Forensics, Elasticities and Benford's Law: Detecting Tax Fraud in International Trade

Banu Demir
Bilkent U. and CEPR

Beata Javorcik
Oxford and CEPR

January 2018

Motivation

- Tax evasion is associated with efficiency costs and leads to fiscal losses.
- Taxes collected by Customs account for about 30% of total tax revenues across all countries (World Customs Organization, 2015).
- Yet customs evasion, as other types of tax evasion, is difficult to observe.

This paper

- Proposes two novel methods for detecting evasion of border taxes:
  - applying Benford's Law
  - comparing price and trade cost elasticities
- Shows evidence consistent with an increase in evasion after an unexpected increase in import taxes in Turkey.
- Shows that evasion induces a bias in the estimation of trade cost elasticity of import demand, leading to miscalculation of gains from trade based on standard welfare formulations.
- Shows theoretically the implications of evasion for welfare in the context of a simple Armington trade model.

This paper

- Proposes two novel methods for detecting evasion of border taxes:
  - applying Benford's Law
  - comparing price and trade cost elasticities
- Shows evidence consistent with an increase in evasion after an unexpected increase in import taxes in Turkey.
- Shows that evasion induces a bias in the estimation of trade cost elasticity of import demand, leading to miscalculation of gains from trade based on standard welfare formulations.
- Shows theoretically the implications of evasion for welfare in the context of a simple Armington trade model.

This paper

- Proposes two novel methods for detecting evasion of border taxes:
  - applying Benford's Law
  - comparing price and trade cost elasticities
- Shows evidence consistent with an increase in evasion after an unexpected increase in import taxes in Turkey.
- Shows that evasion induces a bias in the estimation of trade cost elasticity of import demand, leading to miscalculation of gains from trade based on standard welfare formulations.
- Shows theoretically the implications of evasion for welfare in the context of a simple Armington trade model.

Outline of the talk

- Policy context
- Evidence based on the "missing trade" approach of Fisman and Wei (2004, *JPE*).
- Detecting evasion using Benford's Law
- Detecting evasion by comparing price and trade cost elasticities

The policy context

- Resource Utilization Support Fund (RUSF) is a tax collected since 1988 when foreign credit is utilized to finance the cost of imported goods.
- It aims to "regulate foreign trade for the benefit of the economy of the country" as stated in the Article 167 of the Turkish Constitution.
- Only imports with external financing are subject to RUSF.
- RUSF applies to ordinary imports (processing imports have always been exempted).
- **On 13 October 2011, RUSF was *unexpectedly* raised from 3% to 6% of transaction value.**

The policy context

- Resource Utilization Support Fund (RUSF) is a tax collected since 1988 when foreign credit is utilized to finance the cost of imported goods.
- It aims to "regulate foreign trade for the benefit of the economy of the country" as stated in the Article 167 of the Turkish Constitution.
- Only imports with external financing are subject to RUSF.
- RUSF applies to ordinary imports (processing imports have always been exempted).
- **On 13 October 2011, RUSF was *unexpectedly* raised from 3% to 6% of transaction value.**

The policy context

- Resource Utilization Support Fund (RUSF) is a tax collected since 1988 when foreign credit is utilized to finance the cost of imported goods.
- It aims to "regulate foreign trade for the benefit of the economy of the country" as stated in the Article 167 of the Turkish Constitution.
- Only imports with external financing are subject to RUSF.
- RUSF applies to ordinary imports (processing imports have always been exempted).
- **On 13 October 2011, RUSF was *unexpectedly* raised from 3% to 6% of transaction value.**

The policy context

- Resource Utilization Support Fund (RUSF) is a tax collected since 1988 when foreign credit is utilized to finance the cost of imported goods.
- It aims to "regulate foreign trade for the benefit of the economy of the country" as stated in the Article 167 of the Turkish Constitution.
- Only imports with external financing are subject to RUSF.
- RUSF applies to ordinary imports (processing imports have always been exempted).
- **On 13 October 2011, RUSF was *unexpectedly* raised from 3% to 6% of transaction value.**

The policy context

- Resource Utilization Support Fund (RUSF) is a tax collected since 1988 when foreign credit is utilized to finance the cost of imported goods.
- It aims to "regulate foreign trade for the benefit of the economy of the country" as stated in the Article 167 of the Turkish Constitution.
- Only imports with external financing are subject to RUSF.
- RUSF applies to ordinary imports (processing imports have always been exempted).
- **On 13 October 2011, RUSF was *unexpectedly* raised from 3% to 6% of transaction value.**

Payment methods NOT subject to RUSF

- **Cash in advance (CIA)**: importer pre-pays and receives the goods later.
- **Standard letter of credit (LC)**: payment is guaranteed by the importer's bank provided that delivery conditions specified in the contract have been met.
- **Documentary collection (DC)**: involves bank intermediation without payment guarantee.

Payment methods NOT subject to RUSF

- **Cash in advance (CIA)**: importer pre-pays and receives the goods later.
- **Standard letter of credit (LC)**: payment is guaranteed by the importer's bank provided that delivery conditions specified in the contract have been met.
- **Documentary collection (DC)**: involves bank intermediation without payment guarantee.

Payment methods **NOT** subject to RUSF

- **Cash in advance (CIA)**: importer pre-pays and receives the goods later.
- **Standard letter of credit (LC)**: payment is guaranteed by the importer's bank provided that delivery conditions specified in the contract have been met.
- **Documentary collection (DC)**: involves bank intermediation without payment guarantee.

Payment methods subject to RUSF

- **Open account (OA)**: payment is due after goods are delivered in the destination (usually 30 to 90 days).

- **Acceptance credit (AC)**: a type of LC that is payable in full to a beneficiary at a later time, as specified by the time draft, after the submission of the documents.

- **Deferred-payment letter of credit (DLC)**: a type of LC that delays payment for a specified amount of time after shipment or submission of the documents. Time drafts are not required for this type of letters of credit.

