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Fernando Garcia Alvarardo
Antoine Mandel

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The Worldwide Network of Tax Evasion
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GARCIA ALVARADO Fernando*
MANDEL Antoine†

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Abstract

This paper builds on recent insights from network theory and on the rich dataset made available by the Panama Papers in order to investigate the micro-economic dynamics of tax-evasion. We model offshore financial entities documented in the Panama Papers as links between jurisdictions in the global network of tax evasion. A quantitative analysis shows that the resulting network, far from being a random collection of bilateral links, has key features of complex networks such as a core-periphery structure and a fat-tail degree distribution. We argue that these structural features imply that policy must adopt a systemic perspective on the matter. We offer three sets of insights from this perspective. First, we identify through centrality measures tax havens that ought to be priority policy targets. Second, we show that efficient tax treaties must contain exchange information clauses and link tax-havens to non-haven jurisdictions. Third, we show that the optimal deterrence strategies for a social-planner facing a strategic tax-evader in a Stackelberg competition can be characterized using the notion of Bonacich centrality.

JEL: H26, H87, D85, C54

Keywords: Tax Evasion, Socio-economic Networks, Game Theory.

1 Introduction

Curbing tax-evasion has been a permanent issue on the policy agenda ever since the advent of taxation systems. In recent decades, the acceleration and liberalization of financial flows has led to a globalization of the issue whereby tax-evaded wealth circulates through complex chains of jurisdictions and legal entities before finding shelter in tax havens (see e.g. Garcia–Bernardo et al. (2017)). According to Zucman (2014), 8% of the global household income is hence held through entities incorporated in tax havens. This eventually led to a "crackdown on tax havens". In April 2009, G20 countries urged each tax haven to sign at least 12 information exchange treaties under the threat of economic sanctions. Johannesen and Zucman (2014) reported how more than 300 treaties were then signed before the end of 2009. The efficiency

*Ca Foscari University of Venice and Paris 1 Pantheon-Sorbonne. e-mail: fernando.garcia@unive.it

†Paris School of Economics and Paris 1 Pantheon-Sorbonne. e-mail: antoine.mandel@univ-paris1.fr

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of the crackdown has however been questioned. In particular, Johannesen and Zucman (2014) give evidence, using BIS data on cross-border deposits, that the crackdown has led to a mere reallocation of tax-evaded funds. In order to improve upon this state of play, a detailed understanding of the mechanics of tax evasion is required. However, the lack of data and the complex nature of tax evasion schemes have prevented the use of standard micro-economic and microeconometric tools in this perspective. In this paper, we build on recent insights from network theory and on the rich dataset made available by the Panama Papers in order to bridge part of this gap.

The Panama Papers, a leaked dataset that has been made publicly available by the International Consortium of Investigative Journalists (ICIJ) in early 2016, provides information on a set of 213,634 offshore financial entities created by Mossack-Fonseca, one of the leading providers of offshore financial services. Offshore financial entities allow to transfer wealth from a source country, the one of the owner of the entity, to a host country, the one where the entity is registered, in such a way that the identity of the owner is concealed. They can thus be seen as tax-evasion links in a network of countries. Adopting this perspective, we provide a quantitative analysis of the resulting network. This analysis highlights that the network, far from being a random collection of bilateral links, has a hierarchical organization characterized by a core-periphery structure and a fat-tail degree distribution. These structural features indicate that global tax-evasion actually is a complex system (in the sense of e.g. Albert and Barabasi (2002)) and thus that policy must adopt a systemic perspective on the matter.

The paper provides three set of insights from this perspective. First, quantitative phenomenological insights about the most central actors in the global tax evasion network and the preferential attachment features of the network formation process. These can notably be used to identify tax havens that ought to be priority targets of evasion deterrence policy (e.g. building on Albert et al. (2000)). Second, we provide an econometric analysis of the determinants of network formation and of the impact of tax treaties thereupon. Our results are consistent with those of Johannesen and Zucman (2014). In particular, we show that efficient treaties are those that contain an information exchange clause and that link tax-havens to "non-haven" countries. This calls for further refinements of the type of "treaty policy" implemented during the G20 crackdown. Finally, we develop a theoretical model to deliver normative insights on optimal deterrence strategies for a social-planner facing a strategic tax-evader in a Stackelberg competition. Our main formal result in this setting is that the objective of the social planner is equivalent to finding a subgraph maximizing the sum of Bonacich centralities. This result highlights, from another perspective, the need to adopt a systemic perspective on tax evasion as the Bonacich centrality of the network does not depend on local properties of the network but on its global structure. The specific features of the optimal policy also depend on the level of influence the social planner can exert. In this respect, we show that, if his influence potential is low, the social planner shall form quasi-star structures surrounding, successively, each tax-haven with a set of treaties. If his level of influences is relatively large, he shall aim at dismantling directly key connections within the core of the network.

The remaining of the paper is organized as follows. Section 2 reviews the related literature. Section 3 provides an empirical analysis of the global tax evasion network on the basis of the Panama Papers. Section 4 investigates the determinants of network formation and, notably, the impact of treaties. Section 5 provides a formal model of the Stackelberg competition between a representative tax-evader and a social-planner aiming at deterring evasion. Section 6 concludes.

2 Literature Review

The features of tax havens have been extensively studied in the recent literature. In an early contribution, Hines (2007) puts forward a first set of stylized facts. Studying 45 major offshore financial centers, the author mentions that tax havens tend to be small (commonly below 1 million inhabitants), affluent and well-governed. Moreover, such fiscal paradises tend to incentivize economic activity in neighboring non-haven countries. Dharmapala (2008) extends this set of stylized facts, noticing that tax havens are more prone to be island countries, poorly endowed with natural resources, and relatively close to major financial capital exporters. Moreover, most tax havens seem to bear a British legal origin and to account for a highly advanced telecommunication infrastructure. Dharmapala and Hines (2009) perform an econometric study over more than twenty different covariates to define which characteristics make a jurisdiction more or less prone to become a tax haven. The authors find, using probit models, that tax havens tend to have a small population and a large GDP per capita as compared to the world average. Moreover, the governance has a large and statistical significant impact on the probability of a jurisdiction becoming a tax haven. The authors asseverate that only well-governed countries, which may reasonably be seen as trustworthy, qualify as potential tax havens.

A second strand of literature aims to measure the size of tax havens and thus to evaluate their impact on fiscal policy. Zucman (2013) assert that at least 50 percent of all deposits held through tax havens belong to households. Hence tax havens are primarily used as a channel of tax evasion (by households) and not simply as a tool for tax avoidance (by frms). Furthermore, Zucman (2014) estimate that about 8% of the global household income is held through entities incorporated in tax havens, an amount that surges to about 7.6 trillion USD in 2013. Besides, he mentions these coefficients to be a lower bound, which account only for financial wealth and not all types of assets; other sources estimate the amount to be even higher, between 8.9 and 32 trillion US Dollars. Further remarks show an increasing flow of deposits from developing nations, a shrinkage from a large number of small accounts to a reduced amount of affluent 'key-clients' in fiscal paradises and an assumption that about 80% of the wealth held in Switzerland and other havens seems to be evading taxes. Alstadsaeter et al. (2018) conclude that around 10% of the world's GDP is concealed in tax havens, whereas more than 50% of the GDP of certain countries (Russia, the Gulf nations and Latin American countries) is held through offshore financial centers.

A third line of research studies the impact of tax policy on tax havens. Slemrod and Wilson (2009) argue that tax havens are freeloaders for large non-haven economies and do not provide the potential financial incentives other studies (such as Hines and Rice (1994) and Desai et al. (2006)) had implied. The authors suggest that abolishing some, or all, tax havens would increment the welfare in non-haven nations. Moreover, the nullification of even a few large fiscal paradises would leave all other countries better-off, including any of the still remaining tax havens. Indeed, as mentioned by Hines (2010), tax havens are generally pass-through financial locations, where neighboring countries are both the largest sources and destinations of the money flow. The natural experiment induced by the G20 crackdown on tax havens has also generated a substantial literature. As discussed in Picard and Pieretti (2011), offshore financial centers can be persuaded to comply with strict supervision of their funds and shareholders' identities whenever the pressure placed on them poses a sufficiently high risk of damaging their business operations. Johannesen and Zucman (2014) explored how tax treaties between jurisdictions affected the flow of deposits from sources to host countries.

The authors find that whenever a country signed a treaty with a tax haven, there was a reallocation effect, meaning that evaders would shift their deposits to another jurisdiction where no treaty existed. Moreover, the study suggests that tax treaties signed between two tax havens had no statistically significant effects. Accordingly, Braun and Weichenrieder (2015) find that, for German affiliates, TIEA's decreased the number of operations with tax havens by 46 percent. This result sheds light on the importance of secrecy for evaders whenever undertaking operations in fiscal paradises. Related to this, Caruana-Galizia and Caruana-Galizia (2016) studied the effect of the 2005 Tax and Saving Directives. The Savings Directive obliges cooperating jurisdictions to disclose the financial information of entities whose owner is a EU resident. Employing the information leaked in the Panama Papers, the authors find a substitution effect where EU-resident owned entities migrated to non-cooperating jurisdictions; meanwhile, non-EU owned entities remained stable.

Despite this growing literature, the issue of international tax evasion hasn't been investigated from a network perspective. Network approaches have been used to model a wide range of financial systems and the interactions between entities. Iori et al. (2005), Battistion et al. (2011), Chinazzi et al. (2013) and Li and Schurhoff (2019) have analyzed the mechanics of international financial networks, consistently identifying key properties and topological characteristics germane to complex networks. More closely related to our contribution, Garcia–Bernardo et al. (2017) scrutinise corporate tax avoidance networks, through corporate ownership relationships, in order to identify the jurisdictions that work as conduits or final destinations of shifted profits.

The design of efficient policies in such network contexts has also induced a large literature (e.g. Ballester et al. (2006), Bramoulle and Kranton (2007), Allouch (2015), and Elliott and Golub (2019)). In our context, the problem of the social planner amounts to finding a subgraph maximizing the sum of Bonacich centralities. This problem has been addressed in the economic literature, notably by Konig et al. (2014) and Belhaj et al. (2016) who emphasize its connections with nested-split graphs. The problem is also connected to a well-known problem in graph theory, that of finding the graph with a given number of nodes and vertices that has maximal index (see Corbo et al. (2006), and Chand and Tam (2011)). A long-standing conjecture on that problem is that its solutions are either quasi-complete or quasi-star graphs (see Aouchiche et al. (2008) and Cvetkovic et al. (1997) for solutions in some specific cases)

3 Empirical analysis of the global tax evasion network

3.1 Data from the Panama Papers

Our analysis of the global network of tax evasion is based on the Panama papers, a leaked dataset that has been made publicly available by the International Consortium of Investigative Journalists (ICIJ) in early 2016[1]. The dataset documents the activity of Mossack-Fonseca, a Panamian firm that was one of the leading provider of offshore financial services (until the leak). Our working assumption, throughout the paper, is that the activities of Mossack-Fonseca are representative of these of the offshore finance industry. A key part of these activities is the creation of offshore financial entities (shell companies). These entities allow to transfer wealth from a source country, the one of the owner of the company, to an host country, the one where the company is registered and that generally is a tax-haven, in such a way that the identity of

[1]The data is available under https://offshoreleaks.icij.org/pages/database.

the owner is (partly) concealed. An offshore financial entity can thus be seen as a tax-evasion link between two countries.

The Panama Papers provide information on 213,634 offshore financial entities that had been incorporated in different tax havens by Mossack-Fonseca. More precisely, for each entity, the *Entities* file of the Panama papers discloses the name of the registered financial body, the country of the beneficial owner, the jurisdiction where the entity was created, the incorporation date, the company type and the status of the account[2]. Even though the Mossack law firm began operations in 1977 and joined forces with Fonseca in 1986, the operations leaked in the Panama Papers include information regarding shell companies that date back to 1936[3]. After filtering out for entities for which source country, host country or date of incorporation were missing, we have obtained a consolidated dataset of 212,811 entities ranging from the first entity incorporated in Panama by a Swiss holder in November 1936 to the last offshore account registered for a Chilean resident in Wyoming in December 2015.

