, exporters have have no or little incentive to misreport their foreign sales. We also show that imports that are not subject to any tariffs or taxes follow the law as well.

Our main analysis applies Benford's law to Turkish import data disaggregated by firm, 6-digit Harmonised System (HS) product, source country, month and payment method.[7] 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 the policy change.[8]

We further show that our results are robust to applying Benford's law for the joint distribution of the first two leading digits and the first three leading digits. Moreover, we show that placebo tests based on a placebo date (October 2010 instead of October 2011) or processing imports (which are not subject to RUSF) yield results that are not statistically or economically significant.

Then we turn to the well-established approach to detecting tariff evasion, based on "missing trade" and proposed by Fisman and Wei (2004). This alternative approach also 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

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

[8]Our test is 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.

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.

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 takes time to find alternative sources of financing, but in the medium-run many importers may replace trade credit with other sources of financing. They also have an option of switching to domestic sourcing, as shown by Demir et al. (2018). 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. The results based on both methods suggest 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 taking place through other channels. In other words, differential speeds of adjustment through various margins lead to adjustment through evasion overshooting in the short run before settling at its long-run level.

While focusing on this 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 this 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 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.[9] The test could be performed using

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

import transaction data that are collected by customs and hence readily available.[10]

Our paper is related to two strands of the existing literature. First, as explained earlier, it contributes to the literature on firms' adjustment to trade policy changes by drawing attention to a neglected margin of adjustment—namely, evasion of border taxes. It demonstrates that this margin responds very fast, though later its response may be muted by firms choosing alternative ways of adjustment that require more time to be implemented.

Second, our paper is related to the literature documenting tax evasion in international trade (Yang (2008); Fisman and Wei (2004); Fisman et al. (2008); Javorcik and Narciso (2008); Mishra et al. (2008); Ferrantino et al. (2012); Sequeira (2016); and Javorcik and Narciso (2017)). Our paper contributes to this literature by proposing an alternative method of detecting tax evasion in international trade, which could be easily implemented in practice.

The rest of the paper is structured as follows. Next section describes Benford's law and presents simulations showing that trade values generated by a standard international trade model comply with Benford's law in the absence of tax evasion and that evasion leads to significant deviations from the law. Section 3 explains the policy context and the data and presents the results from the main analysis. Section 4 shows evidence of tax evasion based on the "missing trade" approach. Section 5 examines the persistence of evasion. The last section presents the conclusions.

2 A Novel Approach to Detecting Tax Evasion

2.1 Benford's law

We propose a statistical test to detect tax evasion, which relies on the distribution of first (or leading) digits in economic or accounting data.[11] The method is based on Benford's law,

[10] We view our approach as complementary to the Fisman-Wei approach. While the Fisman-Wei method is more suitable for a country-level analysis, our approach lends itself more easily to investigating evasion at a more disaggregated level.

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

which predicts that a given leading digit d will occur with the following probability:

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

This predicted probability is shown in Figure 1. The law naturally arises when data are generated by an exponential process or independent processes are pooled together.

We expect Benford's law to hold in data on international trade flows 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 skewed, with a mean greater than the median value.[12]

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.[13]

2.2 Simulation evidence

We use simulations to show that trade values generated by a standard international trade model comply with Benford's law in the absence of tax evasion and that evasion leads to significant deviations from the law.

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

[13]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)). In a contemporaneous paper, Barabesi et al. (2018) propose a goodness-of-fit testing procedure for Benford's law and use trade data as an application. Differently from existing studies, our paper shows how Benford's law can be used in a regression analysis.

Consider a simple Armington model of international trade with $n+1$ countries, indexed by c. We refer to Turkey as the home country ($c = 0$).[14] 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 ($c = 0$).

For each source country, there is a representative importer in the home country, indexed by k. International trade is subject to policy-induced costs which take the ad-valorem form and are borne by importers: $\tau > 1$. Importers may underreport prices to evade taxes.[15] Let p_c denote the true price of the good exported by country c. Instead of reporting the true price, an importer may report its fraction $(1 - \alpha_k)p_c$, where $\alpha_k \in [0, 1)$. Tax evasion is subject to a cost that is proportional to the true price and quadratic in the extent of evasion (α_k). 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 $((\gamma/2)\alpha_k^2)p_c$, $\gamma > 0$.

With probability θ_k, importers are subject to a more careful inspection at the border, which will reveal the true price. If $\alpha_k > 0$, they pay a penalty for the undeclared amount, denoted by $f > 2(\tau - 1)$. Importers in the home country are heterogenous in their belief about the probability of being caught, and these probabilities follow a uniform distribution on the interval $\theta_k \in [0, 1]$. An importer k minimizes the cost of importing by misreporting

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

[15] This assumption is consistent with the results presented in Section 4

$\alpha_k^*(\theta_k)$ fraction of the true price. At an interior solution, it yields:[16]

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

The expression implies that tax evasion increases with the tax rate (τ), and it decreases with the cost of evasion (γ), probability of being inspected (θ), and the fixed penalty (f). Therefore, the expected cost of importing with evasion is:

$$\tau^e(\theta_k)p_c = \left[1 + (1-\alpha_k)(\tau - 1) + (\gamma/2)\alpha_k^2 + \theta_k \alpha_k f\right] p_c,$$

where τ^e denotes the evasion-inclusive tax rate. The first term in square brackets represents the amount of 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.

We generate trade values based on the model and examine the distribution of their first digits with and without tax evasion. Table 1 summarizes the variables and parameters used in simulations. We run 1,000 simulations and simulate 500 countries in each run. Country-level productivities (ϕ), which determine prices, are assumed to have a log-normal distribution with (μ, ν). 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 γ to 0.125. Finally, in line with the discussion in Section 3.1, 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

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

expression:

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

where P denotes the standard CES price index. In the presence of evasion, it becomes:

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

To measure deviations of the simulated data from Benford's law, we follow Cho and Gaines (2007) and Judge and Schechter (2009) and use the following distance measure:

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

where $\hat{f}_d$ denotes the observed fraction of leading digit d in the data, and f_d fraction predicted by Benford's law. Figure 2 shows deviations from Benford's law, based on the distance formula in equation (2), 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.[17] 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, the simulations based on a standard trade model illustrate that deviations from the law increase significanty with the tax rate in the presence of evasion.

The simulation exercise also allows us to calculate the government's revenue loss from

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

taxes due to evasion. Figure 3 shows that revenue losses due to evasion are significant, particularly when $\tau = 1.06$: on average, they amount to 8% of potential tax revenues.

3 Application: Policy Shock in Turkey

3.1 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 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.[18] The RUSF applies to ordinary imports as processing imports have always been exempted from import duties and other taxation.