Customs form

Payment methods subject to RUSF

- **Open account (OA)**: payment is due after goods are delivered in the destination (usually 30 to 90 days).
- **Acceptance credit (AC)**: a type of LC that is payable in full to a beneficiary at a later time, as specified by the time draft, after the submission of the documents.
- **Deferred-payment letter of credit (DLC)**: a type of LC that delays payment for a specified amount of time after shipment or submission of the documents. Time drafts are not required for this type of letters of credit.

Customs form

Payment methods subject to RUSF

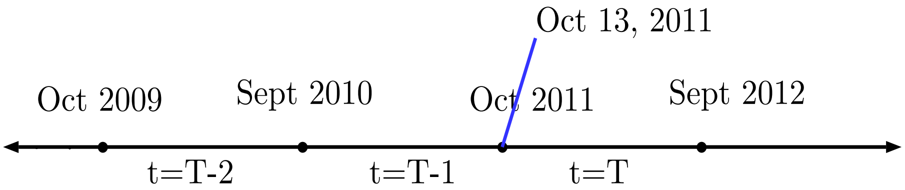
- **Open account (OA)**: payment is due after goods are delivered in the destination (usually 30 to 90 days).

- **Acceptance credit (AC)**: a type of LC that is payable in full to a beneficiary at a later time, as specified by the time draft, after the submission of the documents.

- **Deferred-payment letter of credit (DLC)**: a type of LC that delays payment for a specified amount of time after shipment or submission of the documents. Time drafts are not required for this type of letters of credit.

Customs form

Timing



Measuring exposure to the shock

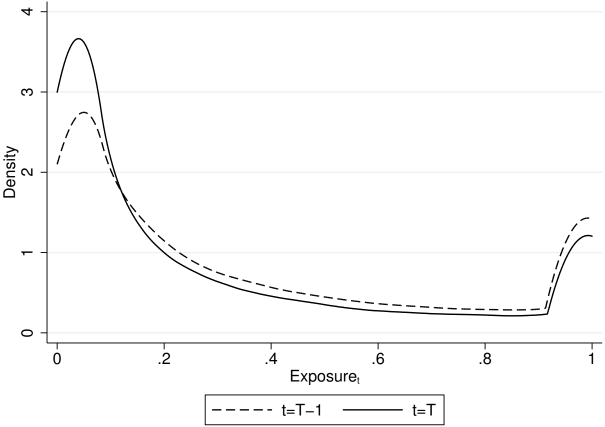
- Construct *Exposure* using monthly value of Turkey's ordinary imports in USD disaggregated by
  - importing firm,
  - 6-digit HS product,
  - source country,
  - payment method (e.g. CIA, OA, LC, etc.).
- Define the share of annualized imports of product h from country c coming with external financing at time $t = \{T-2, T-1, T\}$.

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

- *Exposure* constructed for about
  - 150 source countries (all of them members of WTO),
  - 4,700 6-digit HS product codes,
  - 75,000 country-product pairs.

Share of ordinary imports with external financing (hc level)

$\overline{Exposure}_{hc,t=T-1} = 0.195$; $\overline{Exposure}_{hc,t=T} = 0.137$



Evidence based on the "missing trade" approach of Fisman and Wei (2004)

Evasion gap

- Consider Turkey's imports of product h from country c at time t

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

- $\ln X^{c}_{hct}$ is logarithm of country c's exports of product h to Turkey as reported by c.
- $\ln M^{TUR}_{hct}$ is the logarithm of imports of h from c as reported by Turkey.
- COMTRADE data on imports of 4,295 products from 98 countries
- As import statistics include freight and insurance charges, we expect $MissingTrade < 0$.

Evasion gap

- Consider Turkey's imports of product h from country c at time t

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

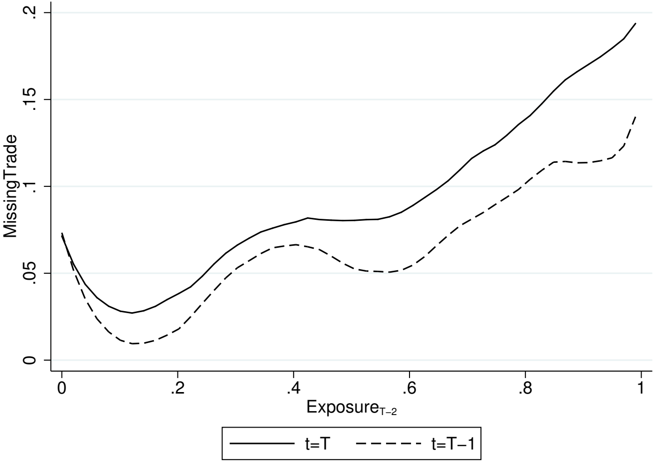
- $\ln X^{c}_{hct}$ is logarithm of country c's exports of product h to Turkey as reported by c.

- $\ln M^{TUR}_{hct}$ is the logarithm of imports of h from c as reported by Turkey.

- COMTRADE data on imports of 4,295 products from 98 countries

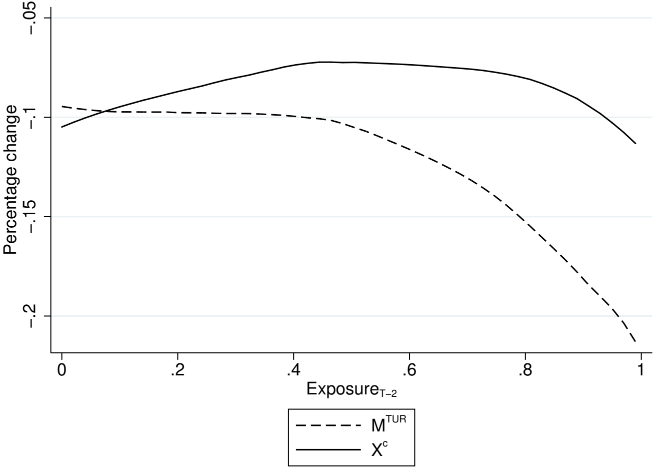
- As import statistics include freight and insurance charges, we expect $MissingTrade < 0$.

Missing trade and exposure



Notes: Figure shows $MissingTrade$ at time T and $T-1$ as a function of $Exposure$ constructed for $T-2$ at the country-product level. The figure is obtained from local polynomial regressions with Epanechnikov kernel.