In the following, these entities are interpreted as time-stamped links between two countries in the global network of tax evasion. More precisely, we consider networks for which the set of nodes, N, are the 161 jurisdictions which appear at least once as a source or host in the dataset (see Table 12 in the Appendix) while the set of links is defined by considering there is a link from country $i \in N$ to country $j \in N$ if and only if there exists an entity incorporated in country j whose owner is located in country i.

We shall then construct different networks by considering different subset of links: (i) the cumulative (also referred to as static) network that has all possible links independently of their time stamps, (ii) dynamic sequences of networks where only links formed within a given year are considered. All the networks considered are directed (from source to host country) but we will consider both unweighted and weighted networks, where the weight corresponds to the number of entities incorporated during the period under consideration. Finally, entities where source and host countries happened to be the same country were neglected, which allows us to consider only simple graphs (i.e. without self-loops).

3.2 Global structure of the tax-evasion network

The existing literature hints at the complex nature of tax evasion mechanisms. Garcia–Bernardo et al. (2017) highlighted the elaborate nature of tax evasion circuits implemented by multinational companies. The reallocation of funds among offshore centers after the G20 tax haven crackdown, which has been put forward by Johannesen and Zucman (2014), emphasizes the adaptive capacity of the tax evasion system. In this subsection, we investigate whether these complex adaptive features are reflected in the network structure.

[2]The dataset in fact comprises 4 other files. The *Addresses* file shows the location where the entity was registered. The *Intermediaries* and *Officers* files show, respectively, the broker and shareholder names assigned to the entity. The *Edges* relate entities, addresses, intermediaries and officers. Moreover, the ICJ provides three additional datasets on global tax evasion, the *Bahamas Leaks*, the *Offshore Leaks* and the *Paradise Papers* but these do not provide enough information to recover systematically the beneficial owner's country of residence, the jurisdiction where the entity was incorporated and the date of incorporation.

[3]This is due to the fact that registered agents can change over time; so a company may have had a registered agent (a law firm as Mossack-Fonseca) when it was created and years later changed it. We thank the ICIJ and Emilia Diaz Struck for clarifying this question.

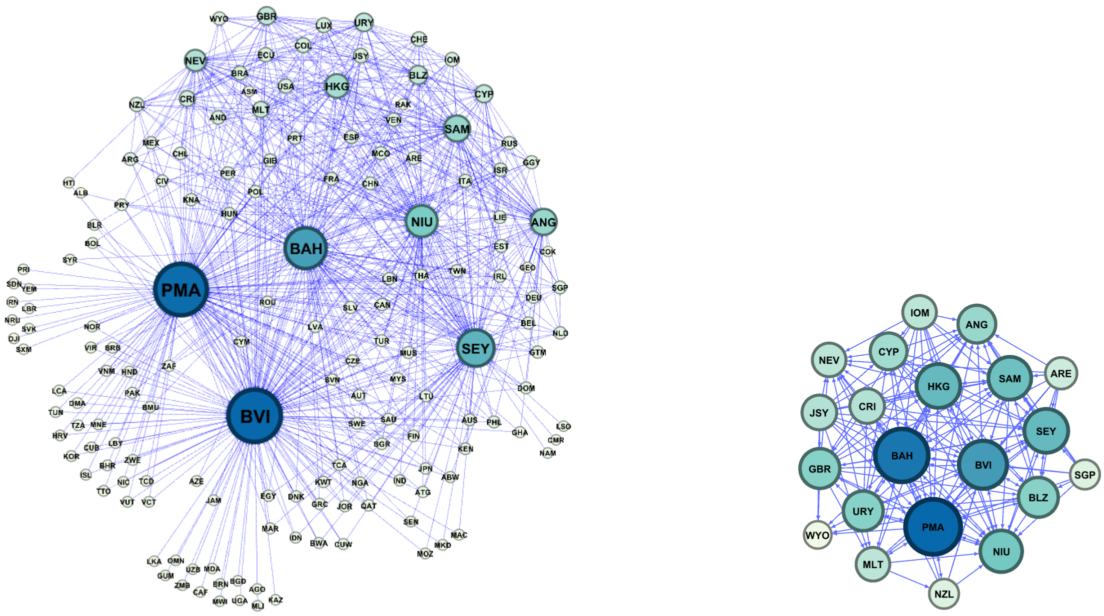

Figure 1: Graphical representation of the network (left panel) and detailed view of the core (right panel). The size and the color intensity of the nodes are proportional to the degree (i.e. to the number of connections).

The intertemporal tax evasion network (containing all links independently of their time stamps) is represented in Figure 1. One of its specific features is that, among the 161 nodes of the network, only 21 have an incoming link (i.e. Mossack-Fonseca incorporated at least one entity). The corresponding countries are listed in Table 1. These host countries correspond, unambiguously, to offshore financial centers. Notably, they have the key features that have been put forward by Dharmapala and Hines (2009) as characteristic of tax heavens: low population, high GDP per capita and high governance index (see details in Table 1). The global structure of the network is organized around these host countries. Namely, the network has a core-periphery structure. The core consists of the set of host countries that are strongly connected, i.e. each country in the core can be reached via a sequence of directed links from every other country in the core (see right panel of Figure 1). The periphery of the network consists of source countries that have only outgoing links, towards the core.

This hierarchical core-periphery structure is also reflected quantitatively in the degree distribution (Figure 2, left panel) and in the relation between degree and clustering (Figure 2, right panel). The degree distribution exhibits much fatter tails than the random benchmark. A large number of nodes are weakly connected but a significant number of them are highly linked: in particular 5% of the jurisdictions have more than 50 links and 2% have more than 100 links each. As illustrated in the right panel of Figure 2, these high-degree nodes are also privileged connections: the negative slope of the degree-clustering relationships highlights that high degree nodes receive specific links. This is indicative of a hierarchical structure in which nodes receive links according to a priority order highly correlated with the degree (see Li and Schurhoff (2019) as well as the definition of nested split-graphs in Section 5 below). Accordingly, as underlined in Table 2, high degree nodes in the core are also characterized by high

Code	Jurisdiction	Pop.	GDP pc	Gov. Ind.	Hub Dist.	Haven	Eng.	Brit. Law
ANG	Anguilla	14.61	22,596.89	0.86	3,600	1	1	1
ARE	UAE	9,154.30	39,122.05	0.57	5,240	0	0	1
BAH	Bahamas	386.84	30,483.82	0.86	2,125	1	1	1
BLZ	Belize	359.29	4,950.26	-0.2	3,300	1	1	1
BVI	Brit. Virg. Ilds	30.11	31,697.83	0.93	2,420	1	1	1
CRI	Costa Rica	4,807.85	11,393.02	0.69	3,575	0	0	0
CYP	Cyprus	1,160.98	23,212.22	0.94	3,290	1	0	1
GBR	United Kingdom	65,128.86	44,305.55	1.45	320	0	1	1
HKG	Hong Kong	7,291.30	42,431.89	1.39	2,940	1	1	1
IOM	Isle Of Man	83.17	81,672.02	1.45	320	1	1	1
JSY	Jersey	100.47	73,569.64	1.45	440	1	1	1
MLT	Malta	445.05	23,759.03	1.03	1,740	1	1	0
NEV	Nevada	2,883.06	44,026.00	1.25	140	0	1	1
NIU	Niue	1.63	19,025.57	-0.67	9,280	0	1	1
NZL	New Zealand	4,595.70	38,649.38	1.85	9,280	0	1	1
PMA	Panama	3,969.25	13,684.13	0.15	3,590	1	0	0
SAM	Samoa	193.76	4,149.41	0.68	9,280	0	1	1
SEY	Seychelles	93.42	14,725.10	0.46	8,940	0	1	0
SGP	Singapore	5,535.00	54,940.86	1.46	5,300	1	1	1
URY	Uruguay	3,431.55	15,524.84	0.94	8,560	0	0	0
WYO	Wyoming	586.10	57,182.00	1.25	140	0	1	1
	Sample Average	**8,580.26**	**17,555.85**	**0.06**	**3,689**	**0.23**	**0.37**	**0.34**

Table 1: Characteristics of countries in the core of the tax evasion network. Pop. refers to population (2015) expressed in thousands. GDP pc refers to GDP per capita in USD (2015). Gov. Ind. refers to governance index (from the World Bank worldwide governance indicators). Hub. Dist refers to the the distance to the closest major trade hub (Rotterdam, New York City or Tokyo), Haven denotes a 1 if the jurisdiction was labeled as a tax haven by Dharmapala and Hines (2009) and 0 otherwise, Eng. is a dummy variable indicating for English as the main language and Brit. Law a dummy variable for British law origins (from the database of Dharmapala and Hines (2009)).

levels of centrality.

First of all, this core-periphery structure highlights the partition of countries between sources (the periphery) and hosts (the core) of tax evasion. Moreover, and perhaps more importantly, it emphasizes the complex structure of tax evasion circuits. Indeed, the fact that the core is formed by a set of tax-havens highlights the fact that funds incoming in a tax haven are likely to be rerouted towards other tax-havens. Table 3 demonstrates that this rerouting of funds among tax havens constitutes one of the key activities of the network. As a matter of fact, some of the countries with the largest number of incoming links, such as Panama or Hong-Kong, also have large number of outgoing links. Hence the network is not a collection of random bilateral links that operate independently. Funds incoming into a tax haven are rerouted towards other tax-havens, most likely to reduce tractability of the funds, as suggested by Johannesen and Zucman (2014).

From a conceptual point of view, our results highlight that the global network of tax evasion genuinely is a complex network, characterized by a core-periphery structure and a fat-tail degree distribution. This suggests that the process of network formation is not random but rather

Wealth Receivers		
(1) In-Degree	(2) Eigencentrality	(3) Bonacich ($\beta = 0.05$)
BVI	PMA	BVI
PMA	BVI	PMA
BAH	BAH	BAH
SEY	SEY	SEY
NIU	NIU	NIU
ANG	SAM	ANG
SAM	HKG	SAM
NEV	ANG	HKG
HKG	BLZ	NEV
BLZ	URY	BLZ
GBR	GBR	GBR

Table 2: This centrality ranking with aggregate data from 1936 to 2015 features how the tax havens in the core which attain a high node-degree are also characterized by high levels of centrality.

Country Pair	Activity %	Host	Activity %	Source	Activity %
BVI-HKG	13.30%	BVI	54.82%	CHE	18.52%
BVI-CHE	9.60%	PMA	20.62%	HKG	18.50%
PMA-CHE	5.66%	BAH	7.56%	JSY	6.98%
BVI-JSY	5.11%	SEY	7.23%	LUX	5.29%
PMA-LUX	2.73%	NIU	4.62%	PMA	4.75%
BVI-GBR	2.65%	SAM	2.52%	GBR	4.67%
BVI-PMA	2.34%	ANG	1.57%	GGY	3.58%
BVI-GGY	2.30%	NEV	0.62%	ARE	3.55%
SEY-HKG	1.83%	HKG	0.20%	URY	2.39%
BVI-SGP	1.77%	BLZ	0.06%	IOM	2.39%
Other 800:	52.70%	Other 11:	0.19%	Other 149:	29.37%

Table 3: Activity rates for the 10 most prominent country pairs, hosts, and sources (measured through the share of offshore entities created). In particular, the first two columns show that more than 13% of the entities where incorporated in the British Virgin Islands (BVI) by a Hong Kong (HKG) beneficiary and that the 10 most prominent links channel almost half of the total offshore registries. The second two columns show that BVI holds more than 50% of the listed offshore accounts and that a group of four countries (BVI, Panama, Bahamas, Seychelles) holds roughly 90%. The third pair of columns highlight the role of Switzerland (CHE) and Hong Kong (HKG) as major sources of tax–evaded wealth.

