Estimation of Unaccounted Income Using Transport as a Universal Input: A Methodological Note

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A methodological note*

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Abstract

There has been a lot of interest in understanding and measuring the size of unaccounted incomes in economies. There are several methods to measure size of unaccounted income (or shadow economy) - e.g., monetary approach (or currency demand approach), latent variable approach and global indicator approach. Present paper proposes an alternative method by using transport as a universal input. The method is applied to Indian data. To capture the changing structural relationship between input-output and annual volatility of demands, we tested the methodology for two successive Input-Output tables and three consecutive financial years. Since the analysis is based on assumptions, a comparative static analysis is carried out to check the sensitivity of estimates to changes in the assumptions.

Key Words: *Unaccounted income, Under-reporting of GDP, Road Freight Transport, Input-Output Approach, Diesel Adulteration, India.*

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A methodological note

1. Introduction

There has been a lot of interest in understanding and measuring the size of unaccounted incomes in economies.[1] Acharya (1983) classifies literature on unaccounted income into two broad groups - a) those dealing with incomes which should have been reported to tax authorities but were not, and b) extent of under-reporting of national income (or Gross Domestic Product) and output because of non-reporting (or under-reporting) of incomes and output. While these two concepts will have overlaps, they do not coincide.[2] Since under-reporting in GDP can limit the scope of study for a variety of aspect of the economy, the present attempt focuses on this aspect.

While there are a number of established methods in the literature, each of these has faced some criticism. Briefly, the available approaches are classified into three broad categories: the *monetary method (or currency demand approach)*, the *latent variable method* and the *global indicator method*. The *monetary method* works on the assumption that unaccounted segment of the economy works primarily through cash (Ardizzi et al. 2014, Ahumada et al. 2007, Tanzi 1983, Gupta and Gupta 1982, Feige 1979, Gutmann 1977). Apart from the other difficulties with this method, given the transformation in the economy and the extensive discussion on money laundering, it now appears that this may not be a valid assumption. The second set of methods predicts the value of the *latent variable* based on observable variables (Frey and Week-Hannemann 1984, Aigner et al. 1988, Schneider 2005, Chaudhuri et al. 2006). These methods yield an index which throws light on the changes in latent variable over time. To get an actual estimate of the level in any given year, they need to be calibrated using some alternative estimates. The third set of approaches is referred to as the *global indicator approach* which uses some "universal input" to measure the amount of unaccounted incomes. Two examples of this approach exist in the literature – one based on consumption of electricity (Kaufmann and

[1] See for instance, Capasso and Jappelli 2013, Schneider 2005, Bajada and Schneider 2005, Eilat and Zinnes 2002, Caridi and Passerini 2001, Bajada 1999, Bagachwa and Naho 1995, Frey and Pommerehne 1984, Tanzi 1983. For a comprehensive review of literature on unaccounted/ shadow economy see OECD (2002).

[2] OECD (2002) classifies unrecorded economic activities into underground production, illegal production, informal sector production and production of households for own final use.

Kaliberda 1996) and one based on use of labour (Contini 1982). In these cases, there is need to identify a benchmark year where the extent of unaccounted incomes is zero or close to zero. Alternatively, these measures can provide an estimate of the extent to which the unaccounted incomes have changed over the years.[3]

The present paper proposes to add an approach within the category of "global indicator" method. It aims to use "transport" as the universal input on the basis of which unaccounted incomes in the economy can be measured. The rationale for using road freight transport as a global indicator can be summarized as follows:

a) Road freight transport services are used as inputs by all sectors of the economy.
b) Services of transport sector cannot be stored – whenever there is demand for transport it is supplied. Therefore, if one can measure supply credibly, it can be taken as a measure of demand for the service. Further, since demand for road freight transport is a derived demand, we can infer about the output produced in the rest of the economy from these estimates of size of transport sector.

The paper is organized as follows - in the next section we present methodological foundation and assumptions of this paper. We estimate the supply and demand for road freight transport in section 3 and estimate the unaccounted GDP. In section 4, we present a sensitivity analysis with respect to the key assumptions. Section 5 presents some results to establish the robustness of the estimates from this method and in section 6 some concluding comments are presented.