Change in imports and exposure at $t = T$



Notes: Figure shows Turkey's imports, as reported by Turkey and source countries, at time T and $T-1$ as a function of *Exposure* constructed for $T-2$ at the country-product level. The figure is obtained from local polynomial regressions with Epanechnikov kernel.

Estimating equation

- Estimate:

$$
\begin{aligned}
MissingTrade_{hct} &= \gamma_0 + \gamma_1 1\{t = T\} * Exposure_{hc,T-2} \\
&+ \alpha_{ht} + \alpha_{ct} + \alpha_{hc} + \varepsilon_{hct}
\end{aligned}
$$

- Include three periods: $t = \{T-2, T-1, T\}$.
- $Exposure_{hc,t=T-2}$ is share of imports of product p from country c coming with external financing at time $t = T-2$.
- $\gamma_1 > 0$ consistent with an increase in tax evasion after the hike in the RUSF tax rate in October 2011.

Results consistent with an increase in evasion

$$\begin{aligned} MissingTrade_{hct} &= \gamma_0 + \gamma_1 1\{t = T\} * Exposure_{hc,T-2} \\ &+ \alpha_{ht} + \alpha_{ct} + \alpha_{hc} + \varepsilon_{hct} \end{aligned}$$

	(1)
MissingTrade in	Value
$1\{t = T\} * Exposure_{hc,T-2}$	**0.062****
	(0.028)
N	70089
R^2	0.812
Fixed effects	hxt,cxt,hxc

Notes: *, **, *** represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors are clustered at the country and 4-digit HS product level.

Magnitudes

At the mean value of the gap (in value) at $t = T - 1$, increasing $Exposure$ from zero to one triples $MissingTrade$ after the hike in the RUSF.

▸ Summary stats

Misreporting quantities or prices?

	(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
$1\{t = T\} * Exposure_{hc,T-2}$	**0.064***	0.014	**0.050****
	(0.034)	(0.042)	(0.025)
$1\{t = T - 1\} * Exposure_{hc,T-2}$	0.005	-0.016	0.021
	(0.030)	(0.038)	(0.024)
N	70089	70089	70089
R^2	0.812	0.788	0.711
Fixed effects	hxt,cxt,hxc	hxt,cxt,hxc	hxt,cxt,hxc

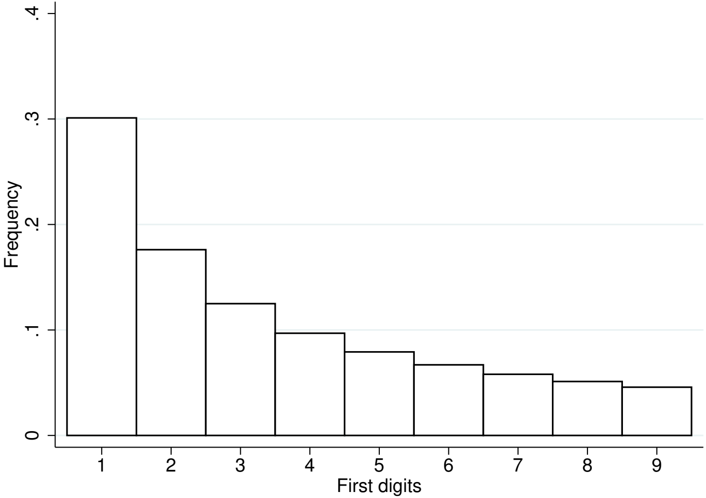
Notes: *, **, *** represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors are clustered at the country and 4-digit HS product level.

▸ Placebo ▸ Non-linear

Using Benford's Law to Detect Evasion

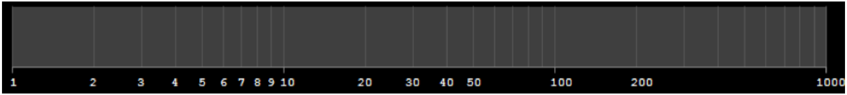
Benford's distribution of first digits

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



Why does it work?

- Consider a line of one unit in length.
- Assume it grows continuously.
- It has to double in length before the leading digit of its length to change from one to two; i.e. length will be $1.x$ during this time period.
- Once its length reaches two, it only needs to grow 50% for the leading digit to change from 2 to 3.
- The following figure generalizes the idea.



Benford's law

- Benford's law describes the distribution of first digits in economic or accounting data
- It naturally arises when data are generated by an exponential process or independent processes are pooled together.
- Deviations from Benford's distribution have been used to detect reporting irregularities in macroeconomic data (Michalski and Stoltz (2013,*REStat*)) and survey data (Judge and Schechter (2009,*JHR*)).

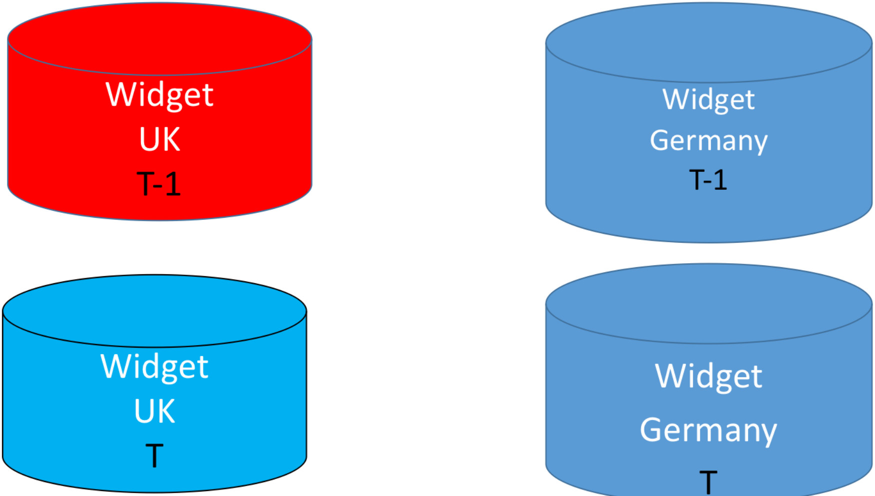
Why do we expect it to hold in our data?