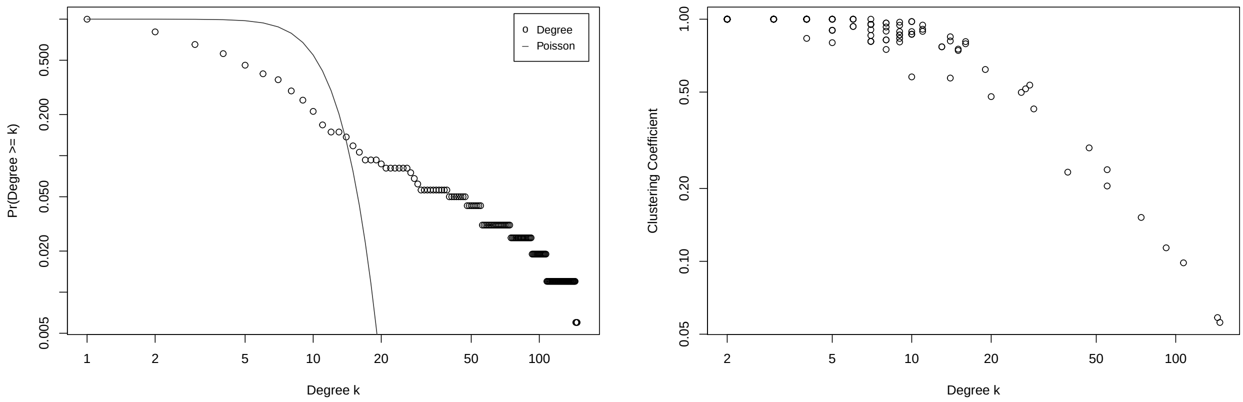

Figure 2: Degree distribution of the network compared to the benchmark Poisson distribution corresponding to a random network (log-log plot, left panel). Relation between degree and clustering coefficient (log-log plot, right panel). The clustering coefficient measures the extent to which the connections of a node are linked among themselves (see e.g. Jackson (2008)). Thus a low clustering coefficient indicates that links are highly specific to a node and the negative slope of the degree-clustering relationship in the right panel indicates that high-degree nodes receive links preferentially as in a nested-split graph.

driven by a process in which network characteristics matter for link formation, as in Barabasi and Albert (1999) and Jackson and Rogers (2007). In other words, tax evasion links (offshore financial entities) are created in a systemic perspective that accounts not only for the individual characteristics of the tax havens but also for their position in the tax evasion network, e.g. in view of further routing of tax-evaded wealth as emphasized above.

3.3 Dynamics of network formation

In order to assess the robustness of the preceding results, and to gain a better understanding of the dynamics of network formation, we investigate the properties of the time series of networks obtained by restricting attention to links formed within an annual time-window. In other words, the network of period t contains a link between country i and country j if an offshore entity was created in country j by an agent of country i during period t. It is important to note in this respect that entities can be created by anticipation by a provider of offshore financial services in order to provide to future tax evader offshore entities with some 'historical' legitimacy (these are also known as 'shelf' companies, see Carr and Grow (2011) and Alvarez and Marsal (2017)). Hence, the network actually observed in year t partly accounts for the demand of tax evasion channels anticipated by the provider of offshore financial services.

Our dynamic analysis focuses on the last twenty years of the database, from January 1996 to December 2015, which account for over 80% of the available data. The key features of the network dynamics over this period are displayed in Figure 3. One observes that the number of nodes and links grew steadily until 2009 and then faced a sizeable negative shock, likely caused by the treaty obligations imposed by the G20 on offshore financial centers, as extensively discussed below. The decrease in the number of nodes is larger in magnitude and in duration than that of the number of links, implying that the shock incidentally caused an increase in the density of the network.

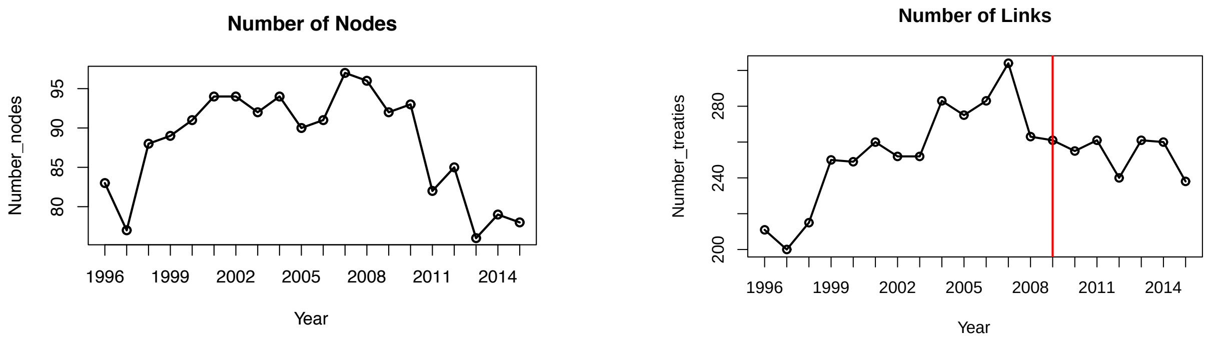

Figure 3: Dynamic evolution of the tax evasion networks 1996-2015

From a structural perspective, Figure 4 and Figure 5 highlight the persistence of a core-periphery structure and of fat-tails. This persistence is explained by the stability of tax-evasion links. Indeed, as detailed in Table 4, 75% of all links and 85% of links between core jurisdictions remain stable on a year-to-year basis.

Remark 1. *Although the structural features of the network remained stable over time, the role of individual jurisdictions has evolved. For example, Niue and Bahamas lost while Seychelles or Anguilla gained centrality over time. Also, Panama and the British Virgin Islands have continuously maintained a very high centrality.*

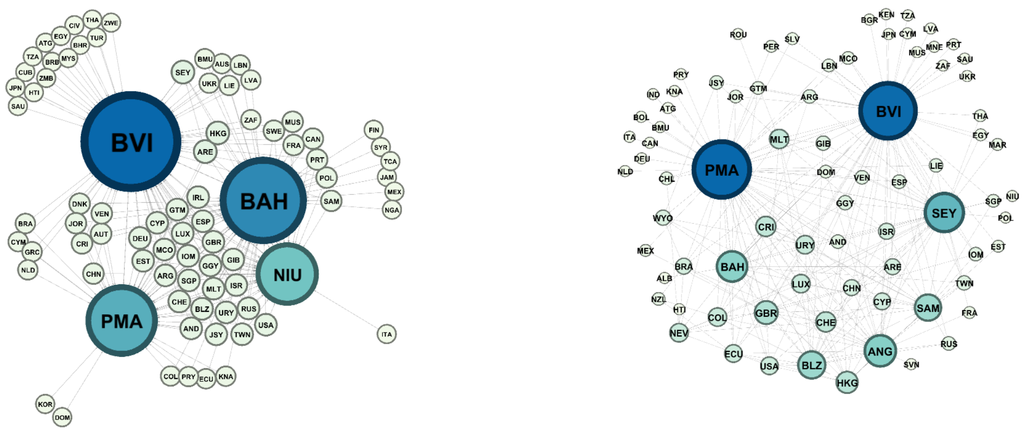

Figure 4: Graphical representation of the network for the years 1996 (left panel) and 2014 (right panel).

The presence of fat tails can further be explained by an analysis of the micro-level dynamics of the network. Indeed, newly formed offshore entities are directed preferentially towards high-degree nodes, as seen in Figure 6. Namely, 47% of offshore entities were created in the British

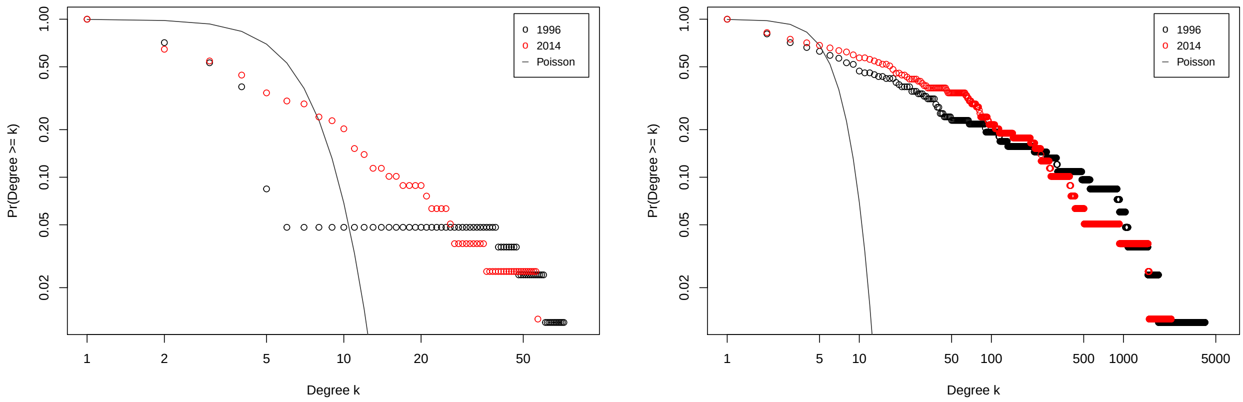

Figure 5: Temporal evolution of the unweighted (left panel) and weighted (right panel) degree distributions of the global tax evasion network. The left panel shows an increasing fattening of tails in the network from 1996 to 2014.

	Link next year			
	All nodes		Core nodes	
Link this year	=0	=1	=0	=1
=0	88%	12%	87%	13%
=1	25%	75%	15%	85%

Table 4: Stability of node centrality: From 1996 to 2015

Virgin Islands, 21 % in the Bahamas, 17% in Panama and 10% in Niue. This correlation between degree and linkage probability is consistent with the preferential attachment process, which is well-known to lead to scale-free degree distributions, as discussed in detail by Barabasi and Albert (1999). As a matter of fact, for the years 2010 to 2015, the null hypothesis that the degree distribution of the network follows a power-law distribution is not rejected by a goodness-of-fit test following the bootstrap procedure of Clauset et al. (2009).

4 Determinants of network formation

In order to gain further insights on the economic drivers of network formation and on the impact of the G20 tax haven crackdown on the structure of the network, we perform an econometric analysis of the determinants of bilateral link formation. In this perspective, we interpret the sequence of annual networks inferred in the preceding section as a panel dataset of bilateral links. More precisely, we use a dynamic logit panel-data model to estimate the determinants of the binary link formation variable $L_{i,j,t}$, which assumes a value of 1 if there is a link (an offshore entity) from jurisdiction i to jurisdiction j in period t and a value of 0 otherwise. The data spans 20 years, from 1996 to 2015, and accounts for 178,163 observations of offshore entities created. Building on the results of the previous section, the set of host jurisdictions is restricted to these that have at least an incoming link, i.e. that actually were documented as offshore financial centers by the Panama Papers.

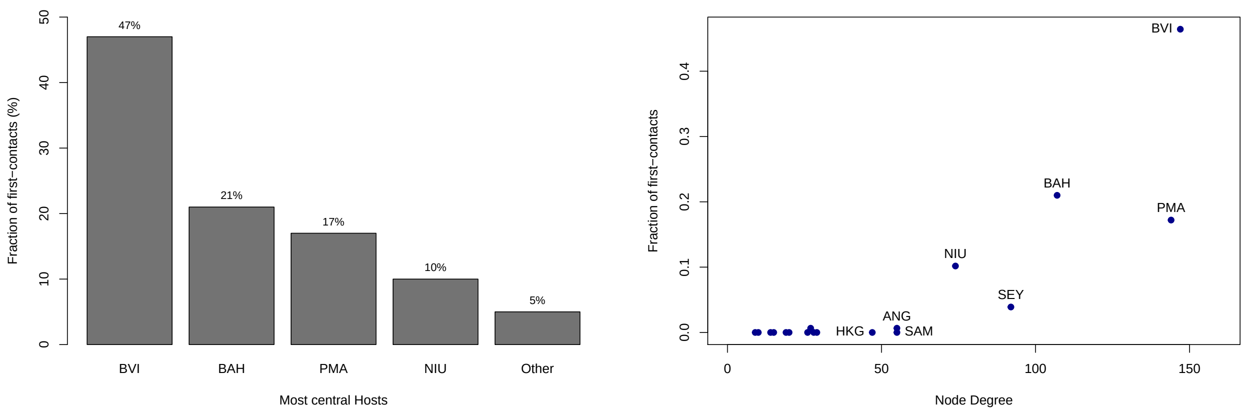

Figure 6: Bar plot showing the hegemony sustained by a few jurisdictions which act as the 'first-ever' destinations for evaded wealth (left panel) and the noticeable correlation between the node degree held by the tax havens with respect to the fraction of first-ever contacts(right panel).

