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**HOW TO ENFORCE VALUE-ADDED TAX?
THE ROLE OF INTER-SECTORAL LINKAGES**

By

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How to Enforce Value-Added Tax? the Role of Inter-sectoral Linkages

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Abstract

This paper models and empirically tests a self-enforcing feature of the value added tax (VAT) which is absent in the theory: An incentive that makes formal traders buy from suppliers who pay VAT too. In addition, it explores how the government can deploy this feature to enforce VAT more efficiently by reallocating the enforcement spendings among different sectors. The results suggest that the government should identify the non-compliant firms more strictly in the backwardly linked sectors –which buy their inputs from the others– and focus on revealing within-firm information. In contrast, in forwardly linked industries, the government should zoom on double checking the transaction records with the corresponding input credit claims. Empirical evidence from Indian service sector enterprises strongly confirms the existence of VAT self-enforcement effect, even in the absence of government punishments.

Keywords: Value-added tax, Informality, Tax enforcement, Linkage analysis

JEL code: H26

1 Introduction

Value added tax (VAT) has been an essential element of tax reform since its first establishment in 1950s. It is now adopted in near 140 countries and many of them are among the poorest, thus its optimal design is a key challenge especially for developing countries. Recent studies in public economics model VAT from different angles. Some, on more broad level, compare the efficiency of VAT to the other indirect taxes like tariff and RST (e.g. [Emran and Stiglitz \[2005\]](#)), while others concentrate on its optimal policies like rates and exemption levels (e.g. [Keen and Mintz \[2004\]](#)). However, to date, little research has been focused on VAT evasion and avoidance and this area is almost neglected by theorists. Basically, VAT has a self-enforcing feature in the sense that each formal trader wants its supplier to be formal too, because it needs a proper VAT invoice for getting input credit. By modeling the feature, this paper sheds new light on optimal tax enforcement under a VAT system. It shows how the government can make VAT less vulnerable to fraud and evasion by designing the optimal allocation of enforcement among different activities. Hence, this paper focuses on how VAT administration should behave to maximize revenue given enforcement is costly.

As a first shot, I present a stylized fact from the UK economy. Figure 1 illustrates VAT collection efficiency defined as $\frac{\text{VAT revenue}}{\text{Value-Added} \times \text{VAT rate}}$ among different UK activities versus the share of final consumption in each sector.¹ It can be clearly seen that there is negative relationship between VAT efficiency and the share of final

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¹The data and its sources are described in the appendix B.1.

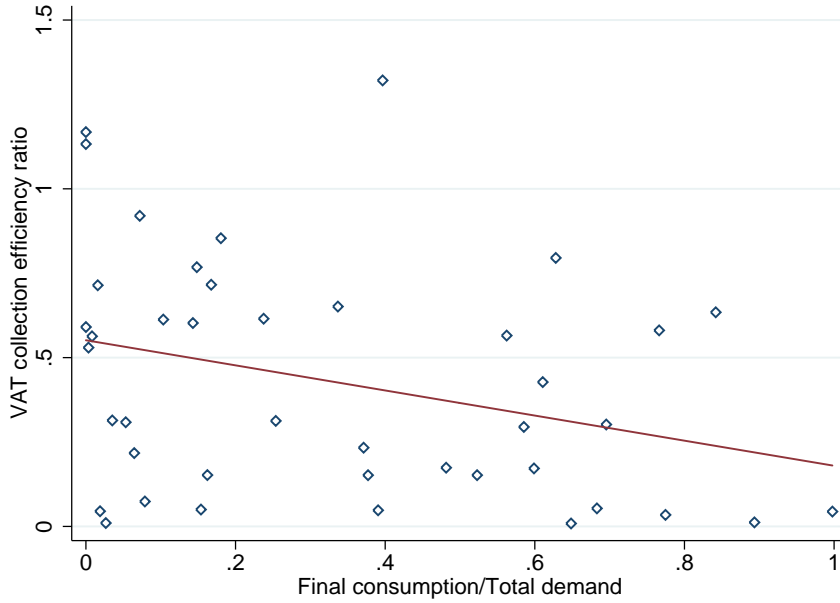


Figure 1: VAT collection efficiency defined as $\frac{\text{VAT revenue}}{\text{Value-Added} \times \text{VAT rate}}$ and final consumption in different UK activities, tax year 2006-07. See Appendix B.1 for data details.

consumption in a sector. One of the possible explanations for this can be a self-enforcing feature in VAT, in the sense that sectors with more business-to-business (less business-to-household) transactions comply more. Consequently, one can question how the optimal enforcement policy changes across different activities? This paper analyses this question in detail and tries to find an answer for that.

The aim of this paper is to construct a model and perform an analysis of the optimal VAT enforcement policy. I start with an input-output (I-O) model and define forward and backward linkages in that setting. Moreover, I elaborate how the government can fight informality and explain cross-checking invoices –matching each input credit claim with a corresponding output tax payment– as a distinct enforcement tool in a VAT system. The results suggest that in each sector, the optimal government enforcement is positively associated with the backward linkages of that sector. Furthermore, the government should focus on revealing internal information of the firms by policies like rewards to whistle blower. In comparison, in the forwardly linked industries the government should concentrate on arm-length transactions and double checking the invoice with the corresponding input credit claim. In the next step, I show that the results of the model are robust to relaxing Leontief production function assumption and assuming a general CES function. Finally, I examine the existence of self-enforcing feature of VAT using Indian service sector data of over 54,000 enterprises. The results confirm a positive relationship between activity’s forward linkages and VAT registration even when firms are not obliged to register. Such a relationship is not significant for backward linkages.

The nexus of indirect tax policy and the size of the informal sector has been the subject of a number of contributions in the literature. [Emran and Stiglitz \[2005\]](#) study the inefficiencies of VAT compared to tariff in an economy with a large informal sector. They argue that the standard policies to replace trade taxes with

VAT reduces welfare under plausible assumptions, given the size of informal market in developing countries. Their arguments based on the assumption that the informal sector may escape from paying VAT, but cannot avoid border taxes. The follow-up by Keen [2008] argues that Emran and Stiglitz [2005] undervalue the power of VAT to absorb revenue under large informal sector by neglecting the intermediate inputs in the production side of the economy. He explores the function of VAT as a tax on the inputs of the informal sector because non-compliant firms are unable to recover the VAT paid on the inputs bought from compliant firms. However, he mentions that the existence of a large informal sector can invalidate the conventional policies on replacing trade taxes with VAT and the ability of the government to reduce informality can shift the optimal policy toward VAT. For modeling informality, this paper uses a same framework as Emran and Stiglitz [2005] and Keen [2008], in the sense that the number of formal and informal firms are given, while informal producers set their production level according to the tax rate and enforcement policies. The empirical evidence in this field also emphasizes the importance of an efficient design and administration of VAT especially in developing economies. Baunsgaard and Keen [2010] in a panel study of 117 countries, show that recovering the loss in trade taxes with VAT has failed in low income countries in spite of its success in the developed world. This paper, although does not directly discuss trade taxes, gives straightforward policy recommendations to solve the enforcement inefficiencies in VAT for overcoming the problem of revenue loss in replacing border tax with domestic sources.

On the tax enforcement side, the literature points to the close connection between tax administration efficiency and information gaps –for a survey see Slemrod and Yitzhaki [2002]. Kopczuk and Slemrod [2006] study the role of the firm in tax enforcement theory especially its function to provide information. They argue that arms-length transactions between firms and the ability of the government to check the verifiable information records considerably alleviates tax enforcement. For this reason, they show in a simple model that VAT has a great administrative advantage to retail sales tax (RST) that possess no business-to-business transactions records. This paper also emphasizes the importance of arms-length transaction records as a valuable information source for the VAT administration. In addition, based on Figure 1, here I argue that as long as the share of arms-length transactions is not the same across activities, the optimal enforcement policy also differs among them. Next, I link this variation with inter-sectoral linkages and find the optimal policies by taking such differences into consideration.

The second role of the firm in tax enforcement is providing information through third party reporting. Kleven et al. [2009] use this function of the firm to answer why governments can tax so much nowadays. They indicate that the standard tax evasion models like Allingham and Sandmo [1972] fail to explain the high level of tax compliance in the developed world, given the low enforcement by governments. In order to address this issue, they argue that generally a firm can collude with its employees to un- or under-report its income to the government, but in practice such collusion is fragile when the firm is big with a large number of employees. One reason for breaking the collusion is random shocks due to unintentional mistakes or conflicts

within firm, another can be rational whistle blowing due to the rewards by the government. In this paper, I take this function into consideration by linking the probability of detection of informal firms to the number of their employees. In comparison to [Kopczuk and Slemrod \[2006\]](#) who emphasize the importance of inter-firm information networks, [Kleven et al. \[2009\]](#) focus on intra-firm information sources. The key advantage of VAT is enabling the government to use both of these information sources for detecting fraud and evasion. Therefore, this paper presents the optimal policy for VAT enforcement by putting together two instruments for revealing firms' true information: checking arms-length transactions and third party reporting.

The bulk of other papers that address the role of the firm in tax enforcement just focus on the direct taxes and the role of firms in indirect taxation, for the most part, is absent from the literature. Nevertheless, linking between consumers and the government, firms are crucial players for the proper payment of indirect taxes like VAT. To the best of my knowledge, there is no other paper modeling the role of inter-sectoral linkages in designing the tax enforcement system, in particular VAT. The most related paper to this is [De Paula and Scheinkman \[2010\]](#) who address the informality problem in a VAT setting. They consider a model in which firms have different managerial abilities and assume that above a cut-off production informal firms are detected by the government. In this setting, they show that low ability firms remain small and informal, but high abilities become formal to produce with no restriction. Then, they indicate that under VAT, (in)formal firms trade with their (in)formal peers in the production chain not the other type. Their results are based on variation in managerial ability and are silent about the industry in which the firm works. In comparison, this paper looks from a different point of view by assuming the same ability for all managers, but different sectors in which a firm can work. This approach has a great practical advantage since instead of relying on unobservable variables like ability and entrepreneurship, it addresses the optimal tax agency's policy in each sector based on measurable characteristics like linkages and connections with the other sectors.

The findings of this paper contribute to the tax enforcement literature and have important policy implications. They show how with the same level of effort, policymakers can raise VAT revenue by reallocating their enforcement among different activities. Backwardly linked sectors that are usually at the bottom of production chains should be the first objective for revealing internal information of firms by policies like higher audit rate and reward to whistle-blowers. On the other hand, forwardly linked industries, normally located up the production chain, are the best objectives for invoice cross-checking. Finally, the most enforcement expenditure should be spent in sectors with strong involvement in production networks and the least spendings –and maybe exemptions– should be dedicated to the sector with no linkage with others.

Before proceeding, some caveats are in place. While this paper models the informal firms' decisions, it assumes that such decision is an internal maximum of profit function. However, if the demand of the sector imposes a binding condition, a corner solution can be optimal and the informal firms may choose other strategies like matching or vertical integration. Moreover, the formal firms can react to an evading firm differently, but here they all act the same. Although these issues do not change the overall results, in a follow

up paper (Hoseini [2013]), they are studied in detail and the potential complementary policies are presented there. At a broader level, the model in this paper ignores some issues regarding VAT enforcement such as under-reported sales, multiple rates and misclassification of commodities which are mentioned in Smith and Keen [2006]. It also dismisses benefits of formality which are stressed in the literature like access to finance and legal institutions. Considering these issues should not change the qualitative implications of the model, which just focus on VAT collection efficiency from the view point of inter-industry connections and networks.

This paper is organized as follows. Section 2, constructs the basic model and explains government's enforcement strategies. Next, in section 3, I look into the optimal enforcement policy in each sector and section 4, extends the basic model to a general CES production function. In the section 5, I empirically examine the existence of the self-enforcing feature and finally, I conclude.

2 The Basic Model

Consider an input-output (I-O) economy with $n = 1, \dots, N$ competitive sectors each producing a homogeneous and unique product x_n . Each product can either be used as an input of other sectors or be consumed by final consumers. The production technology of all sectors is a Leontief function;² its elements are labor as the source of value added³ and intermediate inputs. For each unit of x_n , a_{kn} units of x_k and a_{Ln} units of labor are necessary. So if x_{kn} is the amount of x_k that is used for the production of x_n , we have $x_{kn} = a_{kn}x_n$. The labor market is competitive and labor is the numeraire so that the wage rate can be normalized to one.