The Turkish law stipulates 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 th e tax rate from 3% to 6% of the transaction value lowers profit margins of importers.[19] Firms can respond to the shock in a number of ways. First, they can reduce imports or even stop importing altogether. Second, they can switch away from importing on trade credit.[20] 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.[21] 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

[18]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).

[19]A report published by the Istanbul Chamber of Industry in 2015 on the leather and related products industry argued that RUSF hurts competitiveness as the industry relies heavily on imported inputs and trade credit. The report called for the tax rate to be reduced to 1% and abolished for imported inputs that are not available in the domestic market.

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

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

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 or imported, but only the number of the commercial invoice that includes these details. The evading importer needs to obtain two invoices with the same number, but with different total values of the transaction. 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.

3.2 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 2010-2013 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).[22] Import values include cost, insurance and freight (c.i.f.). Exports are reported on f.o.b. basis. We restrict the sample to the trading partners which are members of the World Trade Organization.

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

In the baseline analysis, we use monthly import data, which 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.[23]

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

$$Exposure_{hct} = \frac{\sum_{m \in \{OA,AC,DLC\}} M_{hcmt}}{\sum_m M_{hcmt}}, \tag{3}$$

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 the shock (October 2009-September 2010), $Exposure_{hc,T-2}$.[24] 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.[25]

The tax increase mattered. As illustrated in Figure 4, the distribution of $Exposure_{hc}$ for ordinary imports (in the upper panel) shifted to the left after the increase in the RUSF rate.

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

[24]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.

[25]In any case, adjustment taking place in anticipation of the policy change would work against us finding any reaction to the policy shock.

In particular, the average 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).

3.3 First look at the trade data

We expect that Turkish export data should conform to Benford's law, as exporting firms have no or little incentive to misreport their foreign sales. Therefore, export data provide a benchmark against which we compare the conformity of import figures. To do so, we use Turkey's monthly transaction-level exports and imports data and calculate the following χ^2 goodness-of-fit-statistic for each partner country before and after the RUSF shock:

$$N \sum_{d=1}^{9} \frac{(f_d - \hat{f}_d)^2}{f_d},$$

where $\hat{f}_d$ is the fraction of observations with the leading digit d in the data and f_d is the fraction predicted by Benford's law. The test statistic converges to a χ^2 distribution with eight degrees of freedom as $N \to \infty$. The corresponding 10%, 5% and 1% critical values are 13.4, 15.5, and 20.1. To reduce the influence of the number of observations on the test statistic, we draw a random sample of 500 transactions for each country cell.

Figure 5 presents the distribution of the test statistic before the shock for exports and ordinary imports that are not subject to any tariffs or the RUSF tax. In both cases, conformity with Benford's law is rejected at the 5% level *in less than 5 percent* of the country cells. The average value of the statistic is below 8 in both distributions, and the difference between the two averages is not statistically different from zero at the conventional levels (p-value is 0.7). Figures 9-12 in the Appendix show that the distribution of the χ^2 test statistic for imports that are not subject to tariffs or RUSF does not vary significantly by industry, firm size or Turkish regions. Overall, we conclude that exports as well as imports that are not subject to tariffs or the RUSF tax conform to Benford's law.

Figure 6 compares the distribution of the test statistic for imports that are subject to tariffs (but not RUSF) and imports that are not subject to any tariffs or taxes before October 2011. Conformity with Benford's law is rejected at the 5% level in 10 percent of the country cells for the former, as compared to less than 5 percent of the cells for the latter. The average value of the test statistic is statistically higher for imports subject to tariffs than for other imports (p-value is 0.07). This implies that the distribution of imports deviates more from Benford's law when there is greater incentive for tax evasion.

Finally, Figure 7 presents the distributions of the χ^2 test statistic for imports that are subject to RUSF (but not tariffs and those that are not subject to any taxes before and after the shock. In the earlier period, the mean and median values of the two distributions are not statistically different from each other.[26] After the tax rate was raised from 3% to 6%, the distribution of the test statistic for flows that are subject to RUSF shifted to the right, while the one for imports that are not subject to RUSF remained almost unchanged. In this period, the average value of the test statistic is statistically higher for imports subject to RUSF (p-value is 0.06). This finding is suggestive of evasion taking place in flows subject to the tax in the aftermath of the policy change.

3.4 Econometric evidence

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. 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 2. We estimate the following

[26] For a discussion of possible reasons, see Section 5.

specification:

$$D_{hct} = \theta_0 + \theta_1 1\{t = T\} * Exposure_{hc,T-2} + \alpha_{ht} + \alpha_{ct} + \alpha_{hc} + e_{hct}, \tag{4}$$

The equation controls for unobservable heterogeneity at the product-country level with α_{hc} fixed effects as well as for time-varying product (α_{ht}) and country (α_{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.

Before presenting the results from estimating equation (4), in Figure 8, we plot local polynomial regressions of our measure of deviations from Benford's law, D, in the year prior to the shock and after the shock as a function of $Exposure_{hc,T-2}$. As evident from the figure, D increases with exposure to the tax. For tax exposure of about 10 percent, the vertical distance between the two curves is negligible. However, the D 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 initial exposure to the tax.

The results obtained from estimating equation (4) are presented in the first column in the upper panel of Table 3. Column 1 shows 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 $t = T - 1$.[27]

In the second 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 3, we conduct another placebo exercise by focusing on

[27] 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%.

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.

In Tables 4 and 5, we conduct robustness tests where we test the deviation of the joint distribution of the leading two or three digits, respectively, from the 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, we construct deviations of the observed distribution from the predicted distribution and re-estimate equation (4). The results are in line with the baseline findings and point to an increase in evasion after the increase in the RUSF rate in October 2011.

4 "Missing trade" approach as external validation

As an alternative test for detecting evasion, we 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 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.

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).[28]

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.

To test whether underreporting of imports after the policy change increases systematically with the initial exposure to the tax, we estimate the following equation:

$$MissingTrade_{hct} = \gamma_0 + \gamma_1 1\{t = T\} * Exposure_{hc,T-2} + \alpha_{ht} + \alpha_{ct} + \alpha_{hc} + \varepsilon_{hct}. \qquad (5)$$

The equation controls for product-year, country-year and product-country fixed effects. Our coefficient of interest is γ_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 (5) are presented in the first column of Table 6. Our coefficient of interest γ_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. We do so by defining $MissingTrade$ in terms of quantities and unit values. The results presented in the second and third columns suggest that evasion tends to take place through underreporting of prices rather than quantities, though

[28]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.

the coefficient in the quantity estimation is relatively large, albeit statistically insignificant.[29]

In sum, this alternative approach to detecting tax evasion yields results supporting our earlier conclusions.

5 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. Third, as documented by Demir et al. (2018), who consider the same shock, 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.

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 Table 7, the spike in evasion appears to have died down at $T+1$. Even though the coefficient of interest still bears a reasonably sizeable estimate, it does not appear to be statistically significant.