- "Second-generation" distributions, i.e. combinations of other distributions, conform with Benford's law, e.g. quantity x price (Hill (1995,*StatSci*)).
- Distributions where mean is greater than median, and skew is positive (Durtschi et al. (2004,*JFA*)).
- A χ^2 test can't reject that the law holds in our data prior to the shock and post-shock for the flows not subject to the tax

Does it hold in our data? Does it hold in UNCOMTRADE data?

Measuring deviations from Benford's law

Sort observations into bins (hct)



Measuring deviations from Benford's law

Firm 1 importing 1000 widgets from UK on OA in Jan 2011
Firm 1 importing 3000 widgets from UK on OA in Dec 2010
Firm 1 importing 4500 widgets from UK on DLC in Dec 2010
Firm 2 importing 50 widgets from UK on OA in Feb 2011
Firm 2 importing 80 widgets from UK on OA in April 2011

Measuring deviations from Benford's law

Measuring deviations from Benford's law

Measuring deviations from Benford's law

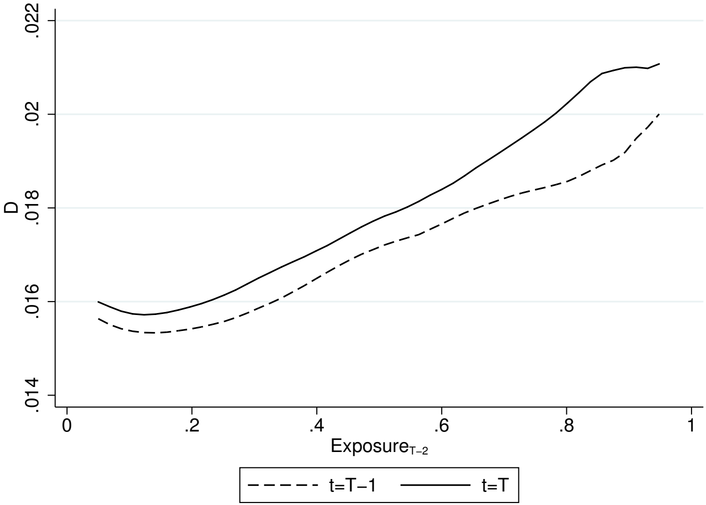
- Use monthly firm-product-country-payment-method level Turkish import data.
- For each hc pair, count the number of first digits at time t and calculate respective frequencies, f^d_{hct}.
- Only keep hc pairs with $n > 30$.

- Follow Cho and Gaines (2007,*Am Stat*) and Judge and Schechter (2009,*JHR*) to calculate deviation from the law:

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

  - $\hat{f}_d$: observed fraction of digit d in the data
  - f_d: fraction predicted by Benford law

Deviations from Benford's law and exposure



Notes: Figure is obtained from local polynomial regression with Epanechnikov kernel of D.

Estimating equation

- Construct D_{hct} and estimate:

$$\begin{aligned} D_{hct} &= \theta_0 + \theta_1 1\{t = T\} * Exposure_{hc,T-2} \\ &+ \alpha_{ht} + \alpha_{ct} + \alpha_{hc} + e_{hct} \end{aligned}$$

- $\theta_1 > 0$ consistent with an increase in tax evasion after the hike in the RUSF tax rate in October 2011.

	Baseline
$1\{t = T\} * Exposure_{hc,T-2}$	**0.00286*****
	(0.00107)
N	26369
R^2	0.645
Fixed effects	hxt,cxt,hxc
Cluster	cxHS4

Notes: *, **, *** represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors are clustered at the country and 4-digit HS product level.

	Baseline	Pre-existing trends	Processing
$1\{t = T\} * Exposure_{hc,T-2}$	**0.00286*****	**0.00228***	0.0000811
	(0.00107)	(0.00137)	(0.000719)
$1\{t = T - 1\} * Exposure_{hc,T-2}$		-0.000970	
		(0.00130)	
N	26369	26369	12468
R^2	0.645	0.766	0.798
Fixed effects	hxt,cxt,hxc	hxt,cxt,hxc	hxt,cxt,hxc
Cluster	cxHS4	cxHS4	cxHS4

Notes: *, **, *** represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors are clustered at the country and 4-digit HS product level.

Magnitudes

At the mean value of D at $t = T - 1$, increasing $Exposure$ from zero to one increases the deviation from Benford's Law by 17% after the tax increase. ▸ Summary stats

A thought experiment

- Consider a random sample with characteristics similar to an average bin in our sample before the shock. e.g. $D = 0.0172$.
- Add "faked" observations: each digit occurring with equal probability.
- What is the fraction of "faked" observations required to generate the estimated increase in D due to an increase in $Exposure$ from zero to one?
- **About 40%!**

A thought experiment

- Consider a random sample with characteristics similar to an average bin in our sample before the shock. e.g. $D = 0.0172$.
- Add "faked" observations: each digit occurring with equal probability.
- What is the fraction of "faked" observations required to generate the estimated increase in D due to an increase in $Exposure$ from zero to one?
- **About 40%!**

Robustness check: second-digit test

- We also test the deviation of the joint distribution of the leading two digits from the predicted distribution by Benford law which is given by:

$$Prob(D_1 = d_1, D_2 = d_2) = log_{10}\left[1 + \left(\sum_{i=1}^{2} d_i * 10^{2-i}\right)^{-1}\right],$$

  where $d_1 \in \{1, 2, ..., 9\}$ and $d_2 \in \{0, 1, 2, ..., 9\}$

- Construct deviations of the observed distribution from the predicted distribution as before and estimate:

$$\begin{aligned} D^{2dig}_{hct} &= \beta_0 + \beta_1 1\{t = T\} * Exposure_{hc,T-2} \\ &+ \alpha_{ht} + \alpha_{ct} + \alpha_{hc} + \varepsilon_{hct} \end{aligned}$$