In equilibrium, each product is traded by a price p_n and consumer demand in each sector x_{n0} is constant and inelastic.⁴ Thus, one can write total representative production of sector n as

$$x_n = x_{n0} + \sum_{k=1}^N a_{nk}x_k \quad (1)$$

Putting wage at unity, the profit of a firm in sector n will be

$$\pi_n = p_n x_n - \sum_{k=1}^N p_k a_{kn} x_n - a_{Ln} x_n \quad (2)$$

Since all markets are competitive, we can write

$$p_n = \sum_{k=1}^N p_k a_{kn} + a_{Ln} \quad (3)$$

To find the equilibrium price and quantity, I employ vectors X , P , and A_L with dimensionality $N \times 1$ containing

²Later, I will extend the model for a general CES function with elasticity ε_n

³Here, labor represents all inputs other than intermediate goods. More general assumption is entering labor and capital or other factors of value-added in the production function and using $k_n^\alpha l_n^{1-\alpha}$ instead of l_n , but it does not change any result of the model.

⁴This paper models the behavior of a taxation agency and welfare concerns are not the goal here. Therefore, I assume a fixed final consumption in each sector. However, assuming an elastic demand function for households does not change the results.

x_n , p_n , and a_{Ln} respectively, together with an $N \times N$ matrix \mathbf{A} built by a_{kn} as elements.⁵ Then (1) is written as

$$X = \mathbf{A}X + X_0 \quad (4)$$

and

$$X = (\mathbf{I} - \mathbf{A})^{-1}X_0. \quad (5)$$

Similarly from (3), we have

$$P = (\mathbf{I} - \mathbf{A}')^{-1}A_L \quad (6)$$

where \mathbf{A}' is the transpose of \mathbf{A} . Since the final demand is always nonnegative ($X_0 > 0$), (4) imposes that $\mathbf{A}X < X$. In this case, the Leontief inverse in (5) always exists and there is unique equilibrium X :

Theorem 1. *Matrix \mathbf{A} is square and nonnegative, then*

$$\mathbf{A}V < V \Leftrightarrow (\mathbf{I} - \mathbf{A})^{-1} = \sum_{m=0}^{\infty} \mathbf{A}^m$$

for some column vector $V \geq 0$.

Proof. See [Ten Raa \[2006\]](#), theorem 2.2. □

Theorem 1 states that if the technology matrix \mathbf{A} is capable of producing a positive output X such that $\mathbf{A}V < V$, the Leontief inverse exists. Then, $X = (\mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \dots)X_0$ where $\mathbf{A}^m X_0$ is the indirect effect of final consumption X_0 in rising production of X through m intermediate goods in between.

2.1 Adding VAT

Regarding taxation, consider the government imposes a uniform VAT rate t and fines all unregistered firms who had to be registered according to the law.⁶ The ad valorem tax in sector n is added to its market price p_n , in the sense that registered firms charge tax on their sales and issue the corresponding invoices to the buyers, who if registered can use this invoice to refund against their own tax liability. Unregistered firms, on the other hand, buy and sell at tax inclusive price, but they do not pay any tax to the government. For coexistence of formal and informal⁷ markets, consistent with [Keen \[2008\]](#), I assume that the number of formal and informal firms are given but they decide about their level of production. The production function is constant returns to scale (CRS) for formals and decreasing returns to scale (DRS) for the informals as a result of the expected fine by the government.⁸

⁵Throughout the paper, lower-case letters like x denotes a scalar, upper-case like X a vector, and bold upper-case like \mathbf{X} a matrix.

⁶At the moment, I assume VAT registration is compulsory for all firms in all sectors. Later, we relax this assumption and add registration threshold to the model.

⁷From now on, by formal (informal), I mean registered and fully tax compliant (unregistered) under VAT.

⁸I ignore the possibility of misreporting in the formal sector. However, one can assume each representative firm sells one part of its production in the formal market (x_n^f) and one part in the informal (x_n^i). In this case, as shown below, if the expected fine of producing x_n^i is the same as an informal firm with that level of production, the results do not change.

To make it more clear, as an example, consider a simple production chain for a final good R with three stages: input supplier (S), manufacturer (M), and retailer (R) such that their pre-tax prices are p_S , p_M , and p_R respectively. We can illustrate the value chain as $0 \xrightarrow{S} p_S \xrightarrow{M} p_M \xrightarrow{R} p_R$. Therefore, at the first stage, one unit of S transforms to one unit of M and then, at the second stage, the new product changes to one unit of final consumer good R. Table 1 shows the balance sheet of each sector if they register under VAT or not:

sector	output price	input price	tax payment	profit
S^f	$p_S + tp_S$	0	$tp_S x_S^f$	$p_S x_S^f$
M^f	$p_M + tp_M$	$p_S + tp_S$	$t(p_M - p_S)x_M^f$	$(p_M - p_S)x_M^f$
R^f	$p_R + tp_R$	$p_M + tp_M$	$t(p_R - p_M)x_R^f$	$(p_R - p_M)x_R^f$
S^i	$p_S + tp_S$	0	0	$(1+t)p_S x_S^i - c_S$
M^i	$p_M + tp_M$	$p_S + tp_S$	0	$(1+t)(p_M - p_S)x_M^i - c_M$
R^i	$p_R + tp_R$	$p_M + tp_M$	0	$(1+t)(p_R - p_M)x_R^i - c_R$

Table 1: Prices and revenues under VAT.

The superscript f represents formal sector and i informal. The main difference between the two groups is that informal firms put the tax payments in their pocket, but instead have a risk of punishment by the government c_n . In the general model with N sectors the same pattern holds. According to Table 1, tax earnings cancel out the payments of representative formal firms to the government, so it takes tax-exclusive prices to measure its profit

$$\pi_n^f = p_n x_n^f - \sum_{k=1}^N p_k a_{kn} x_n^f - a_{Ln} x_n^f, \quad x_n^f \geq 0 \quad (7)$$

which gives (3) as equilibrium prices.

Turning to the informal sector, Table 1 shows that informal firms benefit from evading VAT, but bear a cost c_n . If this cost is zero, formal firms stay out of the market and informal firms, having no restriction, supply all market demand. However, in reality, not registering for VAT creates a risk of being detected and punished by the government. Thus, I introduce a cost function c_n that shows the expected loss from VAT evasion. This cost function allows for the coexistence of formal and informal markets by making the production function of informal firms DRS. Since the production of formal firms is CRS, they are free to choose the level of production, but having a DRS production, informal firms choose a specific amount based on their optimization. On the other hand, the representative demand in each sector is given by (5). Thus, If the optimal production of informal firms is higher than total demand in a sector, informal firms supply all demand. Otherwise, they produce at the optimal level and formal firms produce the rest. Consequently, one can easily show that if final demand is high enough in all sector, the formal production is always nonzero.

Following to Allingham and Sandmo [1972], the literature on tax evasion normally assumes that the cost of evasion c_n depends on two factors. One is the value of the fine, reasonably proportional to the evasion e_n , and the other is the probability of a government audit ν_n –see Slemrod and Yitzhaki [2002] for a survey. In

this model, I enter these properties by the following simple form:

$$c_n(e_n, \nu_n) = \theta e_n \nu_n, \quad 0 \leq \nu_n \leq 1 \quad (8)$$

where $\theta > 1$, a penalty multiplier set by the government, is determined based on legal and political considerations. It should be greater than one, otherwise the marginal benefit of informality always beats its costs. Therefore, the profit function of a representative firm in the informal sector is written as

$$\pi_n^i = (1+t)p_n x_n^i - \sum_{k=1}^N (1+t)p_k a_{kn} x_n^i - a_{Ln} x_n^i - c_n, \quad x_n^i \geq 0. \quad (9)$$

Moreover, from (6) the amount of evasion e_n is equal to $t(p_n - \sum_k p_k a_{kn})x_n^i = ta_{Ln}x_n^i$. Hence, we can rewrite (9) as

$$\pi_n^i = ta_{Ln}x_n^i(1 - \theta\nu_n) \quad (10)$$

Under perfect competition, marginal return is equal to marginal cost, so the first order condition for a representative firm in the informal sector is

$$x_n^i \frac{\partial \nu_n^i}{\partial x_n^i} + \nu_n^i = \frac{1}{\theta} \quad (11)$$

The solution of (11) gives x_n^i which is the production of one informal firm in sector n . We are also able to find $x_n = x_n^f + x_n^i$ from (5), so (in)formality in sector n can be measured. To handle the matrix algebra, we can define $N \times N$ matrices \mathbf{X} , \mathbf{P} , etc. from the corresponding vectors in the sense that $\text{diag}(\mathbf{X}) = X$ and $X = \mathbf{X}J$, where J is a vector of ones (summation vector). Then the desired formality index would be $F = \mathbf{X}^{-1}X^f$ which has elements $f_n = x_n^f/x_n$. In the next step, I define a functional form for the detection probability.

2.2 Probability of detection

Before any further analysis, we need a reasonable assumption about the probability of detection ν_n . Broadly, there are two information sources for the government to check the business records. One is within-firm informations such as profit and wages, the other is external information, verifiable by another sources, such as transactions with other businesses and loans. I first explain these factors and how the government can react to them and then I define a functional form for this probability.

2.2.1 Firm size

On the intra-firm side, a crucial factor that determines tax evasion is the firm size. [Dharmapala et al. \[2011\]](#) argue that generally, enforcement of small firms may not be cost-efficient if there is fixed firm-level compliance

⁹Note that in each sector n , on the production side, we have two types of representative firms: formal and informal producing x_n^f and x_n^i respectively. On the consumption side, three types of customers exist: formal and informal firms and final consumers. Thus, we can write the accounting identity as $x_n^f + x_n^i = \sum_{k=1}^N a_{nk}(x_k^f + x_k^i) + x_{n0}$.

cost. For the purpose of this model, [Kleven et al. \[2009\]](#) show that although theoretically a firm can collude with its employees to unreport its tax liability, in practice, if the number of employees is large, maintaining such collusion becomes very difficult. They indicate this collusion may break for a number of reasons. The first set is a random shock due to unplanned events such as a conflict between employer and employee, moral concerns of a newly hired employee, or a mistake of an employee or employer to reveal the records to the government. The other reason can be rational whistle blowing because of a rewards by the government which is common in several countries.¹⁰ Next, [Kleven et al. \[2009\]](#) show that if the number of employees is large, collusion is fragile and easily breaks down by each of these reasons. Therefore, this third-party reporting dramatically improves tax enforcement of bigger firms. [De Paula and Scheinkman \[2010\]](#) also develop a model with a trade-off between paying taxes versus the firm size. They show that tax registration is positively associated with the revenue and the number of employees among Brazilian firms. To incorporate this effect in the probability function of an informal firm, I use the size of labor $a_{Ln}x_n^i$. However, we cannot use its absolute value, since the probability should always be between zero and one. Therefore, I divide this term by \bar{x}_L which represent the level of labor that collusion always breaks. I also assume that $\forall n, \bar{x}_L \geq x_n$ to ascertain that the probability is always less than one. Then, by defining $\bar{x}_{Ln} = \bar{x}_L/a_{Ln}$, the term $\frac{x_n^i}{\bar{x}_{Ln}}$ reflects the effect of firm size on the detection probability of an informal firm.

2.2.2 Firm-to-firm transactions

The second source of information for the government is the arm's-length transactions of the firm ([Kopczuk and Slemrod \[2006\]](#)). These transaction records enable the government to verify them with the accounts of their business partners. This source is especially a valuable enforcement tool for VAT in which firms are required to keep records of all sales and purchases. If the government has access to all transaction accounts of the formal firms and there is no under- or over-reporting, upstream sectors need to collude with all of their downstream businesses to evade VAT. This feature is well-documented in [De Paula and Scheinkman \[2010\]](#), where they show that under VAT, (in)formal firms trade with their (in)formal peers in the production chain. Moreover, VAT has a self-enforcement feature that creates an incentive for the formal firms to ensure their suppliers provide them invoices acceptable to the government. [Smith and Keen \[2006\]](#) indicate that the advocates of VAT imply

“VAT is self enforcing in the sense that each trader has an incentive to ensure that its suppliers have themselves properly paid VAT, in order that they themselves can claim an appropriate credit.”