2. Methodology

This methodology as mentioned above, is based on the idea that since transport services are not storable, the supply of transport services would necessarily be equal to the demand for the same. Any difference between the supply and the revealed demand therefore can be treated as unaccounted demand for transport services which in turn would be a reflection of unaccounted incomes in the rest of the economy. To derive the extent of unaccounted incomes therefore, we

[3] For an extensive review of methodologies for estimation of unaccounted income, see Chapter 12 of OECD (2002).

need to estimate demand for and supply of road freight transport services. The methodology adopted for deriving the estimates of demand and supply are discussed below.

2.1 Supply of Road Freight Transport

The supply of road freight transport services during any period of time can be derived from the stock of *on road* goods carriages (G_k), their average freight transport capacity (C_k), and their average annual distance travelled (S_k).[4] If we assume that there are 'n' types of goods carriages on road, the supply of road freight transport services (in tonne kilometre) could be written as:

$$Supply\ of\ Road\ Freight\ Transport(T_S) = \sum_{k=1}^{n} G_{ki} C_k S_k \qquad (1)$$

where

G_{ki} is the stock of *on road* goods carriages of kth category of goods carriages in the ith year

C_k is the average freight transport capacity of kth category of goods carriages

S_k is the annual average distance travelled by kth category of goods carriages

To arrive at the stock of goods carriages on the roads, we need a benchmark on the average age of trucks in India. Existing studies do not provide any estimates of the average age of trucks on Indian roads.[5] To attempt an iterative estimate, we consider 15 years as average life of a goods vehicle. Then estimated stock of goods carriages would be 22.52 lakh of Medium and Heavy Commercial Vehicles (M&HCVs) and 31.47 lakh of Light Commercial Vehicles (LCVs) (as on 31 March 2012). With some assumptions on annual distance travelled and goods carried, the supply of road freight transport services would be 2,988 billion tonne Km.[6] However, for these goods carriages to ply, the estimated annual demand for diesel would be 46.21 billion litre.

[4] Following Government of India (2010), we assume that average daily distance travel of Medium and Heavy Commercial Vehicle (M&HCV) is 151 kilometre and Light Commercial Vehicle (LCV) is 55 Km.

[5] While some reports claim that life of goods carriage in India is upto 20 years (World Bank 2005, MoRTH 2011a), there are no studies that establish an age for trucks on Indian roads.

[6] The assumption on average annual distance travel is based on Government of India (2010) and assumption on capacity of goods carriages is estimated based on category-wise vehicle sales data (see Table A1 in Appendix).

The total demand for diesel in road transport would be 69.13 billion litre (including 22.92 billion litre from road passenger transport). However, the availability of diesel for road transport in 2011-12 is only 47.32 billion litre and it is not adequate to meet above demand for diesel.

Given this difficutly, we use an alternative approach where, availability of diesel is used to determine supply of road freight transoport services. By matching the physical demand (D_d) and supply of diesel (D_s) for road freight transport (equation 2), we get the maximum years' stock of goods carriages that could be supported by the available supply of diesel. In other words, given S_k and F_k we estimate G_{ki}, by matching demand and supply (availability) of diesel for road freight transport.

$$D_s = D_d = \sum_{k=1}^{n} G_{ki} S_k F_k \qquad (2)$$

2.2 Methodology for Estimation of Demand for Road Freight Transport

Demand for road freight transport for a point of time can be estimated as follows:

$$Demand\ for\ Road\ Freight\ Transport = \sum_{j=1}^{m} (TI_j * V_j) \qquad (3)$$

Where,

TI_j is the Transport Intensity of the jth sector, and it is the ratio of Demand for Road Freight Transport to Total Output for the sector.

V_j is the Value of Output of the jth sector

Transport intensity here is measured with respect to output and not value added, since the latter would be more sensitive to changes in relative prices. Transport demand should be related to the physical movement of goods which would be related to outputs rather than value added per se.