Robustness check: second-digit test

- We also test the deviation of the joint distribution of the leading two digits from the predicted distribution by Benford law which is given by:

$$Prob(D_1 = d_1, D_2 = d_2) = log_{10}\left[1 + \left(\sum_{i=1}^{2} d_i * 10^{2-i}\right)^{-1}\right],$$

  where $d_1 \in \{1, 2, ..., 9\}$ and $d_2 \in \{0, 1, 2, ..., 9\}$

- Construct deviations of the observed distribution from the predicted distribution as before and estimate:

$$\begin{aligned} D^{2dig}_{hct} &= \beta_0 + \beta_1 1\{t = T\} * Exposure_{hc,T-2} \\ &+ \alpha_{ht} + \alpha_{ct} + \alpha_{hc} + \varepsilon_{hct} \end{aligned}$$

	Baseline	Pre-existing trends	Processing	First two digits
$1\{t=T\} * Exposure_{hc,T-2}$	**0.00286*****	**0.00228***	0.0000811	**0.00069***
	(0.00107)	(0.00137)	(0.000719)	(0.00037)
$1\{t=T-1\} * Exposure_{hc,T-2}$		-0.000970		
		(0.00130)		
N	26369	26369	12468	26369
R^2	0.645	0.766	0.798	0.882
Fixed effects	hxt,cxt,hxc	hxt,cxt,hxc	hxt,cxt,hxc	hxt,cxt,hxc
Cluster	cxHS4	cxHS4	cxHS4	cxHS4

Notes: *, **, *** represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors are clustered at the country and 4-digit HS product level.

Alternative placebo test

- Generate a synthetic import series for $t = T$ assuming that change in imports is proportional to $Exposure_{hc,T-2}$, e.g. $-0.1 * Exposure_{hc,T-2}$
- Construct D_{hct} using
  - monthly firm-product-country-financing term level imports (Baseline)
  - monthly firm-product-country-financing term level imports but replacing data for $t = 2012$ with the synthetic data (Scaled)
- We expect no increase in deviations from Benford's distribution for the scaled series.

	Baseline	Scaled
$1\{t = T\} * Exposure_{hc,T-2}$	**0.00228***	**-0.0112*****
	(0.00137)	(0.00284)
$1\{t = T-1\} * Exposure_{hc,T-2}$	-0.000970	0.000758
	(0.00130)	(0.00152)
N	26369	26369
R^2	0.645	0.690
Fixed effects	hxt,cxt,hxc	hxt,cxt,hxc
Cluster	cxHS4	cxHS4

Notes: *, **, *** represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors are clustered at the country and 4-digit HS product level.

Conclusions

- We propose two new methods of detecting tax evasion based on
  - applying Benford's Law
  - comparing price and trade cost elasticities
- We exploit an unexpected policy change that increased the cost of import financing in Turkey and show evidence consistent with increasing evasion.
- The "missing trade" approach of Fisman and Wei (2004, *JPE*) confirms these conclusions.
- Ignoring evasion leads to a miscalculation of welfare changes from changes in taxes.

Detecting evasion by comparing price and trade cost elasticities

A stylized model

- Does tax evasion affect the elasticity of trade flows with respect to trade frictions and welfare?

- A simple Armington model of international trade with $n+1$ countries, indexed by c.
- Turkey is the home country ($c = 0$).
- Goods are differentiated by country of origin.
- Demand side: consumer preferences represented by a standard CES utility function.
- Two types of trade frictions:
  - Transport costs take the iceberg form: $t_c > 1$.
  - Policy-induced costs take the ad-valorem form and borne by consumers: $\tau > 1$.

A stylized model

- Does tax evasion affect the elasticity of trade flows with respect to trade frictions and welfare?

- A simple Armington model of international trade with $n+1$ countries, indexed by c.
- Turkey is the home country ($c = 0$).
- Goods are differentiated by country of origin.
- Demand side: consumer preferences represented by a standard CES utility function.
- Two types of trade frictions:
  - Transport costs take the iceberg form: $t_c > 1$.
  - Policy-induced costs take the ad-valorem form and borne by consumers: $\tau > 1$.

Financing imports

- There is a continuum of consumers in the home country.
- Consumers have identical preferences over goods.
- When they import, consumers choose between paying immediately and delaying payment (external financing).
- By paying immediately, consumer k incurs a liquidity cost, $r_k > 1$ but saves τ.
- 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 $G(r)$.

Tax evasion

- To evade taxes, consumers choosing delayed payment may misreport prices—consistent with empirical evidence presented earlier.
- p_c denotes the true price including transport costs.
- But consumers may report $(1-\alpha)p_c$, where $\alpha \in [0, 1)$.
- Evading taxes is costly. Evasion cost is proportional to the price and quadratic in α : $[(\gamma/2)\alpha^2]p_c$.
- With probability θ, 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, $f > \tau$

Choice of financing

- Cost of importing when consumer k
  - pays immediately is $r_k p_c$
  - delays payment is τp_c
- With tax evasion, expected cost becomes $\tau^e p_c = [1 + (1-\alpha)(\tau - 1) + (\gamma/2)\alpha^2 + \theta\alpha f]p_c$
- Consumers choose α to minimize expected tax payments. At an interior solution, it yields:

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

- $\alpha^* \uparrow$ as $\tau \uparrow$ or $\gamma, \theta, f \downarrow$

Choice of financing

- Cost of importing when consumer k
  - pays immediately is $r_k p_c$
  - delays payment is τp_c
- With tax evasion, expected cost becomes
  $\tau^e p_c = [1 + (1-\alpha)(\tau - 1) + (\gamma/2)\alpha^2 + \theta\alpha f]p_c$
- Consumers choose α to minimize expected tax payments. At an interior solution, it yields:

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

- $\alpha^* \uparrow$ as $\tau \uparrow$ or $\gamma, \theta, f \downarrow$

Fraction of imports with external financing ($Exposure$)

- Define 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 defer payment.
- Define the share of imports from origin country c with external financing as:

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

Result

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

Proof

Trade elasticity

Result

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

- (Logarithm of) import demand with external financing is:

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

- $\ln \tau^e$ is not observed but instead $\ln \tau$ is observed:

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

- **In the presence of evasion** $\epsilon^{\tau} > \sigma$ since $Cov\left(\ln \tau, \ln\left(1 - \frac{(\tau-1-\theta f)^2}{2\gamma\tau}\right)\right) > 0$.