In other word, before purchasing their input, formal firms would check whether the seller is registered for VAT and if not, there is a chance that they report the informal seller to the government. Although, as mentioned by [Smith and Keen \[2006\]](#), there is an element of truth here and this intrinsic feature should not be overstated, it does not exist in other types of taxes like RST. Moreover, note that the self-enforcement feature is a one-way

¹⁰[Kleven et al. \[2009\]](#) mention some example from OECD countries like the US and Japan.

effect from formal firms to their supplier not costumers. When buying, a formal firm cares about the supplier and requests invoice to send to the government for input credit. Then, the government can use the invoice to check whether the supplier is formal and if not fine the evading firm. However, when a formal firm sells a product, it issues the invoice irrespective of the buyer's type. If the new buyer is a formal firm, again it uses the invoice for input credit and the two records –formal seller's sale and formal buyer's purchase– enables the government to cross-check them together. Otherwise the invoice just informs that the product is sold,¹¹ regardless of whether the buyer is an informal firm or a final consumer. Thus, in this case, the government cannot distinguish between the ones that should be punished (informal firms) and not punished (final consumers).¹² To incorporate this feature in the detection probability, I utilize the share of formal firms purchase in total sales of sector n which is $\sum_{k=1}^N x_{nk}^f/x_n$. The idea is that the larger the relative size of formal buyers of a sector, the bigger the share of transactions that can be checked by the government. Hence, the detection probability is increasing in this index. Note that because both markets are perfectly competitive, a single informal firm cannot change x_n by changing its own production level. Thus, each firm takes x_n as given when optimizing profit.

Given the two government instruments, the reaction of informal firms should also be taken into account. To reduce trembling hand and whistle-blowing threats, informal firms can control their size. For the cross-checking risk, they should pay attention to their costumers' type. One possibility is not caring about the type of buyers and issuing a fake invoice if necessary which makes a risk of detection by cross-checking.¹³ The other one, imposing a search and commitment cost, is to find an informal buyer to contract with. In order to persuade the buyer to commit, the firm may suggest a lower price and share part of the VAT evasion with the buyer. Instead it insures itself against the transactional risk. Additionally, finding such costumer is more difficult in a sector with high level of formality, so I assume that the average matching cost for one unit of evasion is $\mu \sum_{k=1}^N x_{nk}^f/x_n$. Here, μ reflects two factors; one is the share of total evasion $ta_{Ln}x_n^i$ that the firm has to pay for satisfying the informal buyer to cooperate, second it reflects the cost of searching for and contracting with a reliable informal customer. Therefore, it is always positive and can be greater than one. Taking μ into consideration, the informal firm matches with a desired costumer and insures (part of) its transactions against cross-checking risk, if the cost of searching for and persuading an informal buyer is less than the expected risk of detection through that risk. Otherwise, it does not care about the type of its costumers.

I now elaborate how the government can utilize the two above information sources and then translate it to a mathematical probability function for ν_n . Some of the enforcement strategies are not specific to VAT

¹¹I assume that for each input credit, the government checks the corresponding sale's invoice. Thus, a formal firm can just get input credit for the sales that already have VAT payment invoice and no under-reporting is possible.

¹²If the final demand of a sector is zero, the government can detect the informal firms through the missing invoices. However, still the informal sector can survive cross-checking by matching together. This case is discussed in [Hoseini \[2013\]](#).

¹³I assume that formal firms are indifferent about the type of their supplier and always inform the government about them to get input credit. This assumption is relaxed in [Hoseini \[2013\]](#) where formal firms can also choose not to buy from informal firms and look for a formal supplier instead.

such as identification of unregistered firms and the rate of audits –which try to reveal within-firm information. But, as described above, a distinctive strategy for VAT is the cross-checking of the invoices which is nowadays more feasible with the advances in information technology. However, both of these strategies directly depends on the government expenditures and efforts for VAT enforcement. Thus, I assume that government policy in each sector is reflected in a function $\phi_n = \frac{g_n}{\bar{g}}$, where g_n is the government expenditure to enforce tax in sector n and \bar{g} is a fixed term to ensure $\phi_n \leq 1$. Altering across sectors, $0 \leq \phi_n \leq 1$ is the key policy variable and the government seeks to find its optimum allocation for maximizing net VAT revenue. The government also determines the share λ_n of the enforcement to dedicate for invoice cross-checking versus revealing insider information in each sector. This parameter determines the level of cross-checking which means how much the government tries to find and check the seller of x_n that a formal customer, requesting input credit, claims to buy from. It is less than a threshold level $\bar{\lambda} < 1$ because in reality, VAT implementation, similar to other types of tax, needs some core elements like identifying and auditing the firms. So the government can never put all of its efforts just on cross-checking and firms size always plays a role in detection ($\forall n : \lambda_n \leq \bar{\lambda}$).¹⁴

Hence, I can combine all of the above factors in the following functional form:

$$\nu_n = \phi_n \left((1 - \lambda_n) \frac{x_n^i}{\bar{x}_{Ln}} + \lambda_n \frac{\sum_{k=1}^N x_{nk}^f}{x_n} \right) \quad 0 \leq \phi_n \leq 1, \quad 0 \leq \lambda_n \leq \bar{\lambda}. \quad (12)$$

When the enforcement expenditure g_n in a sector n goes up, ϕ_n approaches one and the government finds the informal firms in that sector with a higher probability. Note that since $\sum_{k=1}^N x_{nk}^f + a_{Ln} x_n^i \leq x_n$ and $x_n \leq \bar{x}_L$, the probability is always less than 1. Assuming (12), we can write the cost of evasion in the informal sector as

$$c_n = \frac{\theta e_n (1 - \lambda_n) \phi_n \rho_n}{x_n} (x_n^i + 2\gamma_n \sum_{k=1}^N x_{nk}^f). \quad (13)$$

where $\rho_n = \frac{x_n}{\bar{x}_{Ln}}$ is the share of firms that are detected when the sector is completely informal and $\gamma_n = \frac{\lambda_n}{2(1 - \lambda_n)\rho_n}$ is defined for the sake of better mathematical illustration in below. The following proposition shows the relation between government enforcement and formality defined as $f_n = x_n^f/x_n$.

Proposition 1. *Under cost function (13),*

$$f_n = 1 - \frac{1}{2\theta\phi_n(1 - \lambda_n)\rho_n} + \sum_{k=1}^N \gamma_n a_{nk} \frac{x_k}{x_n} f_k \quad (14)$$

Proof. Appendix A.1 □

Since ϕ_n is directly associated with g_n , the Proposition 1 intuitively indicates that the government's attempt to find informal firms reduces the size of informal market. Moreover, note that because formality is

¹⁴Moreover, if $\bar{\lambda}_n$ represents the turning point that the cross-checking risk rise above the search and matching cost, the government is worse off from setting a λ_n above $\bar{\lambda}_n$ and chooses a policy that informal firms do not have incentive for search and contract. I will discuss it in Proposition 3.

always between zero and one, there can be a corner solution if $\phi_n < \frac{1}{2\theta}$.

2.3 Forward and Backward linkages

Proposition 1 indicates how formality in one sector is linked to formality in the other sectors. In this section, I define the concept of industrial linkages and show how they affect informality under VAT. To find the equilibrium formality, I employ vectors F , Φ^{-1} and J with dimensionality $N \times 1$ containing f_n , $\frac{1}{\phi_n(1-\lambda_n)\rho_n}$, and ones (summation vector) respectively; and $\mathbf{\Gamma}$ and \mathbf{X} diagonal $N \times N$ matrices with γ_i and x_n as diagonal elements. Then (14) is written as

$$F = (J - \frac{1}{2\theta}\Phi^{-1}) + \mathbf{X}^{-1}\mathbf{\Gamma}\mathbf{A}\mathbf{X}F \quad (15)$$

and we immediately get

$$F = (\mathbf{I} - \mathbf{X}^{-1}\mathbf{\Gamma}\mathbf{A}\mathbf{X})^{-1}(J - \frac{1}{2\theta}\Phi^{-1}) \quad (16)$$

Since $\gamma_n \geq 0$, according to Theorem 1 (replace V by $\mathbf{\Gamma}V$), F always has a unique solution. To provide more insight, define $\tilde{F} := (J - \frac{1}{2\theta}\Phi^{-1})$ which is the formality vector in the absence of cross-checking ($\forall n, \lambda_n = 0$) and is always between zero and one. Then, from Theorem 1, (16) can be rewritten as

$$F = (\mathbf{I} + \mathbf{X}^{-1}\mathbf{\Gamma}\mathbf{A}\mathbf{X} + \mathbf{X}^{-1}(\mathbf{\Gamma}\mathbf{A})^2\mathbf{X} + \dots)\tilde{F} \quad (17)$$

where $\mathbf{X}^{-1}(\mathbf{\Gamma}\mathbf{A})^t\mathbf{X}\tilde{F}$ is the indirect effect of formality in other sectors in rising the formality of a sector through t intermediate goods in between. If we expand (17) for each element of F

$$f_n = \underbrace{\tilde{f}_n}_{\text{no linkage effect}} + \underbrace{\sum_{k=1}^N \gamma_n a_{nk} \frac{x_k}{x_n} \tilde{f}_k}_{\text{the firm's own formal costumers}} + \underbrace{\sum_{k=1}^N \sum_{j=1}^N \gamma_n a_{nk} \gamma_k a_{kj} \frac{x_j}{x_n} \tilde{f}_j}_{\text{formal costumers through one intermediate good (formal costumers of costumers)}} + \dots \quad (18)$$

where $\tilde{f}_n = 1 - \frac{1}{2\theta\phi_n(1-\lambda_n)\rho_n}$. Therefore, utilizing the self-enforcing feature of VAT, the government can increase the formal sector size from \tilde{f}_n to f_n .

To elaborate more, I introduce two types of inter-industry effects: *backward linkage*, which measures the flow of products from other industries, and *forward linkage* which quantifies the flow of products to the other industries. To measure these two properties, various indices are defined in the field of linkage analysis. A popular one is proposed by Rasmussen [1957] suggesting to use the row or column sum of the Leontief inverse to find inter-sectoral linkages. Specifically, he proposes the following formulas for forward and backward linkages

vectors:

$$\text{Forward linkage: } FL = (\mathbf{I} - \mathbf{X}^{-1}\mathbf{A}\mathbf{X})^{-1}\mathbf{J} \quad (19)$$

$$\text{Backward linkage: } BL = (\mathbf{I} - \mathbf{A}')^{-1}\mathbf{J} \quad (20)$$

where \mathbf{A}' is the transpose of \mathbf{A} . If we expand (19) and (20) for each element, it gives the coefficient of each sector n :

$$fl_n = 1 + \sum_{k=1}^N a_{nk} \frac{x_k}{x_n} + \sum_{k=1}^N \sum_{j=1}^N a_{nk} a_{kj} \frac{x_j}{x_n} + \dots \quad (21)$$

$$bl_n = 1 + \sum_{k=1}^N a_{kn} + \sum_{k=1}^N \sum_{j=1}^N a_{jk} a_{kn} + \dots \quad (22)$$

fl_n shows how much is the amount of production that goes to the other sectors (not final consumers), normalized by x_n . It includes both direct linkages (customers) and indirect linkages through intermediate goods (customers of customers). Similarly bl_n measures the amount of input that comes from other industries, directly or indirectly, normalized by x_n . Note that these two indices are independent of each other. There may be an industry that has strong linkages in both directions or none of them. For instance, some agricultural products are very primitive in nature and are directly sold to the final consumers. Hence, they do not possess any forward or backward linkages. In comparison, steel is a good example of an industry that has both types of linkages: coal, iron ore, etc. are backward and many items like canned goods are its forward industries.

Furthermore, the two above linkage concepts cover both vertical and horizontal inter-industry connections. The vertical linkage is a chain of industries from up to downstream producing a final good (e.g. petroleum industries from crude oil extraction to plastics), but horizontal linkage is between two industries exchanging their differentiated products and none of them is categorized above or below the other (e.g. Fuels and Iron industries). In the simple example of Table 1, there is a vertical linkage between Supplier, Manufacturer, and Retailer such that S is the upstream and R is the downstream industry. In other words, S is just forwardly linked, R just backwardly and M has both types of linkages. Now, assume that we have two similar production chains A and B which also horizontally linked from the middle (Figure 2). In this case, the upstream industry

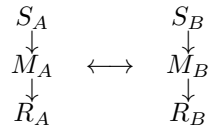


Figure 2: Vertical and horizontal linkages.

S_A , in addition to M_A and R_A , is forwardly linked with M_B and R_B through M_A . Similarly, the backward linkages index of R_A takes into account the indirect effect of S_B and M_B through M_A .

Corollary 1. *Under VAT, formality vector F is positively associated with the forward linkages matrix defined*

as $\mathbf{FL} = (\mathbf{I} - \mathbf{X}^{-1}\mathbf{\Gamma}\mathbf{A}\mathbf{X})^{-1}$.¹⁵

Proof. From (16), we can write $F = \mathbf{FL} \times \tilde{F}$ where \tilde{F} is non-negative. □

The particular interest of Corollary 1 is in explaining Figure 1. From (1) we have

$$\sum_k a_{nk} \frac{x_k}{x_n} = 1 - \frac{x_{n0}}{x_n} \quad (23)$$

The left hand side of (23) is the direct effect of forward linkages in (21). Thus, we can conclude that forward linkages of an industry has a negative relationship with its final demand. Consequently, according to Corollary 1, an activity with more final demand is more likely to be informal and has a lower VAT collection efficiency.