In Table 8, we repeat the same exercise using the"missing trade" approach. Again the results suggest that the spike in evasion observed right after the policy shock (at time T) disappears one period later (at $T+1$). Thus the surge in evasion appears to be short lived.

This finding is in line with the view that differential speeds of adjustment through various margins lead to adjustment through evasion overshooting in the short run before settling at

[29]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 (α_{hc}) fixed effects included in each specification capture the impact of $Exposure_{hc,T-2}$, and hence this variable does not enter the specification.

its long-run level. It may also explain why the distribution of χ^2 statistics in Figure 7 was suggestive of there being no tax evasion prior to the RUSF tax rate increasing from 3% to 6%. Although the pattern presented in Figure 8 is 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 3.1).

6 Conclusions

This study makes two contributions to the existing literature. First, it draws attention to import duty evasion as a neglected margin through which firms adjust to changes in trade policy. It shows that such an adjustment is very fast, though with time, evasion is replaced by other legal channels of adjustment that take longer to implement. Put differently, differential speeds of adjustment through various margins lead to adjustment through evasion overshooting in the short run before settling at its long-run level.

Second, the study proposes a new method of detecting tax evasion in international trade, based on deviations from Benford's law. It applies the method in the context of an unexpected policy change in Turkey which increased the cost of import financing. It finds evidence consistent with an increase in tax evasion in the affected import flows after the shock. A standard approach to detecting tariff evasion, based on "missing trade", confirms these conclusions.

Our findings have practical implications. They suggest that simple tests based on Benford's law could be easily implemented by customs offices using the information they readily have at their disposal. The results of the tests could then be used to decide where to focus further efforts directed at combating corruption and evasion.

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Tables and Figures

Table 1: **List of Parameters Used in Simulations**

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

Notes: This table summarizes the variables and parameters used in simulations in Section 2.2.

Table 2: **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 3: **Evidence of Evasion: Using Benford's law**

	(1)	(2)	(3)
	Baseline	Placebo date	Processing
$1\{t = T\} * Exposure_{hc,T-2}$	**0.00286*****	-0.000343	0.00008
	(0.00107)	(0.00142)	(0.00072)
$Exposure_{hc,T-2}$		-0.000935	
		(0.00122)	
N	26369	17820	12468
R^2	0.766	0.396	0.798
FE	ct,pt,cp	ct,pt,cp	ct,pt,cp

Notes: This table shows the results from estimating specification in equation (4). In all columns the dependent variable is D_{hct}, which measures for each hc-pair the deviation of observed distribution from Benford's law defined as:

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

$1\{t = T\}$ is a dummy variable that takes on the value one for the October 2011-September 2012 period, and zero otherwise. Column 2 restricts the sample to October 2009-September 2011 and assigns a placebo date (October 2010) to the shock. Column 3 is based on the sample of processing imports. *, **, *** 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: **Evidence of Evasion: Using Benford's law for the first two digits**

	(1)	(2)	(3)
	Baseline	Placebo date	Processing
$1\{t = T\} * Exposure_{hc,T-2}$	**0.00069***[*]	0.00086	0.00005
	(0.00037)	(0.00056)	(0.00212)
$Exposure_{hc,T-2}$		-0.00019	
		(0.00056)	
N	26369	17820	12468
R^2	0.882	0.472	0.866
FE	ct,pt,cp	ct,pt,cp	ct,pt,cp

Notes: This table shows the results from estimating specification in equation (4). In all columns the dependent variable measures the deviations of the joint distribution of the leading $k = 2$ 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 $k = 1, 2$. $1\{t = T\}$ is a dummy variable that takes on the value one for the October 2011-September 2012 period, and zero otherwise. Column 2 restricts the sample to October 2009-September 2011 and assigns a placebo date (October 2010) to the shock. Column 3 is based on the sample of processing imports. $^{*}, ^{**}, ^{***}$ 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 5: **Evidence of Evasion: Using Benford's law for the first three digits**

	(1)	(2)	(3)
	Baseline	Placebo date	Processing
$1\{t = T\} * Exposure_{hc,T-2}$	**0.00038*****	0.00017	0.00003
	(0.00011)	(0.00055)	(0.00159)
$Exposure_{hc,T-2}$		0.000159	
		(0.000620)	
N	26369	17820	12468
R^2	0.955	0.494	0.914
FE	ct,pt,cp	ct,pt,cp	ct,pt,cp

Notes: This table shows the results from estimating specification in equation (4). In all columns the dependent variable measures the deviations of the joint distribution of the leading $k = 3$ 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 $k = 1, 2, 3$. $1\{t = T\}$ is a dummy variable that takes on the value one for the October 2011-September 2012 period, and zero otherwise. Column 2 restricts the sample to October 2009-September 2011 and assigns a placebo date (October 2010) to the shock. Column 3 is based on the sample of processing imports. $^{*}, ^{**}, ^{***}$ 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 6: **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 (5). $MissingTrade_{hct}$ 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 7: **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 (4) using an extended sample that covers the additional 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:

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

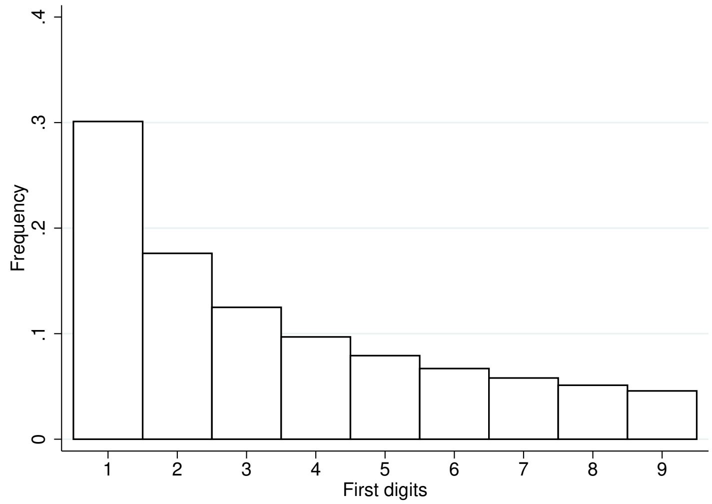
$Exposure_{hc,T-2}$ is share of product-country-level imports with external financing at time $t = T-2$. $1\{t=T\}$ is a dummy variable that takes on the value one for the October 2011-September 2012 period, and zero otherwise. $1\{t=T+1\}$ is a dummy variable that takes on the value one for the October 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 8: **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

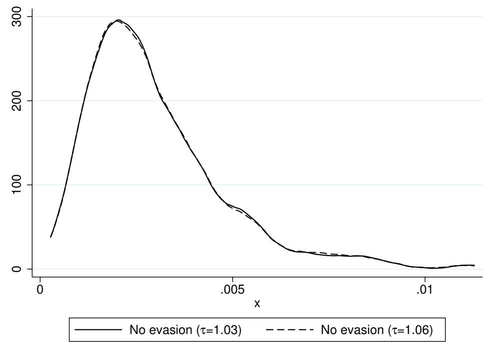
Notes: This table shows the results from estimating an augmented version of equation (5). $MissingTrade_{hct}$ in terms of value is defined as the difference in the value of exports of product h to Turkey reported by country c and imports of h from c reported by Turkey. $MissingTrade$ in terms of quantity 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.