Since Value of Output for services sectors is not available from the National Account Statistics (NAS), for services sectors we have estimated the value of output as follows:

$$V_s = GDP_s * (TO_s / GVA_s) \qquad (4)$$

Where,

V_s is the Value of Output of the sth service sector

GDP_s is the Gross Domestic Product of the sth service scector (available from NAS)

TO_s is the Total Output of the sth service sector (available from I-O Table)

GVA_s is the Gross Value Added by the sth service sector (available from I-O Table)

We have compressed Input-Output (I-O) Table 2007-08 (commodity x commodity) from original 130 commodities and services to 17 sectors. This compression is done for ease of handling. The seventeen sectors considered are - one sector for agriculture and allied activities including mining and quarrying, 14 sectors for manufacturing, and two services sectors - one sector for services other than road transport services (including railways) and one for road transport services (including via pipeline). The rationale for working with a greater disaggregation in manufacturing can be explained as follows: Demand for road transport (as percentage of total output) is not only higher for manufacturing sector as compared to other two sectors (agriculture – including mining and quarrying and services sector – other than road transport services) but also transport intensity (as measured by demand for road transport as percentage of total output) varies across manufacturing sub-sectors substantially (coefficient of variation is 0.43). Therefore to capture the dynamics of road freight transport demand in manufacturing sector, we have taken 14 sub-sectors.

In our analysis, we have assumed that in sectors other than services sectors, demand for road freight transport is same as the input road transport services as given in the I-O Table.[7] For services sectors, it is assumed that the demand for freight services is derived from their demand for input goods. This is estimated as follows:

$$DLT_s = \sum_g SLT_g * X_{gs} \ \ where \ \ \ SLT_g = DLT_g / TO_g \qquad (5)$$

Where,

DLT_s is the demand for road freight transport in sth category of service sector

DLT_g is the demand for road freight transport in gth category of goods sector

SLT_g is the share of road freight transport in total output of gth category of goods sector

TO_g is the total output of gth category of goods sector

X_{gs} is the demand for gth category of goods sector by sth category of service sector

[7] In other words, it is being assumed that the entire demand for road transport services for the goods producing sectors is for freight services alone.

It may be noted that since the Input-Output (I-O) table shows relationship between inputs and outputs for the year for which it is constructed, to avoid problems related to changes in relative prices, the analysis is undertaken in 2007-08 prices.

Finally, if estimated supply of road freight transport is greater than demand, it is considered evidence of under reported demand. Corresponding to this unreported demand, there would be under reported Gross Domestic Product (GDP).

3 Results

3.1 Estimation of Supply of Road Freight Transport

Sector-wise consumption of diesel (High Speed Diesel Oil, HSDO) is available from *Indian Petroleum and Natural Gas Statistics 2010-11* (MoPNG 2012). The availability of diesel for road transport is residually determined in Table 1 by first excluding bulk sales of diesel (railways, industry etc.) and then other sectoral uses of diesel from total sales of diesel for a year. Since sector-wise diesel sales data is not available for 2011-12, we have estimated the sectoral consumptions of diesel for 2011-12 based on total sales of diesel in 2011-12 (i.e., 64,750 thousand tonne) and sector-wise percentage share in total sales for 2010-11.[8]

[8] As published by Petroleum Policy Analysis Cell (PPAC) and available at http://ppac.org.in/WriteReadData/userfiles/file/PT_Consumption_H.xls (accessed on 8 October 2014)

Table 1: Sector-wise Consumption (end use) of Diesel ('000 tonne)

	2007-08	2008-09	2009-10	2010-11	2011-12
Railways	2,036	2,166	2,261	2,371	2,559
	(4.27)	(4.19)	(4.02)	(3.95)	
Aviation and Shipping	622	747	670	562	607
	(1.3)	(1.44)	(1.19)	(0.94)	
Agriculture	9,330	6,153	6,829	7,337	7,919
	(19.57)	(11.9)	(12.14)	(12.23)	
Power Generation	3,243	4,316	4,686	4,890	5,278
	(6.8)	(8.35)	(8.33)	(8.15)	
Mining and Quarrying	925	1,025	1,248	1,366	1,474
	(1.94)	(1.98)	(2.22)	(2.28)	
Manufacturing Industry*	2,368	4,264	4,754	4,946	5,338
	(4.97)	(8.25)	(8.45)	(8.24)	
Miscellaneous & Unknown end use	3,558	2,160	1,956	2,171	2,343
	(7.46)	(4.18)	(3.48)	(3.62)	
Private Sales and Private Imports	31	62	94	112	121
	(0.07)	(0.12)	(0.17)	(0.19)	
Road Transport	25,556	30,817	33,744	36,235	39,110
	(53.61)	(59.6)	(60.0)	(60.4)	
Total	**47,669**	**51,710**	**56,242**	**59,990**	**64,750**
Availability of Diesel for Road Transport (in Billion Litre) (1 tonne=1210 litre)	30.92	37.29	40.83	43.84	47.32