3 Optimal Enforcement

After characterizing the formality of each sector, in this section, I find the optimal enforcement that is the government instrument to control informality. The first step for finding the optimal policy is defining the objective function of the government and its policy variables. The government revenue for each representative x_n is equal to

$$t(p_n x_n^f - \sum_{k=1}^N p_k x_{kn}^f) = t a_{Ln} x_n f_n. \quad (24)$$

On the other hand, the government faces an enforcement expense g_n in each sector which is an increasing function of ϕ_n . If g_n approaches to zero, detection becomes infeasible and if it goes up ϕ_n approaches one. Knowing revenues and costs, we can write the government's optimization problem

$$\max_{\substack{g^1, \dots, g^N \\ \lambda_1, \dots, \lambda_N}} r = \sum_{k=1}^N t a_{Lk} x_k f_k - g_k \quad (25)$$

Proposition 2. *The optimal government expenditure for tax enforcement in industry n is given by*

$$G^2 = \frac{t \bar{g} \bar{x}_L}{2\theta} (\mathbf{I} - \mathbf{\Lambda})^{-1} \mathbf{A}_L^{-1} (\mathbf{I} - \mathbf{A}'\mathbf{\Gamma})^{-1} \mathbf{A}_L \quad (26)$$

where G^2 and A_L are two $N \times 1$ vector with elements g_n^2 and a_{Ln} respectively, and $\mathbf{\Lambda}$ and \mathbf{A}_L are diagonal matrices of λ_n and a_{Ln} .

Proof. Appendix A.2. □

For better illustration, I rewrite (26) in the extensive form for each element

$$g_n = \sqrt{\frac{t \bar{g} \bar{x}_L}{2\theta(1 - \lambda_n)} (a_{Ln} + \sum_{k=1}^N a_{Lk} \gamma_k a_{kn} + \sum_{k=1}^N \sum_{j=1}^N a_{Lj} \gamma_j a_{jk} \gamma_k a_{kn} + \dots)} \quad (27)$$

¹⁵Note that $\mathbf{\Gamma}$ consists of γ_i as diagonal elements which are all nonnegative. Thus, the forward linkages index is different from (19) in the sense that each sector is weighted by its policy variable γ_i which is set by the government.

The immediate results of the Proposition 2 is that the optimal government expenditure to enforce tax in each sector depends on the square root of the tax rate divided by the surcharge rate of punishment. Also, higher \bar{g} and \bar{x}_{Ln} means that the government has to spend more money to reach the same probability of detection.

Apart from these effects, (26) shows that the optimal expenditure is positively associated with backward linkages of the industry defined as $(\mathbf{I} - \mathbf{A}'\mathbf{\Gamma})^{-1}$. This result is of particular interest since it shows how inter-industry linkages can affect the optimal policy. It can be seen that backward linkages weighted by labor intensities increase the optimal enforcement expenditure. This reflects the fact that the self-enforcement of VAT is from costumers to suppliers not vice-versa. In other words, backwardly linked industries are directly or indirectly customers of forwardly linked ones, so their compliance leads to higher compliance of their suppliers too. Therefore, they are better cases to invest for tax enforcement than not backwardly linked sectors.

Next proposition indicates the optimal share of cross-checking in each sector.

Proposition 3. *If the matching cost for one unit evasion is $\mu \sum_k \frac{x_{nk}^f}{x_n}$, the optimal share of cross-checking in the government efforts in each sector is given by*

$$\lambda_n = \begin{cases} \bar{\lambda}_n & \text{if } 2\frac{x_n^i}{\bar{x}_{Ln}} < \sum_k a_{nk} \frac{x_k}{x_n} f_k \\ 0 & \text{if } 2\frac{x_n^i}{\bar{x}_{Ln}} > \sum_k a_{nk} \frac{x_k}{x_n} f_k \end{cases} \quad (28)$$

where $\bar{\lambda}_n = \min\{\bar{\lambda}, \frac{\mu}{\theta\phi_n}\}$, and $\bar{\lambda}$ is the maximum possible share of cross-checking in government enforcement.

Proof. Appendix A.3. □

(28) states that cross-checking is optimal in sector n when it imposes a risk that is at least twice higher than the firm size threat.¹⁶ In this case, the government should put effort into cross-checking as much as it does not persuade informal firms to contract with their peers. Moreover, the right-hand side of the inequality condition is an indicator of forward linkages –see the second term of (21). Therefore, in contrast to ϕ_n , λ_n is positively associated with forward linkages of a sector. Putting Propositions 2 and 3 together yields the implication of interest: *The government should spend more to reveal within-firm information on backwardly linked sectors and make more cross-checking in forwardly linked ones.* For instance, in the simple example of Table 1, the government should put more effort on the downstream R and try to reveal the within-firm information in this sector (e.g. tempting reward for wistle-blowers). But in S, it should dedicate the spending to check the invoices and transactions.

Although in (26), just the positive and direct effect of backward linkages on g_n is visible, forward linkages can also raise g_n through λ_n . In comparison to the linearity of backward linkages, the impact of forward linkages on the optimal expenditures is non-linear. According to Proposition 3, if forward linkages are big enough to hold the upper inequality in (28), g_n increases by factor $\sqrt{\frac{1}{1 - \bar{\lambda}_n}}$, otherwise it does not change by

¹⁶Factor 2 is due to the quadratic functional form of the cost of evasion in x_n^i .

the level of forward linkages. Thus, most of the government spending should be dedicated to sectors that are both forwardly and backwardly involved in the production chain. In contrast, the least spendings should be given to the sectors that does not possess any linkages. Moreover, according to (24) and (27), enforcement is not beneficial in small sectors in which $a_{Ln}x_n < \sqrt{\frac{2\bar{g}\bar{x}_L}{t\theta}}$ and a convenient policy would be exempting these sectors from VAT.

Another important issue for implementing the optimal policy is measuring forward and backward linkages. Like Figure 1, a simple approximation of forward linkages is the share of final consumption to total production of a sector. This measure is enough to find the optimal λ_n in (28) and thus more useful than the complicated form of (21) for policymakers. If the government has an estimate of ρ_n and informality, the share of final consumption provides a simple rule: checking transactions works more efficiently than rewarding whistler-blowers if informality in sector n multiplied by $2\rho_n$ plus the ratio of final consumption is less than one ($2\rho_n(1 - f_n) + x_{n0}/x_n < 1$). Estimation of backward linkages for optimal policy needs more attention. The index used in Proposition 2 is to some extent different with (20) introduced by Rasmussen [1957]. The first difference which can make approximation easier is weighting by labor intensity A_L –compare the extensive forms in (22) and (27). In this manner, by comparing (26) and (6), we see a close relationship between backward linkages index to find g_n and the wage-normalized price of the product p_n . Thus, the magnitude of the spending in each sector can be approximated by

$$g_n \approx \sqrt{\frac{t\bar{g}\bar{x}_L}{2\theta} \frac{p_n}{a_{Ln}(1 - \lambda_n)}} \quad (29)$$

where λ_n , already set by the government, is known and a_{Ln} is labor intensity or the value-added per unit of production. However, p_n is not precisely equal to the backward linkages index in (26), since it does not take cross-checking ratio γ_n into account. When γ_n is entered into consideration, it overstates the linkages, either directly or indirectly through other sectors, with the suppliers that have strong forward linkages and thus high γ_n . But, it drops sectors that are not so forwardly linked to alter λ_n and γ_n from zero, for measuring backward linkages.

The results of this paper have important implications in designing VAT and can increase collection efficiency. To have a sense about the magnitude of the increase in revenue, I compare two cases: (a) when the government optimizes without taking cross checking into consideration, (b) when the government follows the optimality conditions of Proposition 2 and 3. In appendix A.4, I show that if under case (a) the enforcement expenditure in each sector g^a is small relative to net VAT revenue r^a , the growth in revenue from choosing (b) instead of (a) is approximately equal to

$$\frac{r^b - r^a}{r^a} \approx \sum_{n=1}^N \eta_n^a \left(\sum_k \frac{a_{Lk}\gamma_k a_{kn}}{a_{Ln}} + \sum_k \sum_j \frac{a_{Lj}\gamma_j a_{jk}\gamma_k a_{kn}}{a_{Ln}} + \dots \right) \quad (30)$$

where $\eta_n^a = r_n^a/r^a$ is the share of net revenue in sector n to total. Therefore, using the self-enforcing feature of VAT, the government can raise revenue proportional to the weighted average of backward linkages in the economy where the share of each sector in providing revenue determines the weight.

4 General CES production function

In this section, I extend the basic model by relaxing the Leontief production function assumption. In order to do that, I solve the basic model for a CES production function and show that the results are robust to substitution between the inputs. If the production function is a general CES function, we have

$$x_n = \left(\sum_{k=1}^N b_{kn} \left(\frac{x_{kn}}{a_{kn}} \right)^{\sigma_n} + b_{Ln} \left(\frac{l_n}{a_{Ln}} \right)^{\sigma_n} \right)^{\frac{1}{\sigma_n}}, \quad (31)$$

where $\sum_{k=1}^N b_{kn} + b_{Ln} = 1$, $\sigma_n \leq 1$, $a_{kn} \geq 0$ are the Leontief coefficients that depend upon the measuring units, x_{kn} is the amount of product k that is used as an input of sector n , and l_n is the amount of other production factors that are subject to value added tax like labor. At one extreme, if $\sigma_n = -\infty$, (31) becomes a Leontief function like what we had in the previous sections. If $\sigma_n = 0$, (31) is transformed to a Cobb-Douglas function and at the other extreme where $\sigma_n = 1$, it gets a linear form with perfect substitution between the inputs. Next, similar to section 2, we can find the optimal choice of the informal firms.

Proposition 4. *The optimal informal production under CES function is*

$$x_n^i = \frac{1 + \tau_n}{-\partial \tau_n / \partial x_n^i} H(\tau_n) \quad (32)$$

where $\tau_n = t(1 - \theta\nu_n)$ and

$$H(\tau_n) = \frac{p_n - \left(p_n^{\frac{\sigma_n}{\sigma_n-1}} + b_{Ln} \left(\frac{a_{Ln}}{b_{Ln}} \right)^{\frac{\sigma_n}{\sigma_n-1}} \left(\left(\frac{1}{1+\tau_n} \right)^{\frac{\sigma_n}{\sigma_n-1}} - 1 \right) \right)^{\frac{\sigma_n-1}{\sigma_n}}}{p_n - \left(p_n^{\frac{\sigma_n}{\sigma_n-1}} + b_{Ln} \left(\frac{a_{Ln}}{b_{Ln}} \right)^{\frac{\sigma_n}{\sigma_n-1}} \left(\left(\frac{1}{1+\tau_n} \right)^{\frac{\sigma_n}{\sigma_n-1}} - 1 \right) \right)^{\frac{1}{\sigma_n}} \left(p_n^{\frac{\sigma_n}{\sigma_n-1}} - b_{Ln} \left(\frac{a_{Ln}}{b_{Ln}} \right)^{\frac{\sigma_n}{\sigma_n-1}} \right)}. \quad (33)$$

Proof. Appendix A.5 □

When we have an I-O economy $H(\tau) = \frac{-\tau}{1+\tau}$ and (32) transforms to (11), but in general case, $H(\tau)$ is a complicated function to solve. Nevertheless, we can use its linear approximation to study the behavior, since $0 \leq \tau \leq t < 1$ and the higher order approximation terms approaches zero. Then, the results are similar to Proposition 1 and 2:

Proposition 5. *Under cost function (13), formality f_n increases by government enforcement and*

$$f_n \approx 1 - \frac{1}{2\theta\phi_n(1 - \lambda_n)\rho_n} + \gamma_n \sum_{k=1}^N \left(\frac{p_n a_{nk}}{p_k b_{nk}} \right)^{\frac{1}{\sigma_k-1}} a_{nk} \frac{x_k}{x_n} f_k \quad (34)$$