Figure 1: Predicted Probabilities based on Benford's Law

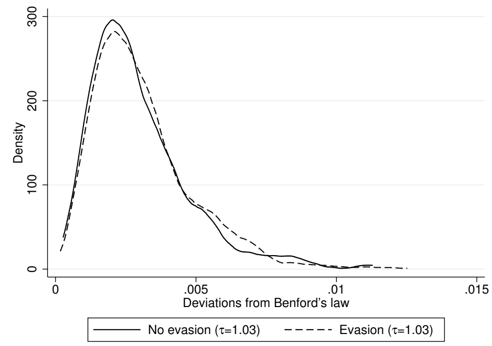


Notes: The figure shows the probability that $\{1, ...9\}$ will occur as the first leading digit in the data as predicted by Benford's law.

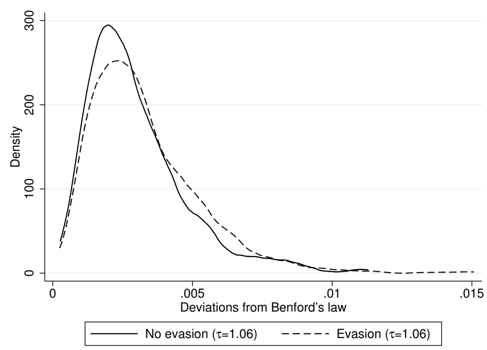
Figure 2: Deviations from Benford's Law in Simulated Data



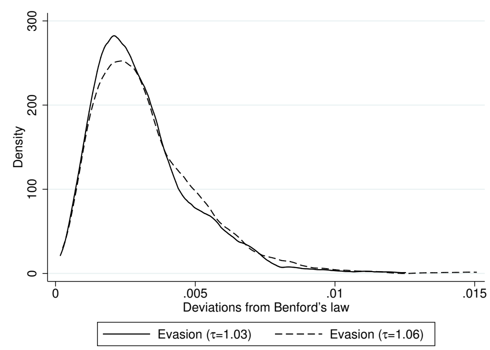
Panel A: Low vs. high tax rate without evasion



Panel B: With and without evasion under low tax rate



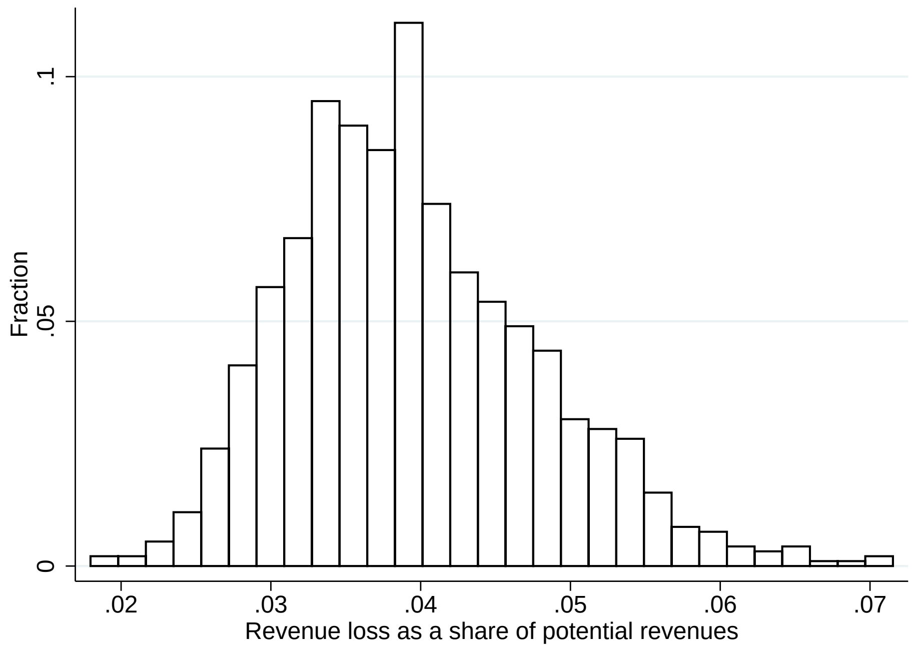
Panel C: With and without evasion under high tax rate



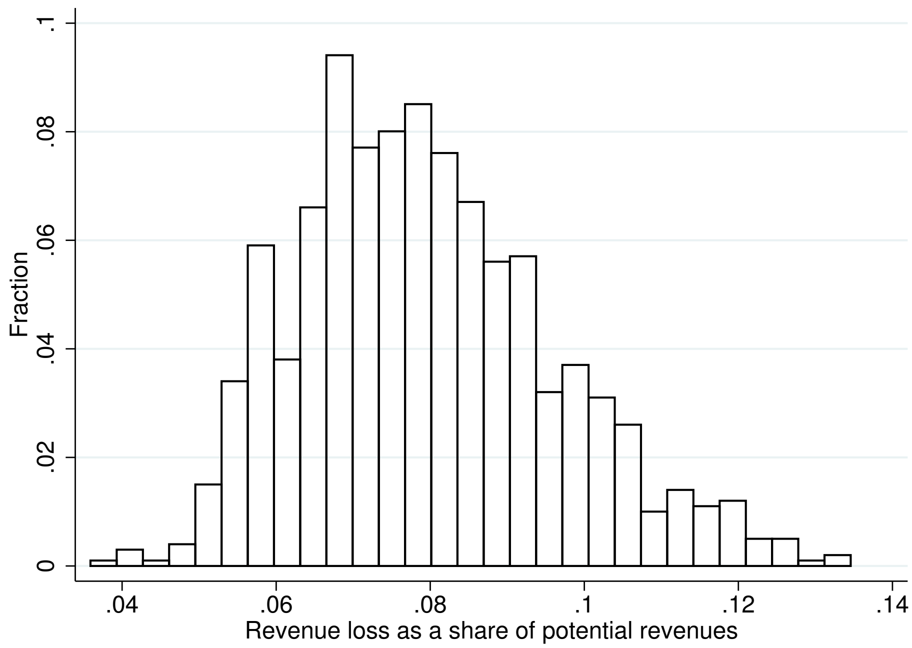
Panel D: Low vs. high tax rate with evasion

Notes: These figures show deviations from Benford's law, using the formula in (2), in simulated data for trade values based on the model. See the text for details.