Notes: * - Manufacturing Industry includes Chemical and Fertilizers, Civil Engineering, Electricals/ Electronics, Mechanical, Metallurgical, Textile, and Other Consumer and Industrial Goods.
Figure in the parenthesis show the percentage share in total diesel sales.
Source: MoPNG (2012)

Road transport consists of road passenger transport and road freight transport. Since reliable estimate on demand for diesel in road passenger transport is not available, we have derived the same based on a few assumptions (see Table 2).[9] Using data on category-wise number of registered motor vehicles, the demand for diesel in passenger road transport is estimated based on some assumptions on the share of vehicles run on diesel and the consumption of diesel by these vehicles (see Table 2).[10]

[9] We have compiled data on category-wise number of registered motor vehicles for All India and Delhi from 31 March 1996 (1995-96) to 31 March 2012 (2011-12). The data is published by the Ministry of Road Transport and Highways (MoRTH) and is also available in www.indiastat.com website.

[10] Though in a few metros taxis, three wheelers and jeeps are running on alternative fuels (like LPG, CNG), reliable estimates of their percentage share in total stock of vehicles and their average daily consumption of fuels is not

Table 2: Estimation of Demand for Diesel in Passenger Road Transport: 2011-12

Category of Passenger Vehicle	No. of registered vehicles		Annual Diesel Consumption (in billion litre)	Annual Diesel Consumption (in litre/ vehicle)	Average Distance Travelled (Km./day)
	Period	Nos. (A)			
Buses (On Road Stock of vehicles: 13 Years)*	1999-2012	842,496	10.03 @	21,080	258
Taxis (9 Years)*	2003-2012	1,137,015	4.15 **	3,650	179
Three Wheelers (13 Years)*	1999-2012	2,766,100	5.05 @@	1,825	175
Passenger Cars (9 Years)	2003-2012	10,975,380	2.02 #	918	45
Jeeps (9 Years)	2003-2012	807,041	1.06 $	1,314	45
Omni Vans/ Buses (9 Years)*	2003-2012	139,949	0.61 $	4,380	120
Total			**22.92**		

Notes:
** Excluding Delhi, as all commercial public transport vehicles (including taxis, three wheelers and Omni vans/buses) are run on CNG.*
@ We assume that 13 per cent of the stock of buses is public buses, and 87 per cent buses are private buses, and private buses are run half the distance an average public bus runs in a day (assumption based on MoRTH 2011b).
 # We assume that 20 per cent of total passenger cars are run on diesel (following Chugh and Cropper 2014).
$ In India, except in Delhi, Jeeps and Omni Vans/ Buses are mostly run on diesel.
*** For taxis, we assume that the daily diesel consumption is @10 litre/day (informal interviews with taxi drivers).*
@@- For three-wheelers, we assume that the daily diesel consumption is @5 litre/day (informal interviews with auto-rickshaw drivers).

Given the availability of diesel for road transport, i.e., 47.32 billion litre in 2011-12, only 24.40 billion litre (or 51.56 percent of total available supply for road transport) is available for road freight transport. On the other hand, the demand for diesel in road freight transport is derived based on stock of goods carriages (as on 31 March 2012), category-wise average fuel efficiency and average annual distance travelled of goods carriages (see Appendix I for assumptions). These estimates are derived for alternative assumptions on the average age of the vehicles. In Table 3, we present the stock of goods carriages (as shown in second and third columns of Table 3) by varying the average age of the vehicles ranging from 1 year to 10 years and the corresponding demand for diesel. Table 3 shows that the availability of diesel is not enough to meet the demand for diesel for 7 years' cumulative stock of goods carriages.

available to us. Therefore, we have not attempted to make any guesstimate and reduce the demand for diesel in passenger road transport.