In order to identify relevant socio-economic covariates, we follow Dharmalapa and Hines (2009) who have performed an extensive analysis of the determinants of tax haven status. They have put forward population, GDP per capita and quality of governance as key characteristics. Accordingly, we have retrieved GDP per capita and population control data from the World Bank (partially complemented with UN Data) and the governance index from the the World Bank's Worldwide governance indicators. The data employed consists of annual observations from 1996 to 2015, with the exception of the governance indices, which are published once every two years. Further, we take advantage of the panel nature of the data to include lagged endogenous characteristics of the network as regressors. More precisely, we build on the results of the previous section about the persistence of links and the importance of degree as a determinant of link formation and thus include the lagged link variable $L_{i,j,t-1}$ as well as the lagged eigencentrality of the target node $E_{j,t-1}$ and the lagged degree of the target node $D_{j,t-1}$ as possible covariates. Finally, following Johannesen and Zucman (2014), the key policy determinant of link formation we consider it the existence of a tax treaty between countries. We thus retrieve the complete set of endorsed tax agreements from Johannesen and Zucman (2014). A fundamental remark in this respect is that the dataset reports two main types of tax treaties: tax information exchange agreements and double taxation conventions. Our analysis will distinguish the impact of these different types of treaties.

Hence, we adopt the following logit panel data model specification.

$$L_{i,j,t} = \alpha + \beta \text{Treaty}_{i,j,t-1} + \gamma L_{i,j,t-1} + \delta S_{i,t} + \phi H_{j,t} + \theta_{i,j} + \xi_t + \epsilon_{i,j,t} \quad (1)$$

Here, the outcome variable $L_{i,j,t}$ assumes a value of 1 if there is a link (an offshore entity) from juridiction i to juridiction j in period t and a value of 0 otherwise. The binary variable $\text{Treaty}_{i,j,t-1}$ indicates the presence of a tax treaty between countries i and j in period $t-1$ (see details below). The lagged variable $L_{i,j,t-1}$ accounts for the presence of a link at time $t-1$. The set of covariates $S_{i,t}$ and $H_{j,t}$ are the logarithmic population, logarithmic GDP per capita and the governance index of the source i and the host j respectively for time t. Moreover, as suggested by Johannesen and Zucman (2014), pairwise fixed-effects $\theta_{i,j}$ and time fixed-effects ξ_t were employed to take into account any other external means of influence in the panel data setup (distance between jurisdictions, same legal origins or language, commonalities and time trends). Lastly, $\epsilon_{i,j,t}$ is the error term.

As mentioned, there exist two main types of tax treaties between countries. Accordingly, we consider three variants of the treaty variable in the model of Equation 1: (i) the existence of any treaty, (ii) the existence of a tax information exchange agreement (TIEA), (iii) the existence of a double taxation convention (DTC). In this context, the main element of interest is the coefficient β, which measures the effect of an existing treaty between source i and host j at time t. Our results are reported in Table 5.

Table 5: Panel Data Regression of Link Formation on Tax Treaties

Observations: Annual	Sources: All		
Variables	Any treaty (1)	TIEA (2)	DTC (3)
Treaty: Any	-0.0470 .		
Treaty: TIEA		-0.0850 **	
Treaty: DTC			0.0435
Lag_Link	-0.0469 .	-0.0849 **	0.0434
Host_Ln_GDP_pc	0.2810 ***	0.2803 ***	0.2815 ***
Host_Ln_Pop	0.4442 ***	0.4571 ***	0.4324 ***
Host_Gov_Index	0.2517 ***	0.2478 ***	0.2524 ***
Source_Ln_GDP_pc	-0.0414 **	-0.0411 **	-0.041 **
Source_Ln_Pop	-0.0394	-0.0448	-0.0466
Source_Gov_Index	0.0362	0.0327	0.0373
Observations	16,060	16,060	16,060
Number of country pairs	803	803	803
Number of years	20	20	20
Country-pair fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Adj. R–Squared	0.0652	0.0657	0.0648

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Notes: Panel Data with Logit Link Function, where the p-values are based on robust standard errors. The dependent dichotomous variable measures the existence or non-existence of a link formation between source i and host j at time t. The sample period goes from January 1996 to December 2015. The three variables of interest, *Treaty*, measure the presence of a signed tax treaty between source i and host j at time $t-1$, specified by type of convention.

With respect, to the impact of socio-economic characteristics on link formation, our results are mostly consistent with those of Dharmapala and Hines (2009). The impact of GDP per capita and governance index in the host country are positive and statistically significant suggesting that economic and legal stability are important determinants in the choice of a tax haven. The impact of population in the host country is also positive and statistically significant. This effect is however opposite to the one found in Dharmapala and Hines (2009). This difference can nevertheless be explained that, in our setting, host jurisdictions are actual tax havens while Dharmapala and Hines (2009) consider the emergence of tax havens among the complete set of countries. Therefore, this positive coefficient on population may be interpreted as tax havens having a sufficiently large population to have 'credible economic activity' (see Hamilton (2016)) or to possess enough 'infrastructure to manage all the transactions, entities, assets, etc.' and not to be an utterly obvious evasion channel. In other words, evaders look for a small fiscal paradise, but not too small. With respect to source characteristics, the main observation is that GDP per capita has a negative and statistically significant impact on link formation. This is consistent with the evidence put forward by Alstadsaeter et al. (2018) and Zucman (2014) about the rising tax-evasion from developing countries. With respect to network covariates, the results are consistent with these of the preceding section. The effect of the lagged link covariate is positive and statistically significant confirming the stability of relationships in the network. Moreover, both the lagged degree-centrality and the eigencentrality of the target destination hold positive and highly statistically significant effects: the more central a jurisdiction is, the more prone it is to form a link with an evasive country. The latter holds true independently of whether the evasive node is a tax haven or not, and whether it is a core or peripheral country (see Table 8 and Table 9 in the Appendix). Finally, the most important result of our analysis concerns the role of tax treaties. We find that tax information exchange agreements (TIEA's) have a negative and statistically significant impact on link formation whereas non-specific treaties and double-taxation conventions do not have a statistically significant impact. This suggests that coordinated policies, such as the G20 crackdown on tax havens can have an impact on tax evasion but that the type of treaty enforced is crucial.

The efficiency of the G20 approach has also been questioned on the basis of the fact that a large number of TIEA's have been signed among tax havens, raising doubts on their actual enforcement (see Johannesen and Zucman (2014)). In order to investigate this issue, we have further specialized our econometric analysis by distinguishing three types of source countries: core-havens, exo-havens and non-haven sources. Core-havens are the core nodes of our network analysis, i.e. jurisdictions that are explicitly identified as tax havens in the Panama Papers because they host an offshore financial entity. Exo-havens are jurisdictions that do not belong to the core of the global tax-evasion network in our analysis but are identified as tax havens by Dharmapala and Hines (2009). These include jurisdictions, such as Switzerland (CHE) and Hong Kong (HKG), that are generally considered as intermediaries in tax-evasion circuits and that have, in our network analysis, very large out-degrees both in absolute terms and relatively to their GDP. Finally, non-havens form the residual category. The flow of funds between these jurisdictions is presumed to unfold as follows. Non-haven sources may evade directly towards core-havens or exo-havens. In the latter case, exo-havens rewire a substantial share of funds towards core-havens. In turn, core-havens may further transfer funds to other nodes in the core.

In our extended analysis, we estimate separately the logit model introduced in Equation 1 for each category of source jurisdictions. The results of this analysis are presented in Table 6. The results of this complementary analysis are consistent with the hypothesis put forward by Johannesen and Zucman (2014). The treaties involving only tax-havens, i.e. signed between an exo-haven and a core-haven or between two core-havens, do not have a statistically significant impact on the formation of tax evasion links. On the contrary, treaties between non-havens and havens do retain a negative and statistically significant impact. Additional robustness checks are available in the Appendix, which shows the persistent effect of TIEA treaties, whenever a signatory is a non-haven country, even after considering endogenous characteristics of the network as regressors, in particular the lagged eigencentrality of the target destination (see Table 8) and the lagged degree-centrality of the offshore financial center (see Table 9).The results are, moreover, robust to different time windows, in particular to monthly (see Table 10 and Table 11) and quarterly link formation processes.

From a public policy point of view, the results of this section first show that tax treaties can have an impact on tax evasion. Second, they emphasize the importance of adding information exchange clauses to ensure an effective impact. Third, they question the relevance of treaties signed between tax havens and thus suggest to revisit the definition of the treaty quota imposed by G20 guidelines.

Table 6: Panel Data Regression of Link Formation on TIEA Treaties

Observations: Annual	Source type		
Variables	Non-Haven (1)	Exo-Haven (2)	Core-Haven (3)
Treaty: TIEA	-0.116 ***	-0.0765	0.0239
Lag_Link	0.2541 ***	0.3117 ***	0.3593 ***
Host_Ln_GDP_pc	0.0349	0.0304	0.0526
Host_Ln_Pop	0.4226 ***	0.3633 **	0.9158 ***
Host_Gov_Index	0.2200 ***	0.2787 ***	0.3073 ***
Source_Ln_GDP_pc	-0.0407 *	-0.0162	-0.0615
Source_Ln_Pop	-0.0076	-0.2191 *	-0.2599
Source_Gov_Index	0.0297	-0.0178	0.0243
Observations	11,020	3,260	1,720
Number of country pairs	551	163	86
Number of years	20	20	20
Country-pair fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Adj. R–Squared	0.0443	0.0853	0.2048

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Notes: Panel Data with Logit Link Function, where the p-values are based on robust standard errors. The dependent dichotomous variable measures the existence or non-existence of a link formation between source i and host j at time t. The sample period goes from January 1996 to December 2015. The variable of interest, *Treaty*, measures the presence of a Tax Information Exchange Agreement (TIEA) treaty between source i and host j at time $t-1$, differentiating by source type. Moreover, 60 observations and 3 country-pairs (BVI-MNE, PMA-MNE, PMA-NRU) where not taken into account for this model as NRU and MNE are not classified: there is not enough covariate information available for either country.

5 A formal model of tax evasion deterrence

The networked structure of the tax-evasion system highlighted in the preceding sections raises a number of questions for the design of an efficient anti-tax evasion policy. Where is tax evaded wealth likely to be located in the network? How does the structure of the network affects tax-evasion behavior in origin countries? What are efficient policies to deter tax evasion given its networked structure? In order to address these issues, we introduce a simple model of the flow of funds in the tax evasion network and investigate in this setting the strategic behavior of an optimizing tax-evading agent and of a social planner aiming at deterring evasion.

5.1 Notation and definitions

We first recall a set of notions and known results related to networks and, in particular, Bonacich centrality .

Definition 1. *Given a network with adjacency matrix* $G \in \mathbb{R}_+^{N\times N}$, *and a discount factor* $\beta \in [0,1]$, *the Bonachich centrality (see Bonacich (1987) as well Ballester et al. (2006)) of a node* i *is defined as the discounted sum of the weights of all paths in the network leading to* i. *Namely, the vector of Bonacich centrality is given by:*

$$b(G,\beta) = \sum_{t\in\mathbb{N}} \beta^t G^t \tilde{e} = (I-\beta G)^{-1}\tilde{e} \tag{2}$$

where $\tilde{e}$ *is the vector* $(1,\cdots,1) \in \mathbb{R}_+^N$.