Furthermore, formality of an industry is positively associated with its forward linkages matrix defined as $\mathbf{FL} = (\mathbf{I} - \mathbf{X}^{-1}\mathbf{\Gamma}\mathbf{A}\mathbf{X})^{-1}$ where \mathbf{A} is $N \times N$ matrix with elements $\mathbf{A}_{(i,j)} = \alpha_{ij}$ where

$$\alpha_{ij} = \left(\frac{p_i a_{ij}}{p_j b_{ij}} \right)^{\frac{1}{\sigma_j - 1}} a_{ij}. \quad (35)$$

and the optimal government expenditure and cross-checking ratio in sector n will be

$$g_n^2 = \frac{t\bar{g}\bar{x}_{Ln}}{2\theta(1-\lambda_n)} \left(\alpha_{Ln} + \sum_{k=1}^N \alpha_{Lk}\gamma_k\alpha_{kn} + \sum_{k=1}^N \sum_{j=1}^N \alpha_{Lj}\gamma_j\alpha_{jk}\gamma_k\alpha_{kn} + \dots \right) \quad (36)$$

$$\lambda_n = \begin{cases} \min\{\bar{\lambda}, \frac{\mu}{\theta\phi_n}\} & \text{if } 2\frac{x_n^i}{\bar{x}_{Ln}} < \sum_k \alpha_{nk} \frac{x_k}{x_n} f_k \\ 0 & \text{if } 2\frac{x_n^i}{\bar{x}_{Ln}} > \sum_k \alpha_{nk} \frac{x_k}{x_n} f_k \end{cases} \quad (37)$$

Proof. Appendix A.6 □

Proposition 5 indicates that the results of Section 2 and 3 are still valid and the only change is replacing a_{kn} with α_{kn} in (35). To see how substitution between the inputs can change the results, assume a simple case with no cross-checking. Then, from (34) and (36), under optimal enforcement informality in each sector will be $\sqrt{\frac{t\bar{g}\bar{x}_{Ln}}{2\theta}}\alpha_{Ln}$. It means that if $\alpha_{Ln} > a_{Ln}$ or equivalently $p_n < a_{Ln}/b_{Ln}$ changing the Leontief production function assumption to a CES function with a positive elasticity of substitution like Cobb-Douglas function implies less informality in sector n . Note that labor is the value-adding input in sector n and it determines the benefit from value-added tax evasion for the informal firms. When it is more expensive relative to some other intermediate inputs that push p_n below a_{Ln}/b_{Ln} , letting the firm select between the inputs, it chooses the cheaper one which is not labor in this case. Thus, substitution between the inputs yields less use of value-adding input and less incentive for evasion. Conversely, if $p_n > a_{Ln}/b_{Ln}$, labor is relatively cheap for the firm and more substitution stimulates the firm to use more of it. In this case, a CES function with positive substitution leads to more informality compared to Leontief. In sum, the results of this section indicate that the results of basic model can be generalized by allowing substitution between the inputs and then finding the optimal government policies using (36) and (37).

5 Empirical evidence on self-enforcing feature of VAT

In this section, I provide some evidence about the existence of VAT self-enforcement from Indian service sector. India is a good developing country to test this hypothesis given its recent policy changes in taxation. In a nutshell, the taxation reforms following Indian liberalization in 1991 led to (i) a substantial reduction in income and wealth tax rates, (ii) a great tariff cut in custom duties, (iii) gradual transformation of central excise duties to VAT, (iv) service taxes introduction in 1994 and VAT adoption in 2003, (v) changing states

sales tax to state-VAT (in 2005 for the bulk of states), and (vi) administrative improvements. In this paper, I concentrate on service tax given its big policy change for VAT adoption in 2003-04.

Service tax in India is levied just at the federal level. It was introduced in 1994 on insurance, stock brokerages, and telecommunication, but the major change happened in 2003-04 by introducing service VAT and expanding the list. Before this change, the credit for inputs was not available. The rate of service tax also has experienced a number of changes. Being 5% initially, the rate increased to 8% in 2003 and then 10.2% in 2004. In the mid 2006, it again rose to 12.24%, and then reduced to 10.3% in 2009. Moreover, service tax exemption has been possible for small firms since 1994 and after VAT adoption those firms can opt for exemption from VAT payment or paying it and getting the credit for inputs, input services and capital goods. The threshold level of exemption was Rs. 0.4 millions up to mid 2007 when it became Rs. 0.8 million, and then it has been Rs. 1 million since 2009.¹⁷

Given the nation-wide service tax policy change in India, I examine the existence of self-enforcing feature by testing whether VAT has been more effective in compliance of forwardly linked activities or not. As shown in Corollary 1, the idea behind this hypothesis is that naturally, firms with strong forward linkages have more business customers and among them formal traders who prefer to buy from VAT compliant suppliers. Thus, we expect more VAT compliance among firms in forwardly linked sectors. For this purpose, I use two data sources; a firm-level survey on services, and I-O tables of Indian economy.

The principal data I use is the survey on unorganized service sector by NSSO.¹⁸ It is conducted occasionally and I obtained rounds 57 and 63 of that which were carried out in 2001-02 and 2006-07 respectively. They have nation-wide representative samples of service enterprises and include a variety of information. The services they covers consist of transport, storage, communication, hotels and restaurants, real estate, financial intermediation, renting and business activities, education, health, social work, and other community, social and personal service activities. The sample excludes government and public sector undertakings and the service sector units registered under the Factories Act or have more than ten employees.

Forward and backward linkages indices are drawn from input-output transaction tables of the national accounts statistics of Indian economy published by Central Statistical Organization. I use I-O tables of 2003-04 and 2006-07 for the first and second survey respectively.¹⁹ The I-O tables consist of 130 sectors including 22 service categories²⁰ and include use (commodity \times industry) and make (industry \times commodity) matrices. Using these two, I construct the (commodity \times commodity) Leontief coefficient matrix \mathbf{A} .²¹ Then, Similar to

¹⁷These facts are obtained from <http://indiataxes.com>.

¹⁸National Sample Survey Organization, which is under Ministry of statistic of India and conducts a variety of surveys including enterprise level on unregistered manufacturing and services.

¹⁹No report is published in 2001-02.

²⁰Railway transport, Land transport, Water transport, Air transport, auxiliary transport activities, Storage and warehousing, Communication, Trade, Hotels and restaurants, Banking, Insurance, Ownership of dwellings, Education and research, Medical and health, Business services, Computer & related activities, Legal services, Real estate activities, Renting of machinery and equipment, Community, social and personal services, Other services, Public administration.

²¹The methodology for calculating matrix \mathbf{A} from use and make tables are available in the Appendix 2 of the manual of Input-Output Transaction Tables: "Mathematical expression on the methodology of construction of associated matrices", which is available at: http://mospi.nic.in/Mospi_New/upload/report&publication/ftest10/appendix202.pdf

(19) and (20), I compute forward and backward linkages in each sector as

$$FL = \mathbf{X}^{-1}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{X}\mathbf{J} - \mathbf{J}, \quad BL = (\mathbf{I} - \mathbf{A}')^{-1}\mathbf{J} - \mathbf{J} \quad (38)$$

Where \mathbf{A} , is the Leontief matrix, \mathbf{X} the diagonal production matrix, and \mathbf{J} the summation vector. Since the minimum of all elements of (19) and (20) is one, I subtract them by vector \mathbf{J} to normalize the starting point to zero. Therefore, if FL (BL) is equal to zero, it means that the industry does not possess any forward (backward) linkages.

To estimate the effect of intersectoral linkages on VAT registration, in the first step, I utilize the following regression setup among the sample of firms that are above registration threshold

$$reg_{sdf} = \beta_0 + \beta_1 L_s + \beta_2 X_f + D_d + \varepsilon_{sdf} \quad (39)$$

where reg is a dummy equal to one if the firm registered for sales or service tax,²² L_s is sector's forward or backward linkages index, and X_f is a vector of firm-level control variables. It includes the log of gross output and the number of workers to control for the size, and the dummy variables for partnership, mixed activity, and work on contract basis. In addition, D_d is a vector of district fixed effects to control for regional factors that can affect informality within each district. Also, To control for underestimation of standard errors, the error terms are clustered at district level.

Before running regressions, I made some modifications in the data. First, I dropped the sectors that are not under service tax rule in the survey year, which leaves behind 18 and 78 services in 2001 and 2006.²³ Second, hair dressing and other beauty treatment services (NIC code 93020) is dropped, because service tax assigned just for beauty treatment not hair dressing and decomposition is not possible.²⁴ Finally, Because the dependent variable is binary and I control for regional fixed effects, the districts that only have unregistered samples are dropped –they just predict one outcome and thus are ineffective in MLL estimation. Table 2 shows the summary statistics. Overall, we have 14217 and 54829 enterprises in the first and second surveys, among which 2.8% and 5.9% registered for VAT respectively. The exempted firms that are below threshold comprise around 90% of total and the registration rate among them is around 3%. Only 5% of unexempted firms registered for tax in 2001-2 but with a considerable growth this number is 32.5% in 2006-7.²⁵ The average of forward and backward linkages are around 1.1 and 0.70 respectively and the correlation between the two is 0.36.

²²The 2006-7 survey has a specific question about service tax registration and I use that as the indicator. However, the survey in 2001-2 does not have such information and instead, the enterprise is asked about sales tax registration. In India, sales tax has three types: central excise duties (central VAT), state-level sales tax (state VAT), and service tax. Because the sample is composed of service sector firms, I assume that in 2001-2, sale tax and service tax registration are highly correlated.

²³The timing of service tax adoption for each activity is available at data appendix B.2. Some of the services like the sub-categories of trade are not sampled in the surveys, so they do not cover all activities that has been the subject of service tax.

²⁴However, the results are robust to including them as assigned or not.

²⁵This low number is because the sample consists of "unorganized service sector" which represents small scale enterprises with less than 10 employees. Therefore it does not reflect the aggregate registration rate of the whole service sector in India.

Table 2: Summary statistics

Survey year	2001-2		2006-7	
	Mean	SE	Mean	SE
sales/service tax registration	0.028	(0.164)	0.059	(0.236)
exemption from registration	0.880	(0.326)	0.908	(0.290)
forward linkages	1.177	(0.363)	1.138	(0.639)
backward linkages	0.713	(0.332)	0.698	(0.404)
obligated and registered	0.050	(0.217)	0.325	(0.468)
exempted and registered	0.025	(0.155)	0.032	(0.177)
Observations	14217		54829	

The results probit estimation of (39) are presented in columns 1-4 of Table 3. I report marginal effects for better interpretation. It can be seen that forward linkages has a positive and strong impact on compliance of firms that are obliged to register just after VAT adoption. One standard error increase in forward linkages in 2006-7 (0.64) raises the probability of registration by 0.065 which is about 20% of total registration rate among non-exempted firms (0.325). This effect is not significant in 2001-2 when VAT was not adopted. Moreover, the effect of backward linkages on registration is negative and insignificant both before and after VAT adoption. Overall, the estimation 1 to 4 strongly justify the self-enforcing feature of VAT among the group of firms that are obligated to register.

In the next step, I estimate the regressions using the whole sample and compare VAT registration between the exempted and obligated firms. By doing so, we can test whether VAT self-enforcement exists even when there is no government punishment or not. Also, this method enables us to eliminate omitted variable bias at sector level, because in (39) the only sector-level variable is the linkages indicator. As mentioned above, service tax registration is compulsory for firms with turnover above a threshold level and below that it is voluntary. In general, the below threshold firms, legally exempted from paying VAT, can work in the market and even sell to the formal firms without any fear about detection. However, linkages and VAT self-enforcement can encourage those firms to register for VAT even when they are not obliged to. If not registering for VAT reduces the demand and the number of customers by far, a firm may choose to be formal even in the absence of government compulsion.²⁶

Some factors can hold back the trade between formal clients and unregistered suppliers that are legally exempted from VAT payment. First of all, note that although exempted firms do not pay VAT on their sales, they also do not get input credit for their purchases. Moreover, as shown in section 2, the major benefit of unregistered firms is selling the product at tax inclusive price and putting the tax payment in their pockets. Otherwise, if they sell at tax exclusive price, they have no incentive to be unregistered, since they sell at the same price of formal firms but do not get input credit.²⁷ On the other hand, if a formal firm buys from an exempted supplier, it can not recover any credit on the purchased input, since no official tax is paid. Therefore,

²⁶For an extensive model and discussion on this see Hoseini [2013].

²⁷Unfortunately the survey has no information on the price of products to compare the exempted and non-exempted ones.

the formal firm only buys from the exempted firm if the price is no more than tax exclusive price, otherwise buying from a formal supplier and getting input credit is more beneficial. As a result, there is no price that could satisfy both parties to trade and if formal demand is determinant for below threshold suppliers, they may prefer to register for VAT. This means that self-enforcing feature should exist even in the absence of any compulsion, in the sense that VAT registration is more likely in forwardly linked sector that have more forward clients.