Table 3: Estimation of Demand for Diesel in Road Freight Transport: 2011-12

Stock of Goods Carriages (in Year)	Stock of Goods carriages (as on 31 March 2012) (in lakh)		Diesel Demand in Road Freight Transport (in Billion Litre/Year)*			Diesel Demand in Passenger Road Transport (in Billion Litre/ Year)	Total Demand for Diesel in Road Transport (billion litre)	Annual Diesel Availability for Road Transport in 2011-12 (billion litre)
	M&HCVs	LCVs	M&HCVs	LCVs	Total			
1 Year	2.96	2.98	5.10	0.70	5.80	22.92	28.72	47.32
2 Years	5.52	6.74	9.51	1.59	11.11	22.92	34.03	47.32
3 Years	7.09	9.08	12.22	2.14	14.36	22.92	37.28	47.32
4 Years	8.90	11.67	15.33	2.76	18.09	22.92	41.01	47.32
5 Years	11.12	14.28	19.15	3.37	22.52	22.92	45.44	47.32
6 Years (+1)	**11.05**	**21.17**	**19.03**	**5.00**	**24.03**	**22.92**	**46.96**	**47.32**
7 Years (+2)	13.38	22.89	23.05	5.41	28.46	22.92	51.38	47.32
8 Years (+3)	16.84	22.26	29.01	5.26	34.26	22.92	57.19	47.32
9 Years (+4)	17.97	23.70	30.95	5.60	36.55	22.92	59.47	47.32
10 Years (+5)	20.54	26.30	35.38	6.21	41.59	22.92	64.51	47.32

Note: *- Estimated based on methodology described in Equation 1.
Source: Estimated by authors

Once physical availability (supply) and demand for diesel for road freight transport is matched, we estimate the supply of road freight transport based on category-wise average gross vehicle weight and average distance travelled per annum by goods carriages. The estimated supply of road freight transport in 2011-12 is 1,537.51 billion tonne kilometer (BTKM) - 1,513 BTKM from 6 years' cumulative stock of goods carriages (Table 4) and additional 24.51 BTKM from goods carriages having vintage more than 6 years.[11]

Table 4: Estimation of Supply of Road Freight Transport: 2011-12

Age of vehicle	Stock of vehicles (in lakh) (as on 31 March 2012)		Annual Distance travelled (in Lakh Km.)		Annual freight transported (in billion tonne Km.)		
	M&HCVs	LCVs	M&HCVs	LCVs	M&HCVs	LCVs	Total
1 Year	2.96	2.98	447	164	360	24	384
2 Years	5.52	6.74	834	371	671	54	725
3 Years	7.09	9.08	1071	499	862	73	935
4 Years	8.90	11.67	1344	642	1,082	93	1,175
5 Years	11.12	14.28	1679	785	1,351	114	1,466
6 Years	11.05	21.17	1669	1165	1,343	170	1,513
7 Years	13.38	22.89	2021	1259	1,626	183	1,810
8 Years	16.84	22.26	2543	1224	2,047	178	2,225
9 Years	17.97	23.70	2714	1303	2,184	190	2,374
10 Years	20.54	26.30	3102	1447	2,496	211	2,707

Source: Estimated by authors

[11] We get 1,513 billion tonne Km. from 6 years' stock of goods carriages for which entire demand for diesel is met by the available of supply, and another 24.51 billion tonne Km. from a few goods carriages (having vintage more than 6 years) for which additional 0.36 billion litre of diesel (over and above meeting the demand for 6 years' stock of goods carriages) is available.

3.2 Estimation of Demand for Road Freight Transport

We have compiled the Gross Domestic Product (GDP, 2004-05 Series) for all the 17 sectors (both at current and constant 2004-05 prices) from National Account Statistics (CSO 2013, 2011). Except for services sectors, we have also compiled the Gross Value of Output (at constant 2004-05 prices) from National Account Statistics database (CSO 2013).