Trade elasticity

Result

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

- (Logarithm of) import demand with external financing is:

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

- $\ln \tau^e$ is not observed but instead $\ln \tau$ is observed:

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

- **In the presence of evasion** $\epsilon^\tau > \sigma$ since $Cov\left(\ln \tau, \ln\left(1 - \frac{(\tau-1-\theta f)^2}{2\gamma\tau}\right)\right) > 0$.

Estimating trade elasticity

- Estimating equation:

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

  where i indexes firms.

- δ_{hct} absorbs $\ln\left(yP^{\sigma-1}\right)$ in the import demand equation.
- ht captures changes in product-level prices over time.
- it captures time-varying firm-level shocks, including shocks to access to financing.
- 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 is given by σ.
- A positive estimate obtained for β_3 would be consistent with significant evasion after the policy change.

Estimating trade elasticity

- Estimating equation:

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

  where i indexes firms.

- δ_{hct} absorbs $\ln\left(yP^{\sigma-1}\right)$ in the import demand equation.
- ht captures changes in product-level prices over time.
- it captures time-varying firm-level shocks, including shocks to access to financing.
- 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 is given by σ.
- A positive estimate obtained for β_3 would be consistent with significant evasion after the policy change.

Empirical challenge

- Classical challenge faced when estimating demand: price is endogenous.
- Instrument p_{ihcmt} with $\ln Distance_{ic}$ – log 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.
- Instrument captures variation in transport costs, which affects the quantity demanded only through its effect on cif prices.

Elasticity estimation

	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		
Fixed effects	hxcxt,ixt	hxcxt,ixt	hxcxt,ixt
F-stat. $\beta_1 = \beta_2$	8.903***	0.0144	0.154
KP test stat		14.08	
CD test stat			11.94

Notes: *, **, *** represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors are clustered at the country and 4-digit HS product level. In the last column, $1\{t = T\} * \ln p_{ihcmt}$ is instrumented with $1\{t = T\} * \ln Distance_{ic}$

Elasticity and welfare calculation with evasion

- We fail to reject equality of price and tax elasticities before the increase in RUSF rate.
- $\beta_3 > 0$ is consistent with greater evasion after the tax increase.
- Ignoring tax evasion leads to an overestimation of welfare changes from changes in taxes.
- Consider the standard welfare formula in ACR:

$$\hat{W} = \hat{\lambda}^{1/\epsilon}$$

  where λ denotes the domestic expenditure share.
- Welfare change after the increase in RUSF rate using ϵ^{τ}
  - w/o evasion is $\Delta W = (0.728/0.719)^{-1/2.181} \approx -0.6\%$
  - w/ evasion is $\Delta W^{e} = (0.728/0.719)^{-1/0.378} \approx -3.2\%$

Elasticity and welfare calculation with evasion

- We fail to reject equality of price and tax elasticities before the increase in RUSF rate.
- $\beta_3 > 0$ is consistent with greater evasion after the tax increase.
- Ignoring tax evasion leads to an overestimation of welfare changes from changes in taxes.
- Consider the standard welfare formula in ACR:

$$\hat{W} = \hat{\lambda}^{1/\epsilon}$$

  where λ denotes the domestic expenditure share.
- Welfare change after the increase in RUSF rate using ϵ^{τ}
  - w/o evasion is $\Delta W = (0.728/0.719)^{-1/2.181} \approx -0.6\%$
  - w/ evasion is $\Delta W^{e} = (0.728/0.719)^{-1/0.378} \approx -3.2\%$

Welfare

- Let $\tau < \underline{r}$, so that $Exposure = 1$
- Money spent on cost of evading taxes is wasted but tariff revenues are redistributed to consumers as a lump-sum transfer.
- Tax-inclusive expenditures on goods imported by Turkey from country c:

$$x_c = q_c(\tau^e p_c) = Y_0 P_0^{\sigma-1}(p_c \tau^e)^{1-\sigma}$$

- Total expenditures in the home country:

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

where $x_0 = Y_0 P_0^{\sigma-1} p_0^{1-\sigma}$.
- Tariff revenues are:

$$T_0 = (1-\alpha^*)(\tau-1)\sum_{c=1}^{n}\frac{x_c}{\tau^e} = \frac{(1-\alpha^*)(\tau-1)}{\tau^e}(1-\lambda_0)X_0$$

where $\lambda_0 = x_0/X_0$.

- Total expenditures should be equal to total income:

$$X_0 = w_0 L_0 + T_0 = \mu_0 w_0 L_0$$

where $\mu_0 = \left(1 - \frac{(1-\alpha^*)(\tau-1)}{\tau^e}(1-\lambda_0)\right)^{-1}$ is a tax multiplier

- Per capita welfare is:

$$W_0^e = \mu_0 \lambda_0^{\frac{1}{1-\sigma}} \underbrace{\frac{\mu_0^e}{\mu_0}}_{\gtrless 1} \underbrace{\left(\frac{\lambda_0^e}{\lambda_0}\right)^{\frac{1}{1-\sigma}}}_{>1},$$

where (μ_0, λ_0) and (μ_0^e, λ_0^e) denote tax multiplier and domestic expenditure share without and with evasion.

- Evasion affects welfare through two channels:
  - unambiguously reinforces gains from trade by lowering the relative price of foreign goods, and thus decreasing λ_0
  - has an ambiguous effect on gains from trade through its effect on μ_0: lower relative price of foreign goods lowers λ_0 while evasion decreases the actual tax rate.