Figure 3: Revenue Loss from Evasion in Simulated Data



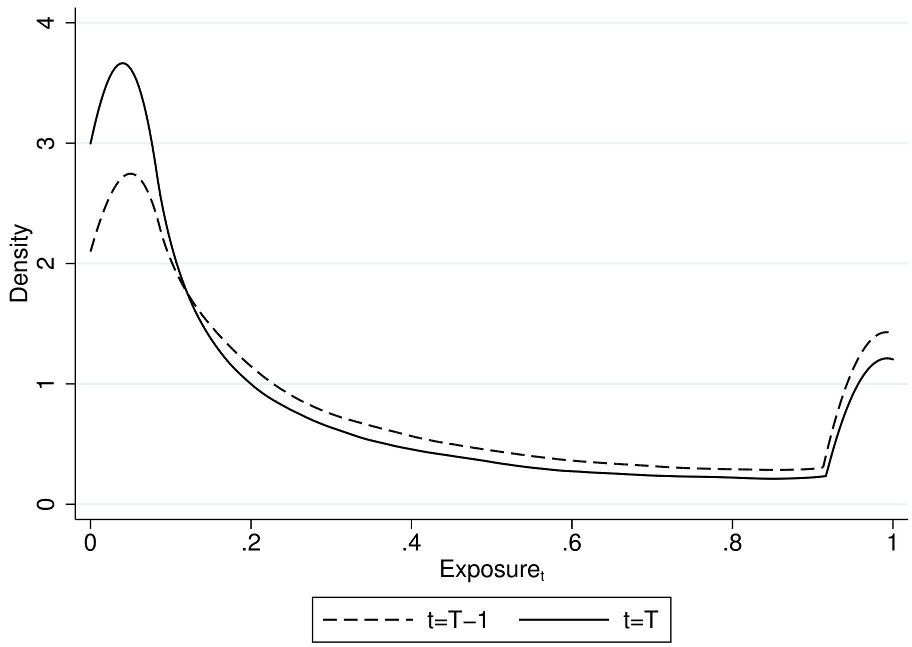
Panel A: $\tau = 1.03$



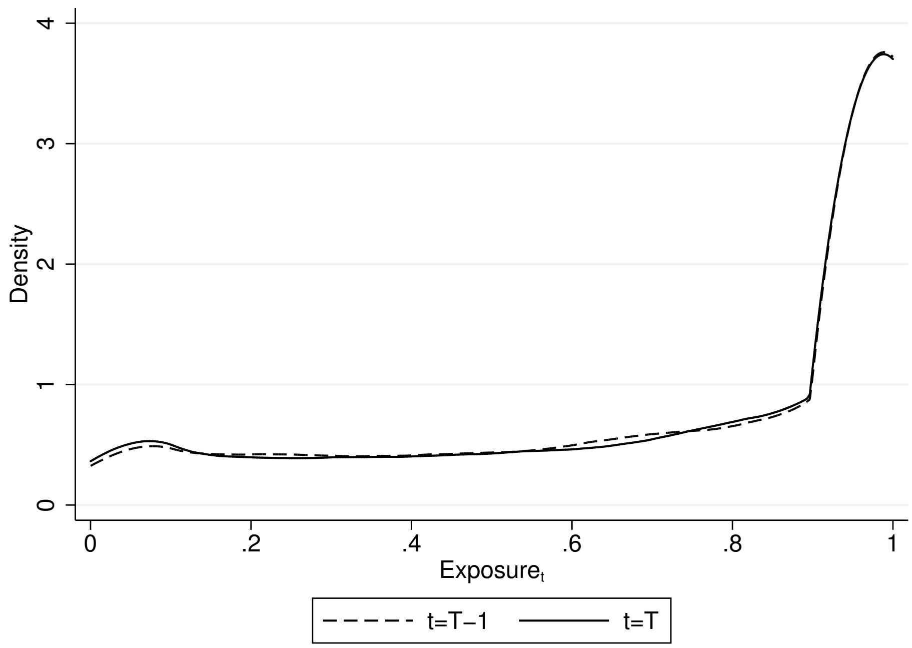
Panel B: $\tau = 1.06$

Notes: These figures show the distribution of reductions in tax revenues relative to potential tax revenues in simulated data.

Figure 4: Distribution of Share of Imports with External Financing ($Exposure_{hc}$)



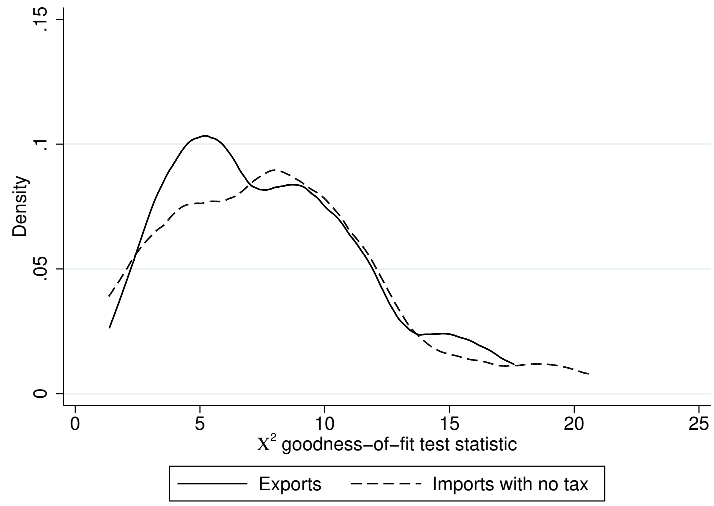
Panel A: Ordinary imports



Panel B: Processing imports

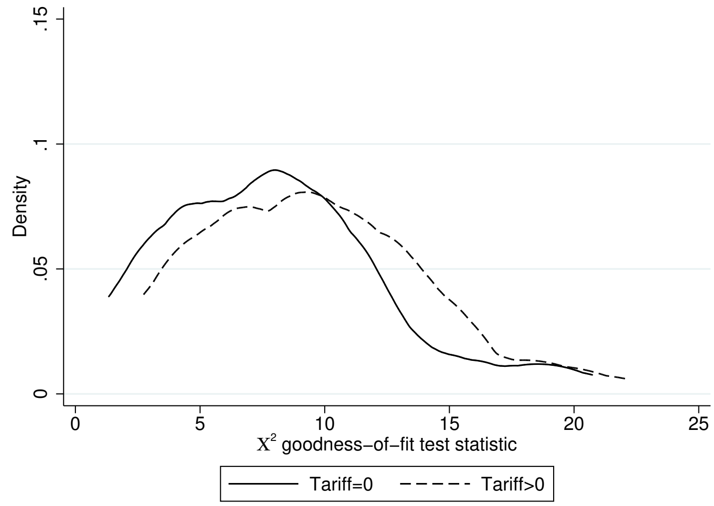
Notes: The figures illustrate the distribution of the share of ordinary (panel A) and processing (panel B) imports with external financing 12 months before and 12 months after the increase in the RUSF rate in October 2011.