On the other hand, some non-price factors can also prevent formal firms from purchasing from exempted firms. For instance, the formal clients that avoid illegal activities do not exactly know whether the unregistered supplier is legally exempted or pretends to be an exempted firm. More importantly, according to [De Paula and Scheinkman \[2010\]](#) difference in firms' managerial abilities causes high ability entrepreneurs become formal and under value-added tax trade with each other not the low abilities. Thus, registering for VAT can be a signal of the ability of the firm to encourage formal clients –which usually are big and have a significant share in the market– to purchase. For all of these reasons, we expect higher voluntary VAT registration in forwardly linked activities because they have more formal customers who want their suppliers to be formal too. To test this hypothesis empirically, I employ is the following regression setup

$$reg_{sdf} = \beta_0 + \beta_1 e_f + \beta_2 e_f \times L_s + \beta_3 X_f + D_d + S_s + \varepsilon_{sdf} \quad (40)$$

where e_f is a dummy equal to one if firm f is exempted from service VAT registration, S_s is a vector of sector dummies, and the rest of variable are exactly like (39). This method enables us to see the effect of inter-sectoral linkages on VAT registration while controlling for other sector-level characteristics. The coefficient β_2 reflects the effect of linkages on the difference between the registration of exempted and unexempted groups. In other words, if we benchmark the firms that are obligated to be formal, β_2 reflects the effect of linkages on registration of firms that can choose between being formal and informal. Column 5 to 8 of Table 3 shows the results of estimation with exemption dummy and its interaction with forward and backward linkages both before and after VAT adoption. I drop gross output from control variables since it is highly correlated with the exemption dummy.²⁸ As we expected, generally exempted firms have less registration than obliged ones in each sector. More interestingly, forward linkages reduce the difference between the two groups but only after VAT adoption and beforehand the effect is not significant. Column 7 indicates that if two firms have identical sector, district and general firm characteristics, but one is exempted and the other is obliged to register, the difference between registration probability of exempted firms reg_e and obliged firm reg_o can be estimated by

$$reg_e - reg_o = -0.094 + 0.005 \times fl_s \quad (41)$$

so moving from a sector to another by one unit more forward linkages reduces the difference by 0.5%. This

²⁸If we include it in the regressions, still the effect of forward linkages is highly significant but the estimated coefficients become smaller.

can explain about 6.4% of total difference, because the mean fl_s is 1.14 which makes (41) equal to 0.088 on average. Moreover, from estimations (1) and (3), we know that among non-exempted firms, registration rate is higher in forwardly linked sectors. Therefore, by dropping the registration gap between above and below threshold groups, forward linkages increase formality among exempted firms too. On the other hand, similar to columns (2) and (4), estimations (6) and (8) of Table 3 show no significant impact of backward linkages index on the registration difference between exempted and unexempted firms. This result is the same before and after VAT adoption. Therefore, the empirical evidence confirms a positive and strong impact of just forward linkages of a sector on VAT registration even when it is not obligatory. This is a reflection of self-enforcing feature of VAT and as discussed above the government can use it for more efficient tax enforcement.

Table 3: Probit regression for the effect of linkages on VAT registration.

Dependent variable: Sample: Survey year:	Sales/service tax registration							
	unexempted firms				all firms			
	2001-2 (before VAT)		2006-7 (after VAT)		2001-2 (before VAT)		2006-7 (after VAT)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
forward linkages	0.029 (0.020)		0.102*** (0.017)					
backward linkages		-0.007 (0.027)		-0.018 (0.035)				
exemption dummy					-0.049** (0.041)	-0.039** (0.027)	-0.094*** (0.013)	-0.077*** (0.013)
forward linkages \times exemption					0.007 (0.009)		0.005*** (0.002)	
backward linkages \times exemption						0.007 (0.011)		0.003 (0.003)
mixed activity	0.073** (0.043)	0.075** (0.043)	0.016 (0.026)	0.004 (0.026)	-0.002 (0.006)	-0.002 (0.006)	0.004*** (0.002)	0.004** (0.002)
contract work	0.014 (0.021)	0.017 (0.023)	-0.021 (0.049)	-0.016 (0.052)	-0.000 (0.004)	-0.000 (0.004)	0.002 (0.003)	0.002 (0.003)
partnership company	0.026* (0.013)	0.025* (0.013)	0.118*** (0.025)	0.124*** (0.025)	0.013*** (0.005)	0.013*** (0.005)	0.032*** (0.004)	0.032*** (0.004)
No. workers	0.000** (0.000)	0.001** (0.000)	-0.001 (0.004)	-0.001 (0.004)	0.000*** (0.000)	0.000*** (0.000)	0.001 (0.000)	0.001 (0.000)
log of gross output	0.011** (0.005)	0.010* (0.005)	0.105*** (0.007)	0.105*** (0.007)				
Observations	1270	1270	4161	4161	14217	14217	54829	54829
District Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector Effects	No	No	No	No	Yes	Yes	Yes	Yes
No. clusters	32	32	197	197	110	110	375	375

Marginal effect coefficients are reported, standard errors in parentheses and clustered at district level.

*, **, and *** show significance at 10%, 5% and 1% respectively.

6 Conclusion

The main contribution of this paper was giving the insight that some sectors are better cases than others to be focused on for VAT enforcement. Many developing countries have moved toward replacement of border taxes with VAT and the optimality of this reform crucially depends on VAT collection efficiency. The great administrative advantage of VAT is that in addition to general tools to reveal intra-firm information, it provides a unique inter-firm information source via its invoice system. This intrinsic feature makes evasion of forwardly linked sectors dependent to their customers' informality. Consequently, the government can utilize this unique tool to improve enforcement by spending more on backwardly linked firms to reveal their internal information. In comparison, the government should spend extra expenses in forwardly linked sectors to cross-check invoices with the corresponding credit claims. Empirical evidence from Indian economy showed that the self-enforcing feature exists even when the registration is not compulsory.

However, the underlying model has some limitations and some further issues are addressed in an accompanying paper. First, in the model I assumed that all formal firms inform the government about their suppliers to get input credit. However, in reality, formal firms can also choose different actions in response to the behavior of informal firms and the government, especially when buying from an informal supplier creates a cost for them. Also, although in the model I take the possibility of simple matching into consideration, VAT adoption may also motivate integration between informal firms which is not discussed here. In addition, in this paper, there is no restriction from the demand side and all informal firms choose their production endogenously. But, limiting market demand can be another government instrument to reduce informality when non-complaint firms decide to match or integrate. These issues are addressed in [Hoseini \[2013\]](#).

More generally, this paper neglected some other enforcement issues, as stressed in [Smith and Keen \[2006\]](#), like under-reported sales, multiple rates and misclassification of commodities, self-consumption, false accountings and claims, and carousel fraud. In spite of these limitations, the findings of this paper have an important implication in VAT enforcement design and can increase VAT collection efficiency by far. The simple calculations showed that conducting the suggested administrative improvements increases VAT revenue by the level of average backward linkages in the economy.

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A Mathematical Appendix

A.1 Proof of Proposition 1

From (11), at the equilibrium, we have

$$\frac{1}{\theta} = \nu_n + x_n^i \frac{\partial \nu_n}{\partial x_n^i} \quad (42)$$

substituting (12) into (42) yields

$$\frac{1}{\theta \phi_n} = 2(1 - \lambda_n) \frac{x_n^i}{x_n} + \lambda_n \frac{\sum_k x_{nk}^f}{x_n} \quad (43)$$

Since $x_n^i/x_n = 1 - f_n$ and $x_{nk}^f = a_{nk} x_k f_k$, we can rearrange (43) to get

$$f_n = 1 - \frac{1}{2\theta \phi_n (1 - \lambda_n)} + \frac{\lambda_n}{1 - \lambda_n} \sum_{k=1}^N \frac{x_k}{x_n} f_k \quad (44)$$

A.2 Proof of Proposition 2

Using (18), I can rewrite (67) as

$$r = t \sum_{m=1}^N x_m \tilde{f}_m (a_{Lm} + \sum_k a_{Lk} \gamma_k a_{km} + \sum_k \sum_j a_{Lk} \gamma_k a_{kj} \gamma_j a_{jm} + \dots) - g_m \quad (45)$$

and since $\tilde{f}_m = 1 - \frac{1}{2\theta \phi_m (1 - \lambda_m) \rho_m}$ and $\frac{1}{\phi_m} = \frac{\bar{g}}{g_m}$

$$\frac{\partial \tilde{f}_m}{\partial g_m} = \frac{\bar{g}}{2\theta (1 - \lambda_m) \rho_m g_m^2} \quad (46)$$

Thus the FOC of (46) becomes

$$\frac{\partial r}{\partial g_m} = \frac{t \bar{g} x_m}{2\theta (1 - \lambda_m) \rho_m g_m^2} (a_{Lm} + \sum_k a_{Lk} \gamma_k a_{km} + \sum_k \sum_j a_{Lk} \gamma_k a_{kj} \gamma_j a_{jm} + \dots) - 1 = 0 \quad (47)$$

and since $\rho_m = x_m / \bar{x}_{Lm}$, the optimum expenditure in each sector becomes

$$g_m^2 = \frac{t \bar{g} \bar{x}_L}{2\theta (1 - \lambda_m) a_{Lm}} (a_{Lm} + \sum_k a_{Lk} \gamma_k a_{km} + \sum_k \sum_j a_{Lk} \gamma_k a_{kj} \gamma_j a_{jm} + \dots) \quad (48)$$

and in the matrix form

$$G^2 = \frac{t \bar{g} \bar{x}_L}{2\theta} (\mathbf{I} - \mathbf{\Lambda})^{-1} \mathbf{A}_L^{-1} (\mathbf{I} - \mathbf{A}' \mathbf{\Gamma})^{-1} \mathbf{A}_L \quad (49)$$

where G^2 is a vector with elements g_n^2 and \mathbf{A}_L is a diagonal matrix with elements a_{Ln} .

A.3 Proof of Proposition 3

From (14), at equilibrium we have

$$x_n^f = x_n - \frac{x_n}{2\theta\phi_n(1-\lambda_n)\rho_n} + \sum_{k=1}^N \frac{\lambda_n}{2(1-\lambda_n)\rho_n} a_{nk} x_k^f \quad (50)$$

since $a_{nk}x_k^f = x_{nk}^f$, by rearranging (50), we can write

$$2(1-\lambda_n)\rho_n x_n^i + \lambda_n \sum_{k=1}^N x_{nk}^f = \frac{x_n}{\theta\phi_n} \quad (51)$$

Then, the derivative of x_n^i with respect to λ_n can be derived from (51)

$$2(1-\lambda_n)\rho_n \frac{\partial x_n^i}{\partial \lambda_n} - 2\rho_n x_n^i + \sum_{k=1}^N x_{nk}^f = 0, \quad (52)$$

so

$$\frac{\partial x_n^i}{\partial \lambda_n} = \frac{1}{1-\lambda_n} \left(x_n^i - \frac{1}{2\rho_n} \sum_{k=1}^N x_{nk}^f \right) \quad (53)$$

Because $1-\lambda_n > 0$, x_n^i is monotone in λ_n and the sign of $\frac{\partial x_n^i}{\partial \lambda_n}$ depends on $2\rho_n x_n^i - \sum_k x_{nk}^f$. If $2\rho_n x_n^i > \sum_k x_{nk}^f$, then x_n^i is increasing in λ_n and the best government choice to reduce informality is $\lambda_n = 0$. On the other hand, if $2\rho_n x_n^i < \sum_k x_{nk}^f$, the derivative is negative and the government should focus on cross checking as much as possible ($\lambda_n = \bar{\lambda}$). However, increasing λ_n decreases the relative cost of search and commitment for the informal buyers. Given the matching cost for one unit of evasion equals to $\mu \sum_k x_{nk}^f / x_n$, if the informal firm tries to find and contract with an informal buyer, the cost function (13) may change into

$$c_n = e_n \theta \phi_n (1-\lambda_n) \rho_n \frac{x_n^i}{x_n} + e_n \mu \frac{\sum_k x_{nk}^f}{x_n} \quad (54)$$

where the first and second terms represent the cost of government detection and matching with an informal customer respectively. The turning point that an informal firm in sector n is indifferent between searching or not caring about its customers is when (13) is equal to (54) which yields $\lambda_n \theta \phi_n = \mu$ given $\gamma_n = \frac{\lambda_n}{2(1-\lambda_n)\rho_n}$ in (13). Hence, if $\lambda_n \theta \phi_n > \mu$ government gains nothing from increasing λ_n even if $2\rho_n x_n^i < \sum_k x_{nk}^f$, so its best choice is $\lambda_n = \frac{\mu}{\theta\phi_n}$. In sum, the optimal cross-checking in each sector can be written as

$$\lambda_n = \begin{cases} \min\{\bar{\lambda}, \frac{\mu}{\theta\phi_n}\} & \text{if } 2\rho_n x_n^i < \sum_k x_{nk}^f \\ 0 & \text{if } 2\rho_n x_n^i > \sum_k x_{nk}^f \end{cases} \quad (55)$$

and substituting $\rho_n = x_n / \bar{x}_{Ln}$ yields (28)