This definition can be extended to account for an arbitrary vector of weights on the origins of paths, leading to the definition of the Bonacich centrality of an adjacency matrix G for a discount factor $\beta \in [0,1]$, and a vector of initial weights $x \in \mathbb{R}_+^N$ as

$$b(G,\beta,x) = \sum_{t\in\mathbb{N}} \beta^t G^t x = (I-\beta G)^{-1} x \tag{3}$$

Remark 2. *The Bonacich centrality is well defined only if* $\beta < \mu_1(G)$ *where* $\mu_1(G)$ *is the largest eigenvalue of* G *(also referred to as the index of* G.*)*

In the following, we shall be concerned with the determination of the network with a given number of links that maximizes the sum of Bonacich centralities. Following Remark 1 and Lemma 1 in Belhaj et al. (2016), such networks necessarily are nested-split graphs in the following sense.

Definition 2. *An (unweighted) network* G *is a nested-split graph if*

$$[G_{i,j} = 1 \text{ and } \deg(G,k) \geq \deg(G,j)] \Rightarrow G_{i,k} = 1.$$

where $\deg(G,k)$ *denotes the degree of node* k *in the network* G.

Such graphs are called nested as it can be shown they are structured by classes of nodes having the same degree and the same set of incoming links. Some notable classes of nested-split graphs are defined as follows:

Definition 3. *The quasi-complete network with n nodes and ν links, denoted by $QC(n,\nu)$ is the graph that contains the complete subgraph K_p with ${}^{p(p-1)}/_2 \leq \nu < {}^{p(p+1)}/_2$ and the remaining $\nu - {}^{p(p-1)}/_2$ links are set between the nodes in K_p and one other node.*

Definition 4. *The quasi-star graph with n nodes and ν links, denoted by $QS(n,\nu)$ is the graph with p central nodes, each having $n-1$ links, and the remaining $\nu - p(n-1)$ links being directed towards a specific node, so as to construct another central node.*

5.2 Centrality and the distribution of tax evaded wealth

We first consider a simple phenomenological model of the dynamics of wealth in a tax evasion network. The network is represented by a column-stochastic adjacency matrix $(G_{i,j})_{i,j=1,\cdots,n} \in \mathbb{R}_+^{n\times n}$ where n is the number of countries in the network and $g_{i,j}$ measures the share of wealth outgoing from country j that is directed towards country i, i.e. the probability that a unit of tax-evaded wealth, which is outgoing from j, is directed towards i. Tax-evasion behavior is captured by a single parameter $\beta \in [0,1]$, which measures the intensity of tax-evasion, i.e. the share of tax-evaded wealth arriving in i that is rerouted further (while $1-\beta$ is the share that stays in the country).

Remark 3. *Empirically, β likely depends on the host country and of the number of countries through which the funds have transited since the origin country. Considering β is constant renders the process homogeneous in space and in time and thus analytically tractable. From the point of view of a tax evader aiming at avoiding detection, this amounts to consider that the probability of detection is independent of the host country and decreases with each link added to the tax evasion path, independently of the trajectory followed previously.*

In this setting, the dynamics of tax evaded wealth can be characterized by $y(t) \in \mathbb{R}_+^n$ the distribution of idle funds in the network and $x(t) \in \mathbb{R}_+^n$ the distribution of funds in circulation in the network. One has:

$$\begin{cases} x(t+1) = \beta G x(t) \\ y(t+1) = (1-\beta)x(t) + y(t) \end{cases} \tag{4}$$

The first equation represents the flow of funds in circulation in the network. The second equation represents the fact that a share $(1-\beta)$ of funds stops circulating in the network at every step. Combining both equations, one can determine the distribution of funds in the network at times t as a function of the initial distribution of funds $x(0)$ (one assumes $y(0) = 0$). Namely, one has:

$$x(t) = \beta^t G^t x(0) \tag{5}$$

$$y(t) = (1-\beta)\sum_{r=0}^{t-1} \beta^t G^t x(0) \tag{6}$$

As long as $\beta < 1$, Equation 5 implies that asymptotically all funds become idle in the network. In turn, Equation 6 implies that at time t, (idle) funds in the network are distributed according to the discounted sum of paths of length less than t. Accordingly, asymptotically, funds are distributed proportionally to the Bonacich centrality of the network. Namely, one has the following proposition.

Proposition 1. *If tax evaded wealth follows the dynamics given by Equation 4 with $\beta < 1$ one has:*

$$\lim_{t \to +\infty} x(t) = 0$$

$$\lim_{t \to +\infty} y(t) = (I - \beta G)^{-1} x(0)$$

where $(I - \beta G)^{-1} x(0)$ is the Bonacich centrality of the network with adjacency matrix G, corresponding to the discount factor β and the initial weight $x(0)$.

Proposition 1 can then be used to estimate the distribution of tax evaded wealth among tax havens on the basis of the structure of the tax evasion network, the propensity to evade taxes and the distribution of wealth among origin countries. When applied to the tax-evasion network inferred from the Panama Papers, this implies that the ranking of tax havens by size is given by the Bonacich centrality reported in Table 2 (for a 5% discount factor).

5.3 Policy and behavior in tax evasion networks

As emphasized in the previous sections, policy makers in source countries have tried to curb the flow of tax evasion by pressuring tax havens to sign information exchange treaties that ought to hamper the circulation of tax evaded money. In other words, they have tried to alter the structure of the network of tax evasion in order to reduce the share of tax evaded money. In order to characterize efficient strategies from this perspective, we analyze the interactions between a tax evader that aims to minimize the probability of being detected by dispersing his funds across a tax evasion network and a social planner that aims at minimizing tax evasion through the implementation of an efficient set of treaties.

Formally, we represent the strategy spaces of the tax evader and of the social planner as follows. On the one hand, that the tax evader chooses the intensity of tax evasion $\beta \in [0, 1]$. On the other hand, the social planner chooses the set of links $(i, j) \in N \times N$ on which a treaty is implemented and tax evasion can thus be detected. We represent this choice by a vector $(h_{i,j})_{i,j \in N} \in \{0, 1\}^{N \times N}$ where $h_{i,j} = 1$ if a treaty is implemented between jurisdiction i and j and $h_{i,j} = 0$ otherwise. These joint choices determine a global probability of detection $\pi(h, \beta)$. Namely, the probability of detecting tax evaded wealth originating from jurisdiction i is given by:

$$\pi_i(h, \beta) = (1 - \beta) + (1 - \beta)\beta \sum_{j \in N} h_{j,i} g_{j,i} + (1 - \beta)\beta^2 \sum_{j_1, j_2 \in N} h_{j_2,j_1} g_{j_2,j_1} h_{j_1,i} g_{j_1,i} + \cdots + (1 - \beta)\beta^m \sum_{j_1, \cdots, j_m \in N} \prod_{\mu=1}^{m} h_{j_{\mu+1},j_\mu} g_{j_{\mu+1},j_\mu} h_{j_1,i} g_{j_1,i} + \cdots \quad (7)$$

where the term $(1 - \beta)\beta^m$ corresponds to the share of wealth that is stored m steps away from the country of origin and the term $\prod_{\mu=1}^{m} h_{j_{\mu+1},j_\mu} g_{j_{\mu+1},j_\mu} h_{j_1,i} g_{j_1,i}$ corresponds to the probability that the tax evader gets caught along the path $(i, j_1, \cdots, j_m)$.

Denoting by $K(h)$ the matrix with coefficients $(k_{j,i} := g_{j,i} h_{j,i})_{i,j \in N}$, one can write in matrix form the probability of detection of tax-evaded wealth initially distributed according to $x \in \mathbb{R}_+^N$, $\pi_x(h, \beta)$ as:

$$\pi_x(h,\beta) := (1-\beta)\tilde{e}^\top \sum_{m=0}^{+\infty} (\beta K(h))^m x = (1-\beta)\tilde{e}^\top (I - \beta K(h))^{-1} x \tag{8}$$

Hence, the probability for a representative (or aggregate) tax evader with initial distribution of wealth $x \in \mathbb{R}_+^N$ to get detected is proportional to the sum of the Bonacich centralities of the nodes of the network $K(h)$ for the discount factor β and the vector of initial weights x.

In this setting, the tax evader has incentives to increase β in order to minimize the probability of detection. However, these incentives can be mitigated by the cost of tax evasion. This cost has many potential drivers: direct financial costs such as payment of tax evasion services, liquidity costs related to the reduced availability of evaded vs non-evaded funds, and reputation and psychological costs in case of detection. We shall denote by $c(\beta)$ the cost of choosing an intensity β of tax evasion and assume throughout that the cost is a smooth (twice differentiable) and increasing function of the intensity of tax evasion. We then assume that the tax evading agent chooses a tax evasion intensity in $[0, \overline{\beta}]$ (where $\overline{\beta} \leq 1$) and arbitrates between the probability of getting detected and the cost of tax evasion. More precisely, we consider that the utility of an agent choosing a tax evasion intensity $\beta \in [0, \overline{\beta}]$ is given by:

$$u(h,\beta) = -\pi_x(h,\beta) - c(\beta)$$

The optimal behavior of the tax evading agent then depends of the properties of the cost function. Yet, one can ensure à priori that given a treaty policy h, there exists an optimal level of tax evasion $\phi(h)$. Indeed, $[0, \overline{\beta}]$ is compact and u is continuous, as c and π_x both are continuous.

As for the social planner, we consider he faces a constraint limiting the actual influence he can exert on the probability of detection, e.g. on the number of treaties he can implement. This constraint is assumed to be of the form $\sum_{i,j\in N} h_{i,j} = \nu$ with $\nu \in \mathbb{N}$, consistently with the constraint imposed by the G20 on tax havens to sign a given number of TIEA's. Formally, the problem of the social planner, if he takes as given the propensity, β, to tax evade, is:

$$\mathcal{S}_{\nu,\beta} := \begin{cases} \max & \pi_x(h,\beta) \\ s.t & \sum_{i,j\in N} h_{i,j} = \nu \end{cases}$$

In other words, the objective of the social planner is to choose a set of treaties (i.e. detection probabilities) h so that the sum of Bonachich centralities in the network $K(h)$ is maximal.

We shall further consider that the social planner acts as a Stackelberg leader who foresees the strategic reply of the tax evader to his policy and chooses the policy accordingly. Hence, in the following, we focus on the Stackelberg equilibrium of the tax evasion game defined as follows.

Definition 5. *A pair (β^*, h^*) is a Stackelberg equilibrium of the tax evasion game if*

1. *$\beta^* = \phi(h^*)$ is a solution of the problem* $\begin{cases} \max & -c(\beta) - \pi_x(\beta, h^*) \\ s.t & \beta \in [0, \overline{\beta}] \end{cases}$

2. *h^* is a solution to* $\mathcal{S}_\nu := \begin{cases} \max & \pi(h, \phi(h)) \\ s.t & \sum_{i,j\in N} h_{i,j} = \nu \end{cases}$

Remark 4. *In our framework the set of treaties are determined by the social planner whereas in practice treaties are signed in a decentralized manner. Yet, our objective is normative. We are interested in determining the efficient set of treaties.*

5.4 Optimal tax evasion behavior

We first characterize the behavior of a tax evader for a given deterrence policy $h \in \{0,1\}^{N\times N}$, which is considered as fixed throughout this subsection. The impact of tax evasion intensity β on the probability of detection is then given by the following proposition.

Proposition 2. *For every $x \in \mathbb{R}_+^N$ and $h \in [0,1]^{N\times N}$, $\pi_x(h,\cdot)$ is decreasing and concave in β.*

The concavity of π_x implies that agents have, à priori, very strong incentives to tax evade: there are increasing marginal returns to tax evasion in terms of probability of non-detection: as β increases, the probability of detection decreases more and more rapidly. This non-convexity originates from the fact that an increase in the intensity of tax evasion is amplified, non-linearly, by the network. Yet, these incentives can be mitigated by the cost of tax evasion. Hence the optimal behavior of a tax evading agent eventually depends of the properties of the cost function.