- Total expenditures should be equal to total income:

$$X_0 = w_0 L_0 + T_0 = \mu_0 w_0 L_0$$

  where $\mu_0 = \left(1 - \frac{(1-\alpha^*)(\tau-1)}{\tau^e}(1-\lambda_0)\right)^{-1}$ is a tax multiplier

- Per capita welfare is:

$$W_0^e = \mu_0 \lambda_0^{\frac{1}{1-\sigma}} \underbrace{\frac{\mu_0^e}{\mu_0}}_{\gtrless 1} \underbrace{\left(\frac{\lambda_0^e}{\lambda_0}\right)^{\frac{1}{1-\sigma}}}_{>1},$$

  where (μ_0, λ_0) and (μ_0^e, λ_0^e) denote tax multiplier and domestic expenditure share without and with evasion.

- Evasion affects welfare through two channels:
  - unambiguously reinforces gains from trade by lowering the relative price of foreign goods, and thus decreasing λ_0
  - has an ambiguous effect on gains from trade through its effect on μ_0: lower relative price of foreign goods lowers λ_0 while evasion decreases the actual tax rate.

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

$$= \frac{q(r^*)g(r^*)\frac{dr^*}{d\tau}\int_{r^*}^{\infty} q(\tau)dG(r) - \int_{\underline{r}}^{r^*} q(r)dG(r)\int_{r^*}^{\infty}\frac{dq(\tau)}{d\tau}dG(r)}{\left(\int_{r^*}^{\infty} q(\tau)dG(r)\right)^2}$$

$$\propto q(r^*)g(r^*)\frac{dr^*}{d\tau}\int_{r^*}^{\infty} q(\tau)dG(r) - \int_{\underline{r}}^{r^*} q(r)dG(r)\int_{r^*}^{\infty} yP^{\sigma-1}p_c^{-\sigma}(-\sigma)(\tau^e)^{-\sigma-1}\frac{d\tau^e}{d\tau}dG(r)$$

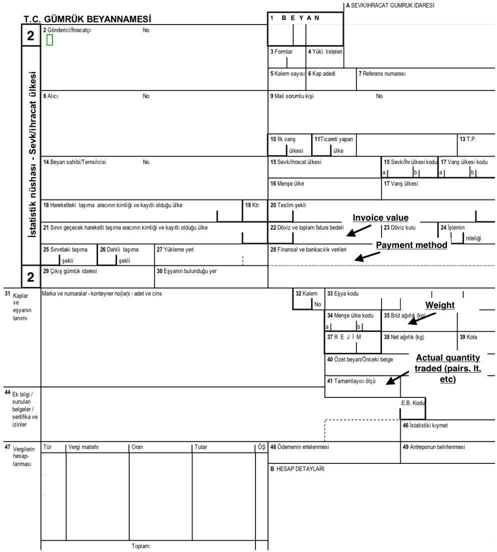
$$= q(r^*)g(r^*)\frac{dr^*}{d\tau}\int_{r^*}^{\infty} q(\tau)dG(r) - \int_{\underline{r}}^{r^*} q(r)dG(r)\int_{r^*}^{\infty} q(\tau)\frac{-\sigma}{\tau^e}\frac{d\tau^e}{d\tau}dG(r)$$

$$= q(r^*)g(r^*)\frac{dr^*}{d\tau}\left(\int_{r^*}^{\infty} q(\tau)dG(r) + \int_{\underline{r}}^{r^*} q(r)dG(r)\right) + \frac{\sigma}{\tau^e}\frac{d\tau^e}{d\tau}\int_{\underline{r}}^{r^*} q(r)dG(r)$$

where $\frac{dr^*}{d\tau} = \frac{d\tau^e}{d\tau} = 1 - \frac{\tau-1-\theta f}{\gamma} = 1 - \alpha^* > 0$. Therefore, $\frac{d(1/Exposure)}{d\tau} > 0 \implies \frac{d(Exposure)}{d\tau} < 0$.

Back

Customs declaration form



Proof of payment method (e.g. bank documents) must also be submitted. Back

Summary statistics for missing trade

	$t = T-2$	$t = T-1$	$t = T$
Missing trade in value	0.014	0.033	0.037
	(1.276)	(1.256)	(1.252)
Missing trade in quantity	0.149	0.184	0.176
	(1.509)	(1.478)	(1.473)
Missing trade in price	-0.135	-0.151	-0.139
	(0.779)	(0.753)	(0.749)

Notes: Table shows mean and standard deviation (in parentheses) of evasion gap measured in terms of import value, quantity, and unit value. Gap is defined as

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

Back

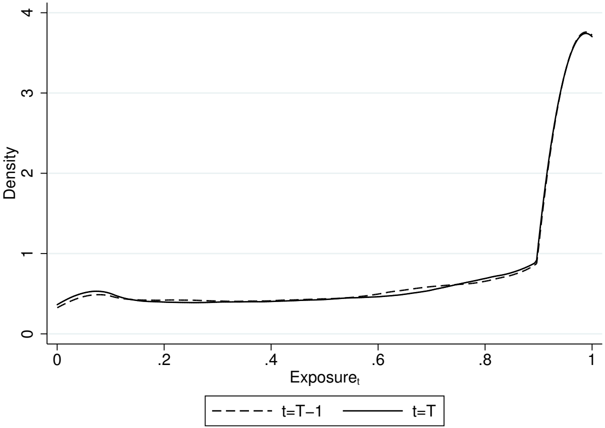
Summary statistics (Benford exercise)

	$t = T-2$	$t = T-1$	$t = T$
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

Back

Placebo: Share of processing imports with external financing (hc level)

$\overline{Exposure}_{hc,t=T-1} = 0.756$; $\overline{Exposure}_{hc,t=T} = 0.755$



▸ Descriptive regressions ▸ DID regressions

Falsification test: *Exposure* constructed using processing imports

	(1)	(2)	(3)
MissingTrade in	Value	Quantity	Price
$1\{t = T\} * Exposure_{hc,T-2}$	0.028	0.000	0.027
	(0.030)	(0.037)	(0.020)
N	23913	23913	23913
R^2	0.858	0.838	0.761
Fixed effects	hxt,cxt,hxc	hxt,cxt,hxc	hxt,cxt,hxc

Notes: *, **, *** represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors are clustered at the country and 4-digit HS product level.