Figure 5: Conformity of Turkish exports and (no-tax) imports with Benford's law



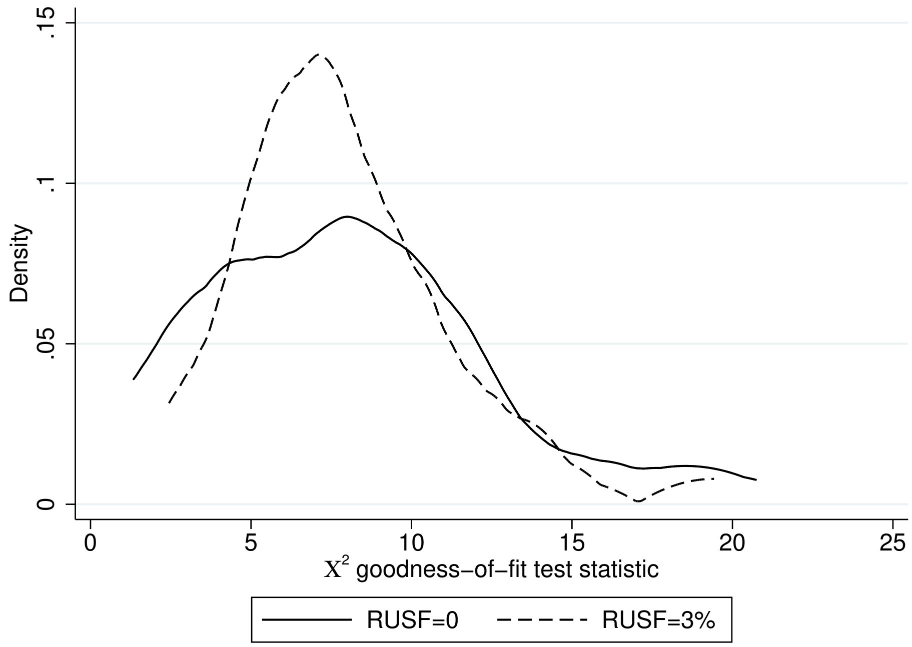
Notes: The figure shows the distribution of the χ^2 goodness-of-fit test statistic values for the observed exports and imports data before the RUSF shock. Imports data only cover flows that are not subject to tariffs or RUSF. For each country, the test statistic is calculated using monthly transaction-level trade data using the following formula: $N\sum_{d=1}^{9}\frac{(f_d-\hat{f}_d)^2}{f_d}$, where $\hat{f}_d$ is the fraction of digit d in the data and f_d is the fraction predicted by Benford's law. To reduce the influence of N on the test statistic, random samples of size 500 are drawn for each country. The test statistic converges to a χ^2 distribution with eight degrees of freedom as $N \to \infty$. The corresponding 10%, 5% and 1% critical values are 13.4, 15.5, and 20.1. The difference in the mean value of the test statistic between the two distributions is -0.23 (0.67).

Figure 6: Conformity of Turkish imports with Benford's law: Effect of tariffs

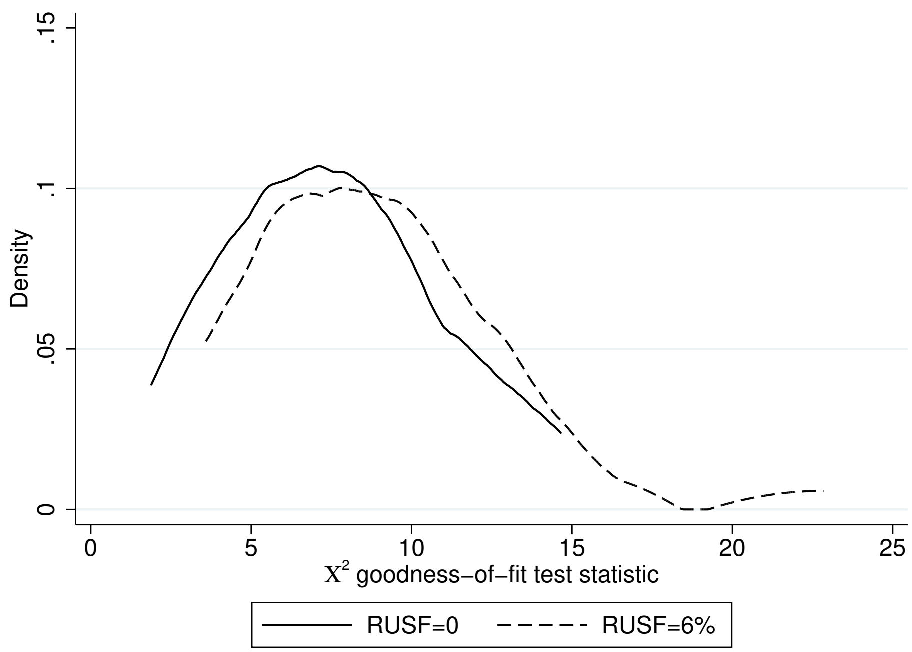


Notes: The figure shows the distribution of the χ^2 goodness-of-fit test statistic values for the observed imports data before the RUSF shock. Imports data are split into two groups: flows that are subject to tariffs but not RUSF (dashed line) and flows that are not subject to any taxes (solid line). For each country, the test statistic is calculated using monthly transaction-level trade data using the following formula: $N \sum_{d=1}^{9} \frac{(f_d - \hat{f}_d)^2}{f_d}$, where $\hat{f}_d$ is the fraction of digit d in the data and f_d is the fraction predicted by Benford's law. To reduce the influence of N on the test statistic, random samples of size 500 are drawn for each country. The test statistic converges to a χ^2 distribution with eight degrees of freedom as $N \to \infty$. The corresponding 10%, 5% and 1% critical values are 13.4, 15.5, and 20.1. The difference in the mean value of the test statistic between the two distributions is -1.49 (0.99).