One can not characterize analytically the optimal behavior of the tax evader in the general case. In particular, one can not guarantee that the optimum is unique, nor determine whether it is in the interior or on the boundary of the domain. However, one can characterize two polar cases that are of particular interest. First, if the cost of tax evasion is concave, i.e. if the marginal cost of tax-evasion is decreasing, there are only two potentially optimal strategies: either the agent does not tax evade at all or she fully tax evades. Namely, letting $\phi(h) = \operatorname{argmax}_{\beta\in[0,\overline{\beta}]} u(h,\beta)$, one has the following proposition.

Proposition 3. *If the cost function c is concave, then the problem $\max_{\beta\in[0,\overline{\beta}]} u(h,\beta)$ can not have an interior solution and one has:*

- *Either $u(h,\overline{\beta}) \geq u(h,0)$ and $\phi(h) = \overline{\beta}$*
- *Or $u(h,\overline{\beta}) \leq u(h,0)$ and $\phi(h) = 0$*

The second polar case is the one where the cost of tax-evasion is more convex than the probability of detection, i.e. the marginal cost of tax evasion is increasing faster than the probability of tax-evasion decreases. Then, there exists a unique optimal level of tax evasion. In particular, if the marginal impact of tax evasion on the probability of detection is large enough, it is optimal to fully tax evade. Namely, one has the following proposition.

Proposition 4. *If c is such that for every $\beta \in [0,\overline{\beta}]$, $-\pi_x''(h,\beta) < c''(\beta)$ then there exists a unique solution $\phi(h)$, to the problem $\max_{\beta\in[0,\overline{\beta}]} u(h,\beta)$ and one has:*

- *If $c'(\overline{\beta}) + \pi_x'(\overline{\beta}) \leq 0$, then $\phi(h) = \overline{\beta}$*
- *If $\pi_x'(0) + c'(0) \geq 0$, then $\phi(h) = 0$.*
- *If $\pi_x'(0) + c'(0) \leq 0$ and $c'(\overline{\beta}) + \pi_x'(\overline{\beta}) \geq 0$, then there exists a unique $\tilde{\beta} \in [0,\overline{\beta}]$ such that $\phi(h) = \tilde{\beta}$*

5.5 Strategic deterrence

Building on Proposition 3, one can provide a simple characterization of the social planner's equilibrium strategy in the case where c is concave.

Proposition 5. *Assume the cost function c is concave. If h^* is a solution to $\mathcal{S}_{\nu,\overline{\beta}}$ then $(\phi(h^*), h^*)$ is a Stackelberg equilibrium of the tax evasion game.*

Hence, in the case where the cost is concave, it suffices to focus on the behavior of the social planner in a setting where the tax evader fully tax evades. This will be our focus for the remaining of this section.

Remark 5. *For an arbitrary cost function, strategic interactions become more complex and the Stackelberg equilibrium can hardly be characterized analytically. A meaningful proxy of the optimal behavior of the social planner can nevertheless be characterized by taking the propensity to tax evade as given, i.e. by solving the problem $\mathcal{S}_{\nu,\beta}$ as done below.*

In this setting, a fundamental remark is that the problem $\mathcal{S}_{\nu,\beta}$ is equivalent to finding the subgraph of G with ν links for which the sum of Bonachich centralities is maximal. This objective function is clearly supermodular because the number of new paths obtained by the addition of a link to a subgraph is an increasing function of the subgraph. Hence our problem amounts to the maximization of a supermodular function under cardinality constraints, which is known to be NP-hard in general (see e.g Nagano et al. (2011)). Nevertheless, one can characterize analytically the solutions for some particular cases of interest.

- If the intensity of tax evasion β is small enough and the ν links with the largest weight in G can be unambiguously identified, then the social planner can focus on the first order connections in the network and simply target the links of G with the largest weight. Namely, one has:

  Proposition 6. *Assume the ν links with the largest weight in G can be unambiguously identified, i.e. there exists $\mathcal{L}_\nu(G)$ such that $|\mathcal{L}_\nu(G)| = \nu$ and for all $(i,j) \in \mathcal{L}_\nu(G)$ and all $(k,l) \notin \mathcal{L}_\nu(G)$, $g_{i,j} > g_{k,l}$. Then, for β small enough, a solution h^* to $\mathcal{S}_{\nu,\beta}$ is such that*

  $$h^*_{i,j} = \begin{cases} 1 & \text{if } (i,j) \in \mathcal{L}_\nu(G) \\ 0 & \text{otherwise} \end{cases}$$

- If the network G is unweighted and complete, i.e. all tax-evasion paths are equally likely à priori, the problem of the social planner amounts to finding from the set of networks with N nodes and ν links, the one for which the sum of Bonachich centralities is maximal. For small β, this problem is investigated in detail by Belhaj et al. (2016), building on Abrego et al. (2009). Namely, one has:

  Proposition 7. *Assume for all $(i,j) \in N \times N$, $g_{i,j} = 1$. Then, for β small enough a solution h^* to $\mathcal{S}_{\nu,\beta}$ is either a quasi-star or a quasi-complete network. Moreover,*

  – *If $\nu \leq \dfrac{n(n-1)}{2} - \dfrac{n}{2}$, then $h^* = QS(n,\nu)$*

– *If* $\nu \geq \frac{n(n-1)}{2} + \frac{n}{2}$, *then* $h^* = QC(n, \nu)$

- If the network G is unweighted and complete and β is large (i.e. β tends towards $1/\mu_1(G)$), Lemma 2 in Corbo et al. (2006) shows that maximizing the sum of Bonacich centrality is equivalent to the well-known problem in graph theory of finding the graph with a given number of nodes and vertices that has maximal index (see for example Chand and Tam (2011)). A long-standing conjecture on that problem is that its solutions are either quasi-complete or quasi-star graphs (see Aouchiche et al. (2008) and Cvetkovic et al. (1997) for solutions in some specific cases). In particular, according to Proposition 1 in Corbo et al. (2006), for n large enough and $n \leq \nu \leq 2n-2$, one has $h^* = QS(n, \nu)$.

This set of results highlights that the optimal policy for a social planner who aims at deterring tax-evasion depends on the structure of the network and on the level of influence he can exert. If his influence potential is low, i.e. he can impact a limited number of links, he shall aim at forming quasi-star structure, that is, isolate tax-havens one after the other. If his level of influence is relatively large, then he shall aim at forming quasi-complete structures, i.e. try to dismantle connections within the core of the network.

Rank	Link	Rank	Link
1	(PMA,BAH)	11	(PMA,GTM)
2	(PMA,BVI)	12	(PMA,USA)
3	(PMA,SEY)	13	(PMA,COL)
4	(SEY,SAM)	14	(PMA,ARE)
5	(NIU,BAH)	15	(PMA,VEN)
6	(SEY,NIU)	16	(ANG,SAM)
7	(BVI,ANG)	17	(BAH,NEV)
8	(PMA,CHE)	18	(BAH,CHE)
9	(PMA,LUX)	19	(PMA,MCO)
10	(PMA,ECU)	20	(PMA,BRA)

Table 7: Top target links for the social planner inferred from a greedy algorithm for the maximization of the probability of detection $\pi_{\tilde{e}}(\beta, :)$ over the intertemporal weighted network. The weights have been assigned proportionally to the number of months, within the period 1996-2015, in which at least one offshore entity was created on the corresponding link. The results are identical for every value of β in $\{0.05, 0.1, 0.15, 0.25\}$.

In the case of arbitrary networks and propensity to evade β, the problem of the social planner is NP-hard, as emphasized above . Nevertheless, one can obtain (weak) approximations of the optimal policy through the greedy algorithm, which sequentially adds to the social planner's strategy the links with the largest marginal contribution (see Kempe et al. (2003) for a detailed description of a similar algorithm and Sviridenko et al. (2017) for approximation bounds). Applying this approach to the global (intertemporal) tax evasion network inferred in Section 3, one obtains an approximation of the optimal strategy of the social planner through numerical simulations whose results are reported in Table 7. The simulations first show that the optimal strategy is independent of β in our context. Moreover, the optimal strategy closely approximates a quasi-star centered around Panama (PMA), which is the node with the largest Bonacich and eigenvector centrality in our framework (when accounting for both incoming and outgoing links). The strategy targets in priority: (i) links with core havens, notably Bahamas

(BHA) and British Virgin Islands (BVI); (ii) links with exo-havens, notably Switzerland (CHE), Luxembourg (LUX) and United Arab Emirates (ARE); (iii) links with large tax-evading jurisdictions: USA, Brazil (BRA). These numerical results are consistent with the analytical ones reported above.

6 Conclusions

In this paper, we have built upon the 'Panama Papers' dataset to provide a network analysis of global tax-evasion. Our analysis first highlights that the global tax-evasion network, far from being a random collection of bilateral links, has a hierarchical organization characterized by a core-periphery structure and a fat-tail degree distribution. Moreover, the dynamics of network formation are consistent with a preferential attachment process, which is characteristic of complex networks. These structural features indicate that global tax-evasion actually is a complex system and thus that policy must adopt a systemic approach on the matter.

In this perspective, taking advantage of the natural experiment induced by the G20 2009 crackdown on tax havens, we have investigated the impacts of fiscal treaties on the formation of tax-evasion links. Our results show that efficient treaties are those that contain an information exchange clause and that link tax-havens to "non-haven" countries.

Finally, we investigate optimal deterrence strategies for a social-planner facing a strategic tax-evader in a Stackelberg competition. The problem turns out to be mathematically equivalent to that of finding the subgraph of a network with maximal Bonacich centrality. This problem has recently received a lot of attention in network and graph theory. We provide both analytical and numerical results that show that an efficient strategy for the social planner is to form quasi-star structures surrounding, successively, each tax-haven with a set of treaties.

The Panama Papers provide a unique opportunity to gain a better understanding of the mechanics of tax evasion. Their usage nevertheless implies some limitations to our analysis. First, we must assume that the activities of Mossack-Fonseca are representative of those of the offshore financial industry. Second, the Panama Papers do not allow to track ownership chains across multiple jurisdictions. Our analysis thus relies on the assumption that tax evasion is "Markovian", i.e. the paths followed by funds leaving a country are independent of their origin.

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Appendix A. Proofs of Propositions

Proof of Proposition 2. We compute the successive derivatives of π_x with respect to β (we omit the variable h to simplify notations)

- Basic calculus shows that the first derivative is given by:

$$\pi_x'(\beta) = (1-\beta)\tilde{e}^\top (I-\beta K(h))^{-1} K\xi - \tilde{e}^\top \xi$$

  where $\xi := (I-\beta K(h))^{-1}x \geq 0$.

  This yields successively:

$$\pi_x'(\beta) = \tilde{e}^\top [(1-\beta)(I-\beta K(h))^{-1}K(h) - I]\xi$$
$$\pi_x'(\beta) = \tilde{e}^\top [(1-\beta)(I-\beta K(h))^{-1}K(h) - I]\xi$$
$$\pi_x'(\beta) = (1-\beta)(\sum_{m=0}^{+\infty} \beta^m \tilde{e}^\top K(h)^{m+1}\xi) - \tilde{e}^\top \xi$$

  Now, given that G is column-stochastic and for all $i,j \in N$, $h_{i,j} \leq 1$, one clearly has for all $m \in \mathbb{N}$,

$$\tilde{e}^\top K^{m+1}\xi \leq \tilde{e}^\top \xi.$$

  Thus, one has:

$$\pi_x'(\beta) \leq (1-\beta)(\sum_{m=0}^{+\infty} \beta^m \tilde{e}^\top \xi) - \tilde{e}^\top \xi = [(1-\beta)\sum_{m=0}^{+\infty} \beta^m - 1]\tilde{e}^\top \xi \leq 0$$

  Hence π_x is decreasing with respect to β.