Back

Extension: non-linear effects

	(1)	(2)	(3)
MissingTrade in	Value	Quantity	Price
$1\{t=T\}$			
$*$Bin 2	**0.0546****	0.040	0.014
	(0.021)	(0.026)	(0.015)
$*$Bin 3	**0.072*****	0.026	**0.047*****
	(0.021)	(0.026)	(0.015)
$*$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
Fixed effects	hxt,cxt,hxc	hxt,cxt,hxc	hxt,cxt,hxc
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****

Notes: *, **, *** represent significance at the 10, 5, and 1 percent levels, respectively. Robust standard errors are clustered at the country and 4-digit HS product level.

Back

A first look at the data

$$\begin{aligned} \ln M_{ihcmt} &= \beta_0 + \beta_1 1\Big\{t = T\Big\} * 1\Big\{m = \{OA, AC, DLC\}\Big\} \\ &+ \beta_2 1\Big\{m = \{OA, AC, DLC\}\Big\} + \alpha_{hct} + \alpha_{it} + \epsilon_{ihcmt} \end{aligned}$$

- $\ln M_{ihcmt}$: log of imports by firm i of product h from source country c on payment method m at time t, where $t = \{T-1, T\}$ and T represents the treatment period (*Oct 2011-Sep 2012*).
- $1\Big\{m = \{OA, AC, DLC\}\Big\}$ indicates treated payment methods.
- $1\Big\{t = T\Big\}$ indicates the treatment period $t = T$; it is zero for $t = T - 1$ (*Oct 2010-Sep 2011*).

	(1)	(2)
	Ordinary	Processing
$1\{t = T\} * 1\{m = \{OA, AC, DLC\}\}$	**-0.169*****	0.0101
	(0.0081)	(0.0231)
$1\{m = \{OA, AC, DLC\}\}$	-0.113***	0.477***
	(0.0080)	(0.0203)
N	1820969	98328
R^2	0.470	0.747
FE	hxcxt,ixt	hxcxt,ixt
Cluster	hxc	hxc

Back

Effect on imports

Did imports of firms with a greater initial reliance on external financing decrease in relative terms after the tax increase?

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

- $Exposure_{i,t=T-2}$ is share of firm-level imports with external financing at time $t = T - 2$.
- $s(i)$ is the 4-digit NACE industry where firm i operates.

Back

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

Back

Controlling for potential endogeneity

- $Exposure_{i,t=T-2}$ could reflect selection into particular payment methods.
  - E.g. if firms use RUSF-affected payment terms for larger flows, then δ_1 will be estimated with an upward bias.
- Construct a "Bartik-type" instrument for firm-level exposure to the shock:
  - Calculate exposure for each $l = hc$ product-source country variety that firm i imported at $T-2$, excluding firm i's imports, $Exposure^{-i}_{l,t=T-2}$.
  - Construct a weighted average of variety-specific exposures, with weights ($\omega_{il,t=T-2}$) equal to shares in firm i's imports at time $T-2$:

$$Exposure^{IV}_{i,t=T-2} = \sum_{l \in \Omega_i} Exposure^{-i}_{l,t=T-2} \omega_{il,t=T-2}$$

where

$$Exposure^{-i}_{l,t=T-2} = \frac{\sum_{k \neq i} 1\{m = \{OA, AC, DLC\}\} M_{klm,t=T-2}}{\sum_{k \neq i} M_{kl,t=T-2}}$$

Back

	OLS	Reduced form	First-stage	IV
$1\{t=T\} * Exposure_{i,t=T-2}$	**-0.119****			**-0.591****
	(0.0530)			(0.244)
$1\{t=T\} * Exposure^{IV}_{i,t=T-2}$		**-0.328****	**0.554*****	
		(0.132)	(0.0353)	
N	45818	45818	45818	45818
R^2	0.888	0.888	0.554	
FE	s(i)xt,i	s(i)xt,i	s(i)xt,i	s(i)xt,i
Cluster	s(i)	s(i)	s(i)	s(i)
KP test stat				77.44

Back

Controlling for composition of imports

$$\ln M_{ihct} = \delta_0 + \delta_1 1\{t = T\} * Exposure_{i,t=T-2} + \alpha_{hct} + \alpha_i + e_{ihct}$$

	OLS	IV	IV	OLS(processing)
$1\{t = T\} * Exposure_{i,t=T-2}$	**-0.023***	**-0.082***	**-0.121***	-0.061
	(0.013)	(0.051)	(0.074)	(0.046)
$1\{t = T-1\} * Exposure_{i,t=T-2}$			-0.062	
			(0.066)	
N	2420712	2420712	2420712	102754
R^2	0.454			0.720
FE	hxcxt,i	hxcxt,i	hxcxt,i	hxcxt,i
Cluster	i	i	i	i
KP test stat		333.8	233.4	

Back

Does it hold in our data?

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 χ^2 goodness-of-fit test statistic values for the observed data. 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 χ^2 distribution with eight degrees of freedom as $N \to \infty$. The corresponding 5% and 1% critical values are 15.5, and 20.1. Back

Does it hold in UNCOMTRADE data?

	Exports		Imports	
	Before	After	Before	After
Test statistic	9.052	7.376	13.926	13.334
No. of obs	52128	52128	52128	52128

Notes: Table shows χ^2 goodness-of-fit test statistic values calculated for the country-product-time-level UNCOMTRADE data. 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 χ^2 distribution with eight degrees of freedom as $N \to \infty$. The corresponding 5% and 1% critical values are 15.5, and 20.1. Back

Literature

- **Evasion and abuse of public trust and regulations:** Jacob and Levitt (2003, *QJE*); Marion and Muehlegger (2008, *JPE*); Fang and Gong (2017, *AER*).
- **Tax evasion at borders:** Fisman and Wei (2004, *JPE*); Fisman et al. (2008, *ReStat*); Javorcik and Narciso (2008, *JIE*; 2017, *JDE*); Mishra et al. (2008, *JPubE*); Ferrantino et al. (2012, *JIE*).
- **Trade elasticity and welfare:** ACR (2012, *AER*); Felbermayr et al. (2015, *JIE*); Sequeira (2016, *AER*).