Figure 7: Conformity of Turkish imports with Benford's law: Effect of RUSF



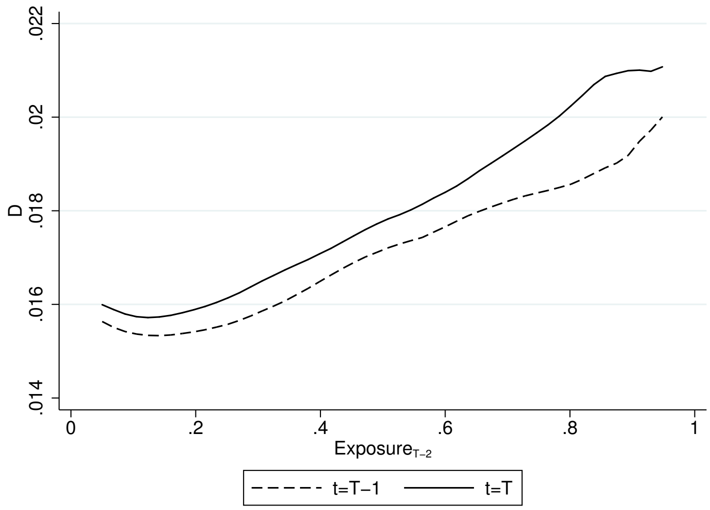
Panel A: $t = T - 1$



Panel B: $t = T$

Notes: The figures show the distributions of the χ^2 goodness-of-fit test statistic values for the observed imports data before (panel A) and after (panel B) the RUSF shock. Imports data are split into two groups: flows that are subject to RUSF but not tariffs (dashed line) and flows that are not subject to any taxes (solid line). For each country, the test statistic is calculated using monthly transaction-level trade data using the following formula: $N \sum_{d=1}^{9} \frac{(f_d - \hat{f}_d)^2}{f_d}$, where $\hat{f}_d$ is the fraction of digit d in the data and f_d is the fraction predicted by Benford's law. To reduce the influence of N on the test statistic, random samples of size 500 are drawn for each country. The test statistic converges to a χ^2 distribution with eight degrees of freedom as $N \rightarrow \infty$. The corresponding 10%, 5% and 1% critical values are 13.4, 15.5, and 20.1. The difference in the mean value of the test statistic between the two distributions is 0.04 (0.85) in panel A, and -1.22 (0.77) in panel B.

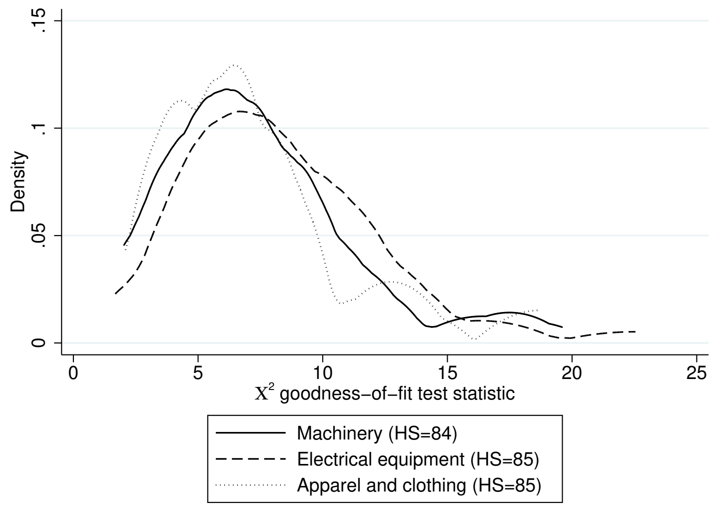
Figure 8: Deviations from Benford's law and exposure



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 $t = T - 2$.

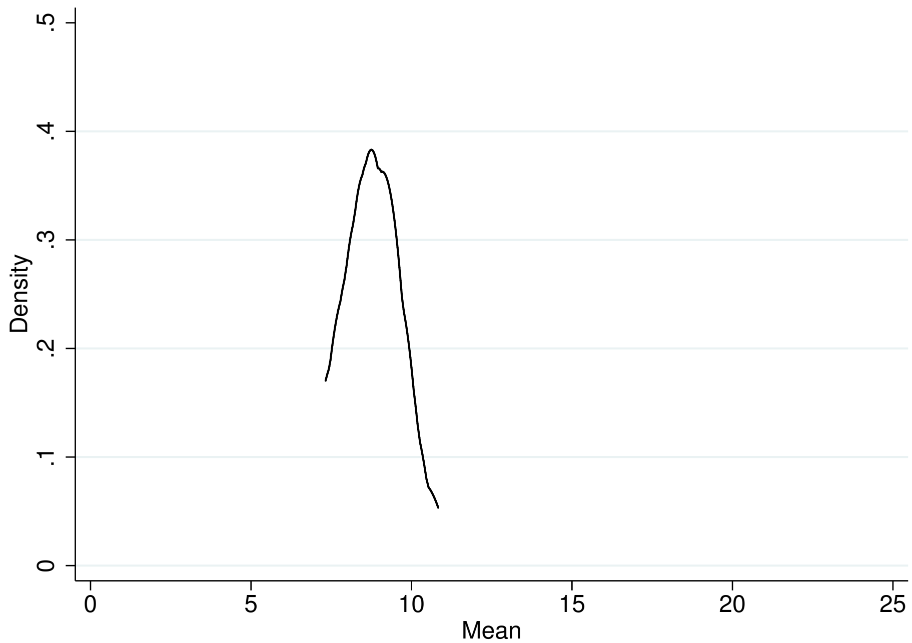
Appendix

Figure 9: Conformity of Industry-level Turkish (no-tax) imports with Benford's law

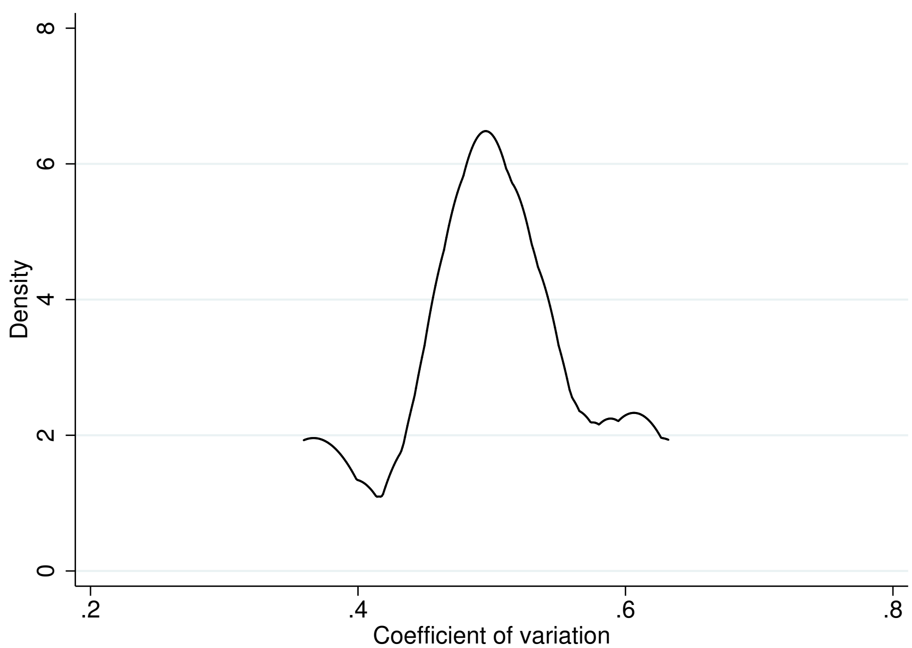


Notes: The figure shows the distribution of the χ^2 goodness-of-fit test statistic values for the observed imports data before the RUSF shock for three industry categories. Data only cover flows that are not subject to tariffs or RUSF. For each country and industry category, the test statistic is calculated using transaction-level trade data using the following formula: $N \sum_{d=1}^{9} \frac{(f_d - \hat{f}_d)^2}{f_d}$, where $\hat{f}_d$ is the fraction of digit d in the data and f_d is the fraction predicted by Benford's law. To reduce the influence of N on the test statistic, random samples of size 250 are drawn for each country. The test statistic converges to a χ^2 distribution with eight degrees of freedom as $N \to \infty$. The corresponding 10%, 5% and 1% critical values are 13.4, 15.5, and 20.1.