- Basic calculus then shows that the second derivative of π_x is given by

$$\pi_x''(\beta) = 2(1-\beta)\tilde{e}^\top (I-tK(h))^{-1}K(h)\zeta - 2\tilde{e}^\top \zeta$$

  where $\zeta := (I-\beta K(h))^{-1}K(h)(I-\beta K(h))^{-1} \cdot x \geq 0$

  Hence, similar arguments as above imply that $\pi_x''(\beta) \leq 0$ and thus that π_x is concave.

□

Proof of Proposition 3. The proof is straightforward given the convexity of u. □

Proof of Proposition 4. If c is such that for every $\beta \in [0,\overline{\beta}]$, $-\pi_x''(\beta) < c''(\beta)$ then u is strictly concave and thus $\max_{\beta\in[0,\overline{\beta}]} u(\beta)$ clearly has a unique solution. Then

- If $c'(\overline{\beta}) + \pi_x'(\overline{\beta}) \leq 0$, then $u'(\overline{\beta}) \geq 0$ and given u' is decreasing, one has $u'(\beta) \geq 0$ for all $\beta \in [0,\overline{\beta}]$. Thus u is increasing over $[0,\overline{\beta}]$ and $\overline{\beta} = \hat{E}\text{argmax}_{\beta\in[0,\overline{\beta}]}\ u(\beta)$.
- If $\pi_x'(0) + c'(0) \geq 0$, then $u'(0) \leq 0$ and given u' is decreasing, one has $u'(\beta) \leq 0$ for all $\beta \in [0,\overline{\beta}]$. Thus u is decreasing over $[0,\overline{\beta}]$ and $0 = \hat{E}\text{argmax}_{\beta\in[0,\overline{\beta}]}\ u(\beta)$.

- If If $\pi'_x(0) + c'(0) < 0$ and $c'(\overline{\beta}) + \pi'_x(\overline{\beta}) > 0$, then $u'(0) > 0$ and $u'(\overline{\beta}) < 0$, thus the strict concavity of u implies there exists a unique $\tilde{\beta} \in [0, \overline{\beta}]$ such that $u'(\tilde{\beta}) = 0$ and $\tilde{\beta} = \hat{E}\mathrm{argmax}_{\beta \in [0,\overline{\beta}]}\, u(\beta)$.

□

Proof of Proposition 5. Assume h^* is a solution to $\mathcal{S}_{\nu,\overline{\beta}}$. On the one hand, one has $u(0, h) = -1 - c(0)$, which is independent of h. On the other hand, one has $u(\overline{\beta}, h) = -\pi(\overline{\beta}, h) - c(\overline{\beta})$. Thus $u(\overline{\beta}, h)$ is clearly minimal for $h = h^*$.

One then has according to Proposition 3,

- Either $\phi(h^*) = \overline{\beta}$ and $u(\overline{\beta}, h^*) \geq u(0)$. Then, for every $h \neq h^*$, one has has $u(\overline{\beta}, h) \geq u(0)$ and thus $\phi(h) = \overline{\beta}$. The fact that h^* is a solution to $\mathcal{S}_{\nu,\overline{\beta}}$ then implies that h^* is a solution to $\mathcal{S}'_k$ and hence that $(\phi(h^*), h^*)$ is a Stackelberg equilibrium of the tax evasion game.
- Otherwise $\phi(h^*) = 0$ and thus $\pi(\phi(h^*), h^*) = 1$. As for all h, one has by construction $\pi(\phi(h), h) \leq 1$, h^* then is a solution to $\mathcal{S}'_k$ and $(\phi(h^*), h^*)$ is a Stackelberg equilibrium of the tax evasion game.

□

Appendix B. Panel Data Robustness Check

Table 8: Panel Data Regression of Link Formation on TIEA Treaties

Observations: Annual	Source type		
Variables	Non-Haven (1)	Exo-Haven (2)	Core-Haven (3)
Treaty: TIEA	-0.1041 ***	-0.0946	0.0335
Lag_Link	0.2079 ***	0.2225 ***	0.2698 ***
Host_Ln_GDP_pc	-0.0266	-0.0268	0.0139
Host_Ln_Pop	0.2552 ***	0.2242 *	0.7793 ***
Host_Gov_Index	0.1605 ***	0.1967 **	0.2486 **
Source_Ln_GDP_pc	-0.016	-0.0031	-0.0507
Source_Ln_Pop	0.0003	-0.2425 *	-0.2448
Source_Gov_Index	0.0186	-0.0287	0.0145
Lag_Host_Eigencentrality	0.2346 ***	0.3354 ***	0.284 ***
Observations	11,020	3,260	1,720
Number of country pairs	551	163	86
Number of years	20	20	20
Country-pair fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Adj. R–Squared	0.0599	0.1111	0.2188

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Notes: Panel Data with Logit Link Function, where the p-values are based on robust standard errors. The dependent dichotomous variable measures the existence or non-existence of a link formation between source i and host j at time t. The sample period goes from January 1996 to December 2015. The variable of interest, *Treaty*, measures the presence of a Tax Information Exchange Agreement (TIEA) treaty between source i and host j at time $t-1$, differentiating by source type. Additionally, the regressor *Lag_Host_Eigencentrality* measures the lagged eigencentrality of the target destination as an endogenous characteristic of the network to test for robustness. Moreover, 60 observations and 3 country-pairs (BVI-MNE, PMA-MNE, PMA-NRU) where not taken into account for this model as NRU and MNE are not classified: there is not enough covariate information available for either country.

Table 9: Panel Data Regression of Link Formation on TIEA Treaties

Observations: Annual	Source type		
Variables	Non-Haven (1)	Exo-Haven (2)	Core-Haven (3)
Treaty: TIEA	-0.0933 **	-0.0795	0.0255
Lag_Link	0.2033 ***	0.2335 ***	0.2987 ***
Host_Ln_GDP_pc	-0.0269	-0.029	0.016
Host_Ln_Pop	0.3014 ***	0.2744 *	0.8363 ***
Host_Gov_Index	0.1876 ***	0.2497 ***	0.2831 **
Source_Ln_GDP_pc	-0.0136	0.0083	-0.0456
Source_Ln_Pop	0.0131	-0.2037 .	-0.2007
Source_Gov_Index	0.0192	-0.0397	0.0119
Lag_Host_Degree	0.0036 ***	0.0046 ***	0.0035 **
Observations	11,020	3,260	1,720
Number of country pairs	551	163	86
Number of years	20	20	20
Country-pair fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Adj. R–Squared	0.0611	0.1054	0.2137

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Notes: Panel Data with Logit Link Function, where the p-values are based on robust standard errors. The dependent dichotomous variable measures the existence or non-existence of a link formation between source i and host j at time t. The sample period goes from January 1996 to December 2015. The variable of interest, *Treaty*, measures the presence of a Tax Information Exchange Agreement (TIEA) treaty between source i and host j at time $t-1$, differentiating by source type. Additionally, the regressor *Lag_Host_Degree* measures the lagged degree-centrality of the target destination as an endogenous characteristic of the network to test for robustness. Moreover, 60 observations and 3 country-pairs (BVI-MNE, PMA-MNE, PMA-NRU) where not taken into account for this model as NRU and MNE are not classified: there is not enough covariate information available for either country.

Table 10: Panel Data Regression of Link Formation on Tax Treaties

Observations: Monthly	Sources: All		
Variables	Any treaty (1)	TIEA (2)	DTC (3)
Treaty: Any	-0.0155		
Treaty: TIEA		-0.0335 **	
Treaty: DTC			0.0203
Lag_Link	0.2782 ***	0.2779 ***	0.2783 ***
Host_Ln_GDP_pc	0.0186 *	0.0172 .	0.0168 .
Host_Ln_Pop	0.1567 ***	0.1623 ***	0.1531 ***
Host_Gov_Index	0.0674 ***	0.0658 ***	0.0675 ***
Source_Ln_GDP_pc	-0.0223 **	-0.0222 **	-0.0224 **
Source_Ln_Pop	0.0031	0.0012	0.0002
Source_Gov_Index	0.0262	0.0248	0.0264
Observations	192,720	192,720	192,720
Number of country pairs	803	803	803
Number of years	20	20	20
Country-pair fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
0.0809	0.0811	0.0809	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Notes: Panel Data with Logit Link Function, where the p-values are based on robust standard errors. The dependent dichotomous variable measures the existence or non-existence of a link formation between source i and host j at time t. The sample period goes from January 1996 to December 2015. The three variables of interest, *Treaty*, measure the presence of a signed tax treaty between source i and host j at time $t-1$, specified by type of convention.

Table 11: Panel Data Regression of Link Formation on TIEA Treaties

Observations: Monthly	Source type		
Variables	Non-Haven (1)	Exo-Haven (2)	Core-Haven (3)
Treaty: TIEA	-0.0379 **	-0.065 .	0.0266
Lag_Link	0.2493 ***	0.2918 ***	0.3308 ***
Host_Ln_GDP_pc	0.0156 .	0.0238	0.0589
Host_Ln_Pop	0.1295 ***	0.1328 .	0.458 ***
Host_Gov_Index	0.0587 ***	0.0724 **	0.0957 *
Source_Ln_GDP_pc	-0.0135	-0.0619 *	-0.0454
Source_Ln_Pop	0.0352	0.0034	-0.2719 .
Source_Gov_Index	0.0067	0.0124	0.0682
Observations	132,240	36,960	22,800
Number of country pairs	551	154	95
Number of years	20	20	20
Country-pair fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Adj. R–Squared	0.0654	0.0925	0.1386

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Notes: Panel Data with Logit Link Function, where the p-values are based on robust standard errors. The dependent dichotomous variable measures the existence or non-existence of a link formation between source i and host j at time t. The sample period goes from January 1996 to December 2015. The variable of interest, *Treaty*, measures the presence of a Tax Information Exchange Agreement (TIEA) treaty between source i and host j at time $t-1$, differentiating by source type. Moreover, 720 observations and 3 country-pairs (BVI-MNE, PMA-MNE, PMA-NRU) where not taken into account for this model as NRU and MNE are not classified: there is not enough covariate information available for either country.

Appendix C. Summary of jurisdictions

Table 12: Summary of Jurisdictions

Code	Jurisdiction	Status	Code	Jurisdiction	Status
ALB	Albania		CHL	Chile	
ASM	American Samoa		CHN	China	
AND	Andorra	H	COL	Colombia	
AGO	Angola		COK	Cook Islands	H
ANG	Anguilla	H	CRI	Costa Rica	
ATG	Antigua and Barbuda	H	CIV	Cote d'Ivoire	
ARG	Argentina		HRV	Croatia	
ABW	Aruba		CUB	Cuba	
AUS	Australia		CUW	Curacao	H
AUT	Austria		CYP	Cyprus	H
AZE	Azerbaijan		CZE	Czech Republic	
BAH	Bahamas	H	DNK	Denmark	
BHR	Bahrain	H	DJI	Djibouti	
BGD	Bangladesh		DMA	Dominica	H
BRB	Barbados	H	DOM	Dominican Republic	
BLR	Belarus		ECU	Ecuador	
BEL	Belgium		EGY	Egypt	
BLZ	Belize	H	SLV	El Salvador	
BMU	Bermuda	H	EST	Estonia	
BOL	Bolivia		FIN	Finland	
BWA	Botswana		FRA	France	
BRA	Brazil		GEO	Georgia	
BVI	British Virgin Islands	H	DEU	Germany	
BRN	Brunei		GHA	Ghana	
BGR	Bulgaria		GIB	Gibraltar	H
CMR	Cameroon		GRC	Greece	
CAN	Canada		GUM	Guam	
CYM	Cayman Islands	H	GTM	Guatemala	
CAF	Central African Republic		GGY	Guernsey	H
TCD	Chad		HTI	Haiti	