A.4 Finding growth in revenue

Here, we compare two cases: (a) the government does not check the transactions and just focus on within-firm information, (b) the government follows the optimality conditions of Proposition 2 and 3. Under policy (a)

$$r^a = \sum_{n=1}^N ta_{Ln} \left(x_n - \frac{\bar{g}\bar{x}_L}{2\theta a_{Ln} g_n} \right) - g_n. \quad (56)$$

Then, following FOC, the optimal expenditure in all sectors will be $g^a = \sqrt{\frac{t\bar{g}\bar{x}_L}{2\theta}}$ and

$$r^a = \sum_{n=1}^N ta_{Ln} x_n - N \sqrt{\frac{2t\bar{g}\bar{x}_L}{\theta}}. \quad (57)$$

On the other hand, the optimal expenditure under (b) can be found from (27) and net revenue becomes

$$r^b = \sum_{n=1}^N ta_{Ln} x_n \zeta_n - \sqrt{\frac{2t\bar{g}\bar{x}_L}{\theta}} \sum_{n=1}^N \sqrt{\frac{\zeta_n}{1-\lambda_n}} \quad (58)$$

where

$$\zeta_n = 1 + \sum_{k=1}^N \frac{a_{Lk} \gamma_k a_{kn}}{a_{Ln}} + \sum_{k=1}^N \sum_{j=1}^N \frac{a_{Lj} \gamma_j a_{jk} \gamma_k a_{kn}}{a_{Ln}} + \dots \quad (59)$$

is backward linkages index normalized by a_{Ln} . By subtracting (57) from (58), we can write the relative difference in revenue between policy (a) and (b)

$$\frac{r^b - r^a}{r^a} = \sum_{n=1}^N \frac{r_n^a}{r^a} (\zeta_n - 1) + 2 \frac{g^a}{r^a} \sum_{n=1}^N \zeta_n - \sqrt{\frac{\zeta_n}{1-\lambda_n}} \quad (60)$$

where r_n^a is revenue in sector n under policy (a). In reality we expect g^a –the expenditure in a single sector– be much less than total VAT revenue. Moreover, $\zeta_n - \sqrt{\frac{\zeta_n}{1-\lambda_n}}$ is positive in backwardly linked sectors, but negative in sectors with strong forward and weak backward linkages. Since, each type of linkages is accompanied by the other one in another sector, these to effect compensate each other in the whole economy and the sum of them is not a great number to make g^a/r^a comparable to the first term. Thus, we can assume that the second term is negligible and estimate the growth in revenue by

$$\frac{r^b - r^a}{r^a} \approx \sum_{n=1}^N \frac{r_n^a}{r^a} (\zeta_n - 1) \quad (61)$$

A.5 Proof of Proposition 4

By putting wage at unity, the profit of formal firms in sector n will be

$$\pi_n^f = p_n x_n^f - \sum_{k=1}^N p_k x_{kn}^f - l_n^f, \quad x_n^f \geq 0 \quad (62)$$

with the FOCs

$$\frac{\partial x_n^f}{\partial x_{kn}^f} = \frac{p_k}{p_n}, \quad \frac{\partial x_n^f}{\partial l_n^f} = \frac{1}{p_n}. \quad (63)$$

The partial derivatives can be computed by differentiating (31):

$$\frac{\partial x_n^f}{\partial x_{kn}^f} = \frac{b_{kn}}{a_{kn}} \left(\frac{x_{kn}^f}{a_{kn} x_n^f} \right)^{\sigma_n - 1} \quad (64)$$

$$\frac{\partial x_n^f}{\partial l_n^f} = \frac{b_{Ln}}{a_{Ln}} \left(\frac{l_n^f}{a_{Ln} x_n^f} \right)^{\sigma_n - 1} \quad (65)$$

Then, we can find x_{kn}^f and l_n^f as function of x_n^f and the prices:

$$x_{kn}^f = a_{kn} x_n^f \left(\frac{a_{kn} p_k}{b_{kn} p_n} \right)^{\frac{1}{\sigma_n - 1}} \quad (66)$$

$$l_n^f = a_{Ln} x_n^f \left(\frac{a_{Ln}}{b_{Ln} p_n} \right)^{\frac{1}{\sigma_n - 1}} \quad (67)$$

Under perfect competition, profit is zero and the prices can be found by substituting (66) and (67) into (31)

$$p_n^{\frac{\sigma_n}{\sigma_n - 1}} = \sum_{k=1}^N b_{kn} \left(\frac{a_{kn} p_k}{b_{kn}} \right)^{\frac{\sigma_n}{\sigma_n - 1}} + b_{Ln} \left(\frac{a_{Ln}}{b_{Ln}} \right)^{\frac{\sigma_n}{\sigma_n - 1}} \quad (68)$$

Thus, having N equations similar to (68), we are able to obtain the prices p_1, \dots, p_N .

On the other hand, the profit of informal firms in each sector becomes

$$\pi_n^i = (1+t)p_n x_n^i - \sum_{k=1}^N (1+t)p_k x_{kn}^i - l_n^i - \theta e_n \nu_n, \quad x_n^i \geq 0. \quad (69)$$

Moreover, similar to Table 1, the amount of evasion is equal to

$$e_n = t(p_n x_n - \sum_{k=1}^N p_k x_{kn}) \quad (70)$$

Hence, we can rewrite (69) as

$$\pi_n^i = \frac{1+\tau_n}{t} e_n - l_n^i \quad (71)$$

where $\tau_n = t(1 - \theta \nu_n)$. Now, FOCs become

$$\frac{\partial x_n^i}{\partial x_{kn}^i} = \frac{p_k}{p_n + \frac{\partial \tau_n / \partial x_n^i}{(1+\tau_n)} e_n / t}, \quad \frac{\partial x_n^i}{\partial l_n^i} = \frac{1}{p_n + \frac{\partial \tau_n / \partial x_n^i}{(1+\tau_n)} e_n / t} \quad (72)$$

and x_{kn}^i and l_n^i can be found similar to (66) and (67)

$$x_{kn}^i = \left(\frac{a_{kn} p_k / b_{kn}}{p_n + \frac{\partial \tau_n / \partial x_n^i e_n / t}{(1 + \tau_n)}} \right)^{\frac{1}{\sigma_n - 1}} a_{kn} x_n^i \quad (73)$$

$$l_n^i = \left(\frac{a_{Ln} / b_{Ln}}{p_n + \frac{\partial \tau_n / \partial x_n^i e_n / t}{(1 + \tau_n)}} \right)^{\frac{1}{\sigma_n - 1}} a_{Ln} x_n^i. \quad (74)$$

Substituting (73) and (74) in (31) and using (68) results

$$p_n + \frac{\partial \tau_n / \partial x_n^i e_n}{(1 + \tau_n) t} = \left(p_n^{\frac{\sigma_n}{\sigma_n - 1}} + b_{Ln} \left(\frac{a_{Ln}}{b_{Ln}} \right)^{\frac{\sigma_n}{\sigma_n - 1}} \left(\left(\frac{1}{1 + \tau_n} \right)^{\frac{\sigma_n}{\sigma_n - 1}} - 1 \right) \right)^{\frac{\sigma_n - 1}{\sigma_n}} \quad (75)$$

and if we combine (73) and (75), substitute the resulting x_{kn}^i into (70), and solve for x_n^f , it turns out

$$x_n^i = \frac{1 + \tau_n}{-\frac{\partial \tau_n}{\partial x_n^i}} H(\tau_n) \quad (76)$$

where

$$H(\tau_n) = \frac{p_n - \left(p_n^{\frac{\sigma_n}{\sigma_n - 1}} + b_{Ln} \left(\frac{a_{Ln}}{b_{Ln}} \right)^{\frac{\sigma_n}{\sigma_n - 1}} \left(\left(\frac{1}{1 + \tau_n} \right)^{\frac{\sigma_n}{\sigma_n - 1}} - 1 \right) \right)^{\frac{\sigma_n - 1}{\sigma_n}}}{p_n - \left(p_n^{\frac{\sigma_n}{\sigma_n - 1}} + b_{Ln} \left(\frac{a_{Ln}}{b_{Ln}} \right)^{\frac{\sigma_n}{\sigma_n - 1}} \left(\left(\frac{1}{1 + \tau_n} \right)^{\frac{\sigma_n}{\sigma_n - 1}} - 1 \right) \right)^{\frac{-1}{\sigma_n}} \left(p_n^{\frac{\sigma_n}{\sigma_n - 1}} - b_{Ln} \left(\frac{a_{Ln}}{b_{Ln}} \right)^{\frac{\sigma_n}{\sigma_n - 1}} \right)}. \quad (77)$$

A.6 Proof of Proposition 5

First, I show that $\frac{\partial}{\partial \phi_n} f_n > 0$. Then, since $0 < \tau_n = t(1 - \theta \nu_n) < 1$, I use the linear approximation of $H(\tau_n)$ around zero. In order to do that, first I calculate $\frac{\partial}{\partial \tau_n} H(\tau_n)$ and then evaluate it in $\tau_n = 0$. Define ϱ , u , and v as follows:

$$\varrho_n(\tau_n) = \left(p_n^{\frac{\sigma_n}{\sigma_n - 1}} + b_{Ln} \left(\frac{a_{Ln}}{b_{Ln}} \right)^{\frac{\sigma_n}{\sigma_n - 1}} \left(\left(\frac{1}{1 + \tau_n} \right)^{\frac{\sigma_n}{\sigma_n - 1}} - 1 \right) \right)^{\frac{\sigma_n - 1}{\sigma_n}} \quad (78)$$

$$u(\tau_n) = p_n - \varrho_n \quad (79)$$

$$v(\tau_n) = p_n - \varrho_n^{\frac{-1}{\sigma_n - 1}} \left(p_n^{\frac{\sigma_n}{\sigma_n - 1}} - b_{Ln} \left(\frac{a_{Ln}}{b_{Ln}} \right)^{\frac{\sigma_n}{\sigma_n - 1}} \right) \quad (80)$$

Then,

$$\dot{\varrho} = - \left(p_n^{\frac{\sigma_n}{\sigma_n - 1}} + b_{Ln} \left(\frac{a_{Ln}}{b_{Ln}} \right)^{\frac{\sigma_n}{\sigma_n - 1}} \left(\left(\frac{1}{1 + \tau_n} \right)^{\frac{\sigma_n}{\sigma_n - 1}} - 1 \right) \right)^{-\frac{1}{\sigma_n}} b_{Ln} \left(\frac{a_{Ln}}{b_{Ln}} \right)^{\frac{\sigma_n}{\sigma_n - 1}} \left(\frac{1}{1 + \tau_n} \right)^{\frac{2\sigma_n - 1}{\sigma_n - 1}} \quad (81)$$

$$\dot{u} = -\dot{\varrho} \quad (82)$$

$$\dot{v} = \frac{1}{\sigma_n - 1} \left(p_n^{\frac{\sigma_n}{\sigma_n - 1}} - b_{Ln} \left(\frac{a_{Ln}}{b_{Ln}} \right)^{\frac{\sigma_n}{\sigma_n - 1}} \right) \varrho_n^{-\frac{\sigma_n}{\sigma_n - 1}} \dot{\varrho}_n \quad (83)$$

$$H = \frac{u}{v}, \quad \dot{H} = \frac{\dot{u}v - u\dot{v}}{v^2} \quad (84)$$

where dot represents derivative with respect to $\tau_n = t - t\theta\phi_n \left((1 - \lambda_n)x_n^i/x_n + \lambda \sum_{k=1}^N x_{nk}^f/x_n \right)$. Note that $\tau_n \geq 0$, otherwise informal production would make negative profit which is impossible. Therefore from