Figure 10: Conformity of Turkish (no-tax) imports with Benford's law: Variation across industries



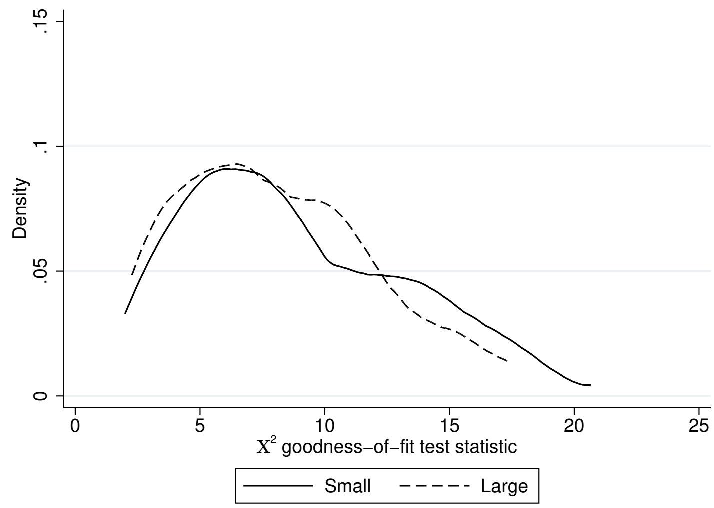
Panel A: Mean of χ^2 test statistic



Panel B: Coefficient of variation of χ^2 test statistic

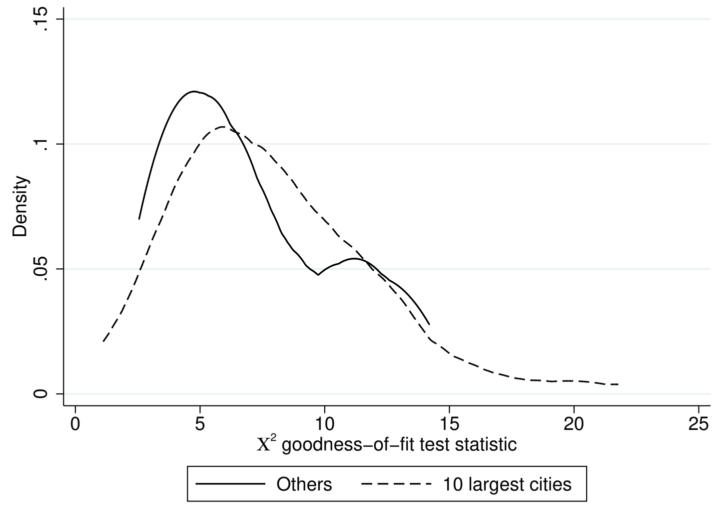
Notes: The figures show the distribution of the mean (panel A) and coefficient of variation (panel B) of the country-level χ^2 goodness-of-fit test statistic for the observed imports data before the RUSF shock across 2-digit HS product codes. Data only cover flows that are not subject to tariffs or RUSF. For each pair of country and 2-digit product code, the test statistic is calculated using transaction-level trade data using the following formula: $N \sum_{d=1}^{9} \frac{(f_d - \hat{f}_d)^2}{f_d}$, where $\hat{f}_d$ is the fraction of digit d in the data and f_d is the fraction predicted by Benford's law. To reduce the influence of N on the test statistic, random samples of size 250 are drawn for each country. The test statistic converges to a χ^2 distribution with eight degrees of freedom as $N \to \infty$. The corresponding 10%, 5% and 1% critical values are 13.4, 15.5, and 20.1.

Figure 11: Conformity of Turkish (no-tax) imports with Benford's law: Large versus small importers



Notes: The figure shows the distribution of the χ^2 goodness-of-fit test statistic values for the observed imports data before the RUSF shock. Data only cover flows that are not subject to tariffs or RUSF. Solid line shows the distribution for importers below the median size threshold, and dashed line shows the distribution for those below the median size threshold, where size is measured by employment. For each country and firm size category, the test statistic is calculated using transaction-level trade data using the following formula: $N \sum_{d=1}^{9} \frac{(f_d - \hat{f}_d)^2}{f_d}$, where $\hat{f}_d$ is the fraction of digit d in the data and f_d is the fraction predicted by Benford's law. To reduce the influence of N on the test statistic, random samples of size 500 are drawn for each country. The test statistic converges to a χ^2 distribution with eight degrees of freedom as $N \to \infty$. The corresponding 10%, 5% and 1% critical values are 13.4, 15.5, and 20.1. The difference in the mean value of the test statistic between the two distributions is 0.69 (0.87).

Figure 12: Conformity of Turkish (no-tax) imports with Benford's law: Large versus small cities



Notes: The figure shows the distribution of the χ^2 goodness-of-fit test statistic values for the observed imports data before the RUSF shock. Data only cover flows that are not subject to tariffs or RUSF. Solid line shows the distribution for importers located in the top-10 largest Turkish provinces in terms of population, and dashed line shows the distribution for those located in other provinces. The top-10 largest provinces are Istanbul, Ankara, Izmir, Bursa, Antalya, Adana, Konya, Gaziantep, Sanliurfa, and Mersin. For each country and province group, the test statistic is calculated using transaction-level trade data using the following formula: $N \sum_{d=1}^{9} \frac{(f_d - \hat{f}_d)^2}{f_d}$, where $\hat{f}_d$ is the fraction of digit d in the data and f_d is the fraction predicted by Benford's law. To reduce the influence of N on the test statistic, random samples of size 500 are drawn for each country. The test statistic converges to a χ^2 distribution with eight degrees of freedom as $N \rightarrow \infty$. The corresponding 10%, 5% and 1% critical values are 13.4, 15.5, and 20.1. The difference in the mean value of the test statistic between the two distributions is -0.99 (0.93).