Code	Jurisdiction	Status
HND	Honduras	
HKG	Hong Kong	H
HUN	Hungary	
ISL	Iceland	
IND	India	
IDN	Indonesia	
IRN	Iran	
IRL	Ireland	H
IOM	Isle Of Man	H
ISR	Israel	
ITA	Italy	
JAM	Jamaica	
JPN	Japan	
JSY	Jersey	H
JOR	Jordan	H
KAZ	Kazakhstan	
KEN	Kenya	
KWT	Kuwait	
LVA	Latvia	
LBN	Lebanon	H
LSO	Lesotho	
LBY	Libya	
LIE	Liechtenstein	H
LTU	Lithuania	
LUX	Luxembourg	H
MAC	Macao	H
MKD	Macedonia	
MYS	Malaysia	
MLI	Mali	
MLT	Malta	H

Code	Jurisdiction	Status
MUS	Mauritius	
MEX	Mexico	
MDA	Moldova	
MCO	Monaco	H
MAR	Morocco	
MOZ	Mozambique	
NAM	Namibia	
NLD	Netherlands	
NEV	Nevada	
NZL	New Zealand	
NIC	Nicaragua	
NGA	Nigeria	
NIU	Niue	
NOR	Norway	
OMN	Oman	
PMA	Panama	H
PRY	Paraguay	
PER	Peru	
PHL	Philippines	
POL	Poland	
PRT	Portugal	
PRI	Puerto Rico	
QAT	Qatar	
ROU	Romania	
RUS	Russia	
KNA	Saint Kitts and Nevis	H
LCA	Saint Lucia	H
VCT	Saint Vincent and the Grenadines	H
SAM	Samoa	
SAU	Saudi Arabia	

Code	Jurisdiction	Status
SEN	Senegal	
SEY	Seychelles	
SGP	Singapore	H
SXM	Sint Maarten (Dutch part)	H
SVK	Slovakia	
SVN	Slovenia	
ZAF	South Africa	
KOR	South Korea	
ESP	Spain	
LKA	Sri Lanka	
SWE	Sweden	
CHE	Switzerland	H
SYR	Syria	
TWN	Taiwan	
TZA	Tanzania	
THA	Thailand	
TTO	Trinidad and Tobago	
TUN	Tunisia	
TUR	Turkey	
TCA	Turks and Caicos Islands	H
VIR	U.S. Virgin Islands	
UKR	Ukraine	
ARE	United Arab Emirates	
GBR	United Kingdom	
USA	United States	
URY	Uruguay	
UZB	Uzbekistan	
VUT	Vanuatu	H
VEN	Venezuela	
VNM	Viet Nam	
WYO	Wyoming	
YEM	Yemen	
ZMB	Zambia	
ZWE	Zimbabwe	

**The status of Haven is understood in the sense of Dharmapala and Hines (2009).

Appendix D. Key characteristics of tax havens

Tax havens may be understood as countries or jurisdictions that have either no-tax or very low tax regimes, particularly for corporate revenues and personal income. Moreover, such nations tend not to comply with international authorities regarding the exchange of tax information. Also, they account for a lack of transparency and a heightened sense of protectionism for the financial information of the people registered inside their jurisdiction. Fiscal paradises benefit directly from having companies registered inside their domains even if the tax levied on them is low; fees are collected upon registration, licensing and annual renewals.

An International Business Corporation (IBC) may be considered an offshore legal entity registered as a company in a jurisdiction where it is exempted of paying local corporate taxes and stamp duties (taxes levied on legal documents), not required to appoint local directors, and is allowed to preserve the confidentiality of the beneficial proprietor of the company. Some jurisdictions, as the case for Luxembourg, waive the withholding tax, or retention tax, levied by government to the payer of employment income, dividends and interests.

The purpose of the current subsection is to briefly explore the characteristics of each tax haven employed by Mossack-Fonseca and understand why these jurisdictions are usually considered fiscal paradises, utilizing recent information gathered from Gleeson (2018).

Niue: 1,470 inhabitans, small island in the Pacific, GDP of 15 million USD per year, employs the New Zealand Dollar. This country has a good political stability and a British legal system. International Business Companies located here have no tax duties and do not need to pay for offshore profits. IBC's are not required to file annual reports, require a single director (which may well be overseas) and demand in return a simple yearly fee of 150 USD. Nonetheless, Niue is not a 'credible' fiscal paradise as it is currently a nation that receives aid from New Zealand.

Seychelles: 92,000 inhabitants, GDP of 2.6 billion USD, Indian Ocean island. Seychelles does not tax income nor profits from financial entities. Corporations may be established in less than 24 hours while paying only an annual fee of 100 USD, regardless of the corporation's size. Identities and personal details of the beneficial owners are not recorded publicly and companies are exempt from stamp duties on all transactions.

Costa Rica: It is a Spanish speaking, non-island, country with 4.9 million inhabitants and a 57 billion USD annual GDP and its own currency (Colon). Costa Rica offers a 100% exemption of corporate income tax for eight-years on newly registered companies.

Belize: 387,000 inhabitants, 1.8 billion USD annual GDP, Belize dollar, English-speaking, non-island, British legal origins.A license to operate in Belize without any reporting duties may be registered in matter of hours. Belize does not charge taxes on earning from abroad, including dividends, capital gains, revenues and interests.

Hong Kong: A small country with a 412 billion USD annual GDP and a population of 7.3 million. Hong Kong taxes income source-based and not residential-based, therefore they would only tax income generated in Hong Kong and not the one produced elsewhere. The country itself is then an ideal node for profit shifting and re-wiring financial activities.This property might have placed Hong Kong as the middle-man of a large fraction of financial intermediation.

New Zealand (Cook Islands): Cook Islands are in free association with New Zealand. Fifteen islands with a GDP of 292 million USD and a population of about 13,000 people. Cook Islands are know for generally disregarding international courts, no taxes on offshore profits and very strict laws restricting international authorities to gain access to any type of financial information; moreover, no registry on any company may be obtained by international law enforces without the consent of the company itself (unless there is a criminal offense pending). The requirements to open an account are one director and one shareholder which may have their meetings anywhere in the world, without submitting any reports and simply paying an annual fee of 300 USD.

Luxembourg and Switzerland: Holding companies are worldwide known financial institutions incorporated in Luxembourg and Switzerland with subsidiaries in other jurisdictions. Such corporations are allowed to carry on offshore activities exempted from paying taxes on capital gains and on dividends. Moreover, there are no withholding taxes applied whenever the beneficiary is incorporated inside the European Union. Lastly, the names of these corporate beneficiary owners are not required to be declared.

Bahrain: Arabic-speaking country with 1.4 million persons and 48.5 billion USD annual GDP. This jurisdiction does not have any tax system at all, meaning that there is no legislation, no auditors and no tax reports. Therefore, Bahrain does not tax inheritances, corporate profits, income from renting real estate nor capital gains.

Andorra: Landlocked nation with 77,000 persons and a GDP of 3.3 billion USD; this country does not tax wealth, capital gains, inheritance nor gifts. Prior to 2015, there was no income tax, however a minor levy on income was installed in 2015.

Cyprus: This Mediterranean island of 1.1 million people and a GDP of 30 billion USD commenced to tax corporations at a rate of 2.5% since 2013 and joined the OECD Automatic Exchange of Financial Information in Tax Matters in 2017, which took away the island's tax haven status.

United Arab Emirates (Dubai): With a population of 2.8 million and a GDP of 360 billion USD, this jurisdiction does not account for any type of taxes: corporate, withholding or personal. Income is taxed nominally at a zero percent tax rate.

Barbados: An English-speaking, British legal system, Barbadian dollar user, Caribbean island of 277,821 people and 4.6 billion USD gdp, Barbados is a well regulated tax haven with very low taxes on profits of less than 2.5%; however, capital gains and dividends are exempt from taxes.

Bahamas: This collection of islands with its own currency, Bahamian dollar, are inhabited by 372 thousand people and possess an annual GDP of 7.4 billion USD. The islands does not levies corporate taxes, capital gains, income tax nor wealth tax; however, there are license fees, stamp duties and property taxes.

United Kingdom (Bermuda, Cayman Islands, Gibraltar, Isle of Man, Jersey, Anguilla and British Virgin Islands) All the following are either Crown dependencies or British Overseas Territories or with their own currency, English-speaking, with British legal origins, very small population and a considerably high GDP per capita.

Bermuda: GDP of 5.6 billion USD per year and a population of 65 thousand citizens. This jurisdiction, which employs minimal standards of regulations and business laws, hosts 400 international insurance companies and is a popular tax destination; moreover, there are no income nor corporate taxes in this island.

Cayman Islands: 3.3 billion USD annual GDP with a population of 56 thousand people, yet manages over 36 billion USD on assets. Regarded as one of the most popular tax havens, hosting offices for 40 of the 50 largest banks in the world, the Cayman Islands do not collect taxes on income, capital gains, nor on wealth. Over 10 thousand hedge funds have been registered inside this jurisdiction.

Gibraltar: 32,000 inhabitants and 2 billion USD of annual GDP, Gibraltar is a low tax haven which also benefits from tourism. Irrespectively if the income is domestic or offshore, corporations are taxed at a 10% rate, whereas capital gains, inheritance, wealth, sales and estates are not taxed. Estimates sustain Gibraltar earns more than 100 million pounds each year for concept of corporate taxation. Moreover, Gibraltar is very jealous of its secrecy and places itself as a well-reputed tax destination.

Isle of Man: A self-governing Crown dependency with 85,000 persons and a 4.5 billion USD annual economy, this island has no wealth, capital gains not inheritance tax. Individual income tax is capped and never higher than 20%, there are no stamp duties and there is a zero percent nominal corporate tax rate (except for rental income and domestic banking profits, which are taxed at a 10% rate).

Jersey: A UK Crown dependency with 6 billion USD annual GDP and 100 thousand people, Jersey has zero corporate tax on all non-financial institutions and a 10% tax rate on the former; utilities are taxed a 20% rate. Recently, Jersey agreed to share information about financial activity with the US, UK and the EU.

Anguilla: 311 million USD annual GDP economy and a population shy of 15,000. The island does not tax individual or corporate profits, capital gains nor estate. However, in 2011 they installed a temporary 3% income tax to stabilize the nation's deficit.

British Virgin Islands: 28,000 inhabitants and an annual GDP of 853 million USD follows a nominal tax rate of 0% over income. Moreover, no tax is levied on capital gains, sales, value added, profit, inheritance, estate, gifts nor corporate tax.

Liechtenstein: Recurring to the Swiss franc, this landlocked European country with less than 38,000 inhabitants and a 5.3 billion USD annual GDP is one of the richest countries per capita in the world. Entities incorporated in this jurisdiction pay no income taxes, so long they carry their commercial and economic enterprises elsewhere, limiting the domestic activities of institutions to manage assets and investments. A nominal annual tax of 0.1% is levied on the capital reserves of companies domiciled in the country.

United States (Delaware, Wyoming and Nevada): Delaware has no state taxes on income, corporate or sales profits. Any person, American or not, may operate anonymously through a listing agent in Delaware, paying about 350 USD on annual license and fees, without having to pay taxes on any earnings, inheritance nor capital gains. Nevada does not have an IRS information sharing agreement, does not levy state taxes, accounts for extreme secrecy, and asks for minimal reporting and disclosing, where stockholders' names are not on public record.

Uruguay: Employing the Uruguayan peso, this Latin American country of 3.5 million inhabitants accounts for an annual GDP of 78 billion USD. Although there is 25% corporate tax, it is only levied on income generated inside the country and all the financial flows brought from abroad are not taxed. Moreover, the jurisdiction holds several free trade zones where entities are exempted to pay local taxes as well. Lastly, Uruguay holds a high standard of bank secrecy.

Panama: This Latin American country with 4 million inhabitants and an annual GDP of 63 billion USD, holding its own currency Balboa, jumped to fame after the leak of 11.5 million very sensible financial documents in 2015. Panama has a corporate tax of 25% for local enterprises, while it offers a full tax exemption for offshore entities that carry out the entirety of their economic activities outside Panama. This jurisdiction has a strict financial secrecy, with no limits on currency exchanges and no requirement for corporate shareholders to publicly record their identities.