(78)-(84)

$$\varrho_n \leq p_n, \quad \varrho_n^{\frac{-1}{\sigma_n-1}} (p_n^{\frac{-1}{\sigma_n-1}} - b_{Ln} (\frac{a_{Ln}}{b_{Ln}})^{\frac{\sigma_n}{\sigma_n-1}}) \leq p_n \quad \rightarrow \quad H(\tau_n) = \frac{u}{v} \geq 0 \quad (85)$$

$$\frac{\partial \tau_n}{\partial \phi_n} = -\frac{t\theta v_n}{\phi_n} < 0, \quad \rightarrow \quad \frac{\partial \tau_n}{\partial \phi_n} - \frac{1 + \tau_n}{\phi_n} < 0 \quad (86)$$

$$\frac{\sigma_n - p_n/\varrho_n}{\sigma_n - 1} \leq 1 \quad \rightarrow \quad \dot{H}(\tau_n) = \frac{-\dot{\varrho}_n}{v^2} \left(p_n - \frac{\sigma_n - p_n/\varrho_n}{\sigma_n - 1} \varrho_n^{\frac{-1}{\sigma_n-1}} (p_n^{\frac{\sigma_n}{\sigma_n-1}} - b_{Ln} (\frac{a_{Ln}}{b_{Ln}})^{\frac{\sigma_n}{\sigma_n-1}}) \right) > -\frac{\dot{\varrho}_n}{v} > 0 \quad (87)$$

On the other hand, from (76)

$$\frac{\partial f_n}{\partial \phi_n} = \frac{-1}{t\theta\phi_n(1-\lambda_n)} \left(H(\tau_n) \left(\frac{\partial \tau_n}{\partial \phi_n} - \frac{1 + \tau_n}{\phi_n} \right) + (1 + \tau_n) \dot{H}(\tau_n) \frac{\partial \tau_n}{\partial \phi_n} \right) \quad (88)$$

Applying (85)-(87) in (88) results

$$\frac{\partial f_n}{\partial \phi_n} > 0 \quad (89)$$

which says formality increases with higher enforcement. Now, if we put $\tau_n = 0$

$$\varrho_n(0) = p_n \quad (90)$$

$$\dot{\varrho}_n(0) = -p_n^{\frac{-1}{\sigma_n-1}} b_{Ln} (\frac{a_{Ln}}{b_{Ln}})^{\frac{\sigma_n}{\sigma_n-1}} \quad (91)$$

$$u(0) = 0, \quad \dot{u}(0) = v(0) = -\dot{\varrho} \quad (92)$$

$$\dot{v}(0) = \frac{1}{\sigma_n - 1} \left(1 - b_{Ln} (\frac{a_{Ln}}{b_{Ln}})^{\frac{\sigma_n}{\sigma_n-1}} p_n^{\frac{-\sigma_n}{\sigma_n-1}} \right) \dot{\varrho} \quad (93)$$

substituting (90)-(93) in (84) results

$$H(0) = 0, \quad \dot{H}(0) = 1 \quad (94)$$

Therefore, we can estimate $H(\tau_n)$ by

$$H(\tau_n) \approx \tau_n \quad (95)$$

Then, I find formality by rearranging (76)

$$t\theta\phi_n(1-\lambda_n)(1-f_n) = \tau_n^2 + \tau_n. \quad (96)$$

Now, I write $\tau_n = t - t\theta\phi_n(1-\lambda_n)(1-f_n + 2\gamma_n \sum_{k=1}^N x_{nk}^f/x_n)$, add $\tau_n + 1$ to the both sides of (96), and take the square root of the both sides

$$1 + \tau_n = \sqrt{1 + t - 2t\theta\phi_n(1-\lambda_n)\gamma_n \sum_{k=1}^N \frac{x_{nk}^f}{x_n}} \quad (97)$$

and finally, I apply the Taylor equivalence $0 < z < 1 \rightarrow \sqrt{1+z} \approx 1 + z/2$ in (97)

$$f_n \approx 1 - \frac{1}{2\theta\phi_n(1-\lambda_n)} + \gamma_n \sum_{k=1}^N \left(\frac{p_n a_{nk}}{p_k b_{nk}} \right)^{\frac{1}{\sigma_k-1}} a_{nk} \frac{x_k}{x_n} f_k \quad (98)$$

Regarding linkages, since P is given from (68) independent of X , we can generalize (16) by redefining \mathbf{A} with elements

$$A_{(i,j)} = \gamma_i \left(\frac{p_i a_{ij}}{p_j b_{ij}} \right)^{\frac{1}{\sigma_j-1}} a_{ij}. \quad (99)$$

Then, (98) can be written in the vector form as

$$\mathbf{F} \approx \mathbf{FL}(\mathbf{I} - \frac{1}{2\theta} \mathbf{\Phi}^{-1})\mathbf{I}. \quad (100)$$

Hence, formality vector is the forward linkages matrix summed across columns by a positively weighted summation vector and an industry with greater forward linkages has more degree of VAT compliance.

Moreover, in this setting, the government revenue for each representative x_n is equal to

$$t(p_n x_n^f - \sum_{k=1}^N p_k x_{kn}^f) = t(1 - \sum_{k=1}^N b_{kn} \left(\frac{a_{kn} p_k}{b_{kn} p_n} \right)^{\frac{\sigma_n-1}{\sigma_k-1}}) p_n x_n f_n. \quad (101)$$

Using (68), I rewrite (101) as

$$t(p_n x_n^f - \sum_{k=1}^N p_k x_{kn}^f) = t \left(\frac{a_{Ln}}{b_{Ln} p_n} \right)^{\frac{1}{\sigma_n-1}} a_{Ln} x_n f_n. \quad (102)$$

Hence, by replacing a_{Ln} with $\alpha_{Ln} = \left(\frac{a_{Ln}}{b_{Ln} p_n} \right)^{\frac{1}{\sigma_n-1}} a_{Ln}$, Proposition 3 is still valid and we obtain

$$g_n^2 = \frac{t\bar{g}\bar{x}_{Ln}}{2\theta(1-\lambda_n)} (\alpha_{Ln} + \sum_{k=1}^N \alpha_{Lk} \gamma_k \alpha_{kn} + \sum_{k=1}^N \sum_{j=1}^N \alpha_{Lj} \gamma_j \alpha_{jk} \gamma_k \alpha_{kn} + \dots) \quad (103)$$

Finally, we can use the same calculations as Appendix A.3 to find the optimal level of λ_n .

B Data appendix

B.1 VAT efficiency and final consumption among different activities in UK

VAT revenue is drawn from VAT Statistical Factsheets, October 2009, HM Revenue & Customs Office, UK: <http://www.uktradeinfo.com>. Other variables are drawn from Supply and Use Tables, 2004 - 2008, UK National Statistic, March 2011: <http://www.statistics.gov.uk>. All numbers are in £Millions. The industry classifications are not exactly the same in the two sources and some of the supply-use activities correspond to single VAT Factsheet code. Also, there are few cases that one supply-use activity correspond to multiple VAT factsheet code. I narrowed the non-matching sectors down in each source, merged the single corresponding sectors together, and dropped the ones with zero or negative VAT payments (negative numbers like for crude oil and fabricated metals are probably due to zero-rating of exports). Also, I dropped beverages and tobacco, since they are subject to excise duty.

Sector	VAT revenue	Gross value-added	Final consumption	Total demand
Forestry and logging	35	321	210	884
Manufacture of textiles	195	2609	14372	23538
Manufacture of wearing apparel	154	1385	33729	40067
Manufacture of leather and related products	26	491	7804	11221
Manufacture of wood, wood products and cork, except furniture	359	2671	1576	10633
Manufacture of paper and paper products	515	3445	4445	24638
Printing and reproduction of recorded media	654	16031	13947	37577
Manufacture of chemicals and chemical products	276	5109	2242	42110
Manufacture of rubber and rubber products	757	7175	4448	31105
Manufacture of other non-metallic mineral products	648	5173	3583	21398
Manufacture of fabricated metal products, except machinery & equipment	1430	13335	4276	41348
Manufacture of computer, electronic and optical products	457	2839	2408	33457
Manufacture of electrical equipment	372	13982	19877	122435
Manufacture of machinery and equipment n.e.c	113	12880	9682	62961
Manufacture of motor vehicles, trailers and semi-trailers	2295	9924	38602	97334
Manufacture of furniture	391	3954	11373	20223
Repair and installation of machinery and equipment	3767	27067	28307	45076
Electricity, gas, steam and air conditioning supply	442	16620	25032	66381
Sewerage	255	8388	9108	18918
Construction of buildings	4100	74619	7408	210196
Wholesale trade, except of motor vehicles and motorcycles	9286	46849	0	448
Retail trade except of motor vehicles and motorcycles	6303	62020	1753	2288
Postal and courier activities	333	8759	1013	15687
Telecommunications	2486	21806	15429	45809
Computer programming, consultancy and related activities	3649	35296	3	71168
Financial service activities, except insurance and pension funding	503	60083	38208	97837
Insurance and pension funding, except compulsory social security	453	17058	27251	52119
Activities auxiliary to financial services and insurance activities	177	13666	2347	29776
Real estate activities	1018	108713	113803	166621
Legal and accounting services	3811	30487	621	39243
Activities of head offices; management consultancy services	3120	15262	0	38033
Architectural and engineering activities; technical testing and analysis	2031	20610	327	40063
Scientific research and development	9	4947	327	12291
Advertising and market research	602	6491	82	23690
Other professional, scientific and technical activities	333	42198	1980	104594
Veterinary activities	138	65621	102655	114886
Rental and leasing activities	662	12104	7201	28376
Education	412	68926	77056	99472
Residential care activities	41	5273	5273	5285
Social work activities without accommodation	31	20344	32148	49576
Sports activities and amusement and recreation activities	1668	32348	39444	67386
Activities of membership organisations	213	7072	6053	10107

B.2 Timing of service tax adoption in India up to 2006.

Source: various notifications of service tax rule, government of India. Available at <http://www.servicetax.gov.in>

<http://www.servicetax.gov.in>

Service name	date of adoption	Service name	date of adoption
General Insurance	01.07.1994	Life Insurance	16.08.2002
Stock Broker	01.07.1994	Auxiliary to Life Insurance	16.08.2002
Courier Services	01.11.1996	Fashion Designer	16.08.2002
Advertising	01.11.1996	Dry Cleaning	16.08.2002
Rent a Cab Operator	16.07.1997	Beauty Parlor	16.08.2002
Air Travel Agent	01.07.1997	Health Club and Fitness Center	16.08.2002
Tour Operator	01.09.1997	Event Management	16.08.2002
Clearing and Forwarding Agent	16.07.1997	Port Services(Other Ports)	01.07.2003
Custom House Agent	15.06.1997	Technical Inspection and Certification Agency	01.07.2003
Steamer Agent	15.06.1997	Foreign Exchange Broker	01.07.2003
Consulting Engineer	07.07.1997	Internet Caf	01.07.2003
Management Consultant	01.07.1997	Business Auxiliary Service	01.07.2003
Manpower Recruitment or Supply Agency	07.07.1997	Technical Testing and Analysis	01.07.2003
Security Agency	16.10.1998	Erection, Commissioning or Installation	01.07.2003
Credit Rating Agency	16.10.1998	Maintenance or Repair Service	01.07.2003
Mandap Keeper	16.10.1998	Commercial Training or Coaching	01.07.2003
Chartered Accountant	16.10.1998	Franchise Service	01.07.2003
Cost Accountant	16.10.1998	Survey and Exploration of Minerals	10.09.2004
Market Research Agency	16.10.1998	T.V. and radio Programme Production Services	10.09.2004
Architect	16.10.1998	Outdoor Caterer	10.09.2004
Interior Decorator	16.10.1998	Airport Services	10.09.2004
Company Secretary	16.10.1998	Opinion Poll Service	10.19.2004
Real Estate Agent / Consultant	16.10.1998	Commercial or Industrial Construction	10.09.2004
Underwriter	16.10.1998	Transport of goods by Air	10.09.2004
Broadcasting	16.07.2001	Business Exhibition Service	10.09.2004
Auxiliary to General Insurance	16.07.2001	Forward Contract Services	10.09.2004
Scientific or Technical Consultancy	16.07.2001	Intellectual Property Service	10.09.2004
Photography	16.07.2001	Pandal or Shamiana Services	10.09.2004
Sound Recording	16.07.2001	Travel Agent other than Air and Rail Travel	10.09.2004
Port Service (Major Ports)	16.07.2001	Site Preparation	16.06.2005
Banking and Other Financial Services	16.07.2001	Transport of goods by Road	01.01.2005
On-line Information and Database Access	16.07.2001	Transport of goods other than water	16.06.2005
Video Tape Production	16.07.2001	Mailing List Compilation and Mailing	16.06.2005
Authorized Service Station	16.07.2001	Survey and Map Making	16.06.2005
Convention Centre	16.07.2001	Cleaning Service	16.06.2005
Cargo Handling	16.08.2002	Packaging Service	16.06.2005
Storage and Warehousing	16.08.2002	Clubs and Associations	16.06.2005
Rail Travel Agent	16.08.2002	Construction of Residential Complex	16.06.2005
Cable Operator	16.08.2002	Dredging	16.06.2005