Based on the methodology described in equations 3-5, we have estimated the demand for road freight transport for all the 17 sectors in Table 5. For 2011-12, total demand for road freight transport services is estimated to be Rs. 248,936 crore (in 2007-08 prices).

Table 5: Estimation of Demand for Road Freight Transport for 2011-12 based on 2007-08 Input-Output Table

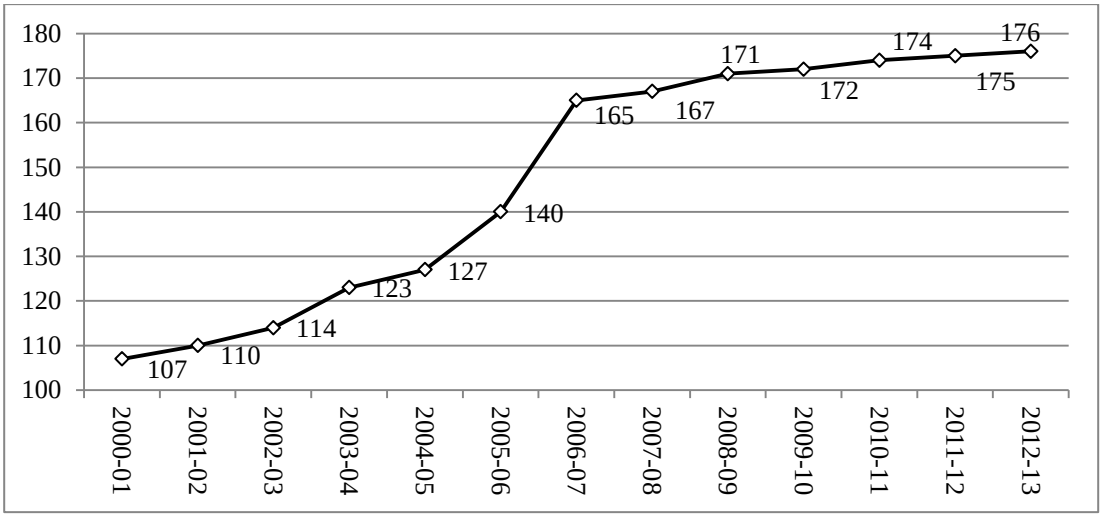
Sector Description	Value of Output (at 2007-08 Prices) (Rs. Crore) 2011-12	Demand for Road Freight Transport/Total Output 2007-08	Demand for Road Freight Transport (Rs. Crore) (at 2007-08 Prices) 2011-12
(A)	(B)	(C)	(D)=(B*C)
Agriculture & Mining	1,441,219	0.016	22,844
Food products	666,714	0.029	19,067
Beverages & tobacco products	74,467	0.032	2,372
Textile products	472,864	0.067	31,775
Wood and wood products, furniture, fixture etc.	102,092	0.042	4,246
Paper and printing etc.	138,355	0.061	8,472
Leather & fur products	51,051	0.044	2,269
Rubber, petroleum products etc.	731,878	0.014	10,357
Chemical and chemical products	501,795	0.042	21,118
Non-metallic products	200,528	0.055	11,110
Basic metals	729,126	0.029	20,946
Metal products & machinery	523,334	0.028	14,442
Electrical machinery	262,118	0.031	8,143
Transport equipment	468,308	0.030	13,824
Other manufacturing	255,890	0.078	19,938
Non-land Transport Services as Input	5,907,936	0.006	32,572
Land (Road) Transport Services as Input	821,589	0.007	5,441
Total			**248,936**

*Note: *- Estimated. Value of Output (at 2007-08 prices) for 2011-12 (Rs. Crore) = Value of Output (at 2004-05 prices) for 2011-12 (Rs. Crore) * (GDP at Current Prices for 2007-08 / GGDP at Constant 2004-05 Prices for 2007-08)*

Sources: Column C: Input – Output Transaction Table for 2007-08 (CSO 2012)

The value of demand for road freight transport (as we estimate in Table 5) is converted into physical units (in Billion Tonne Km.) by using average tariff rate of road freight transport (in Rs. per tonne Km.). The average tariff of road freight transport for 2011-12 is derived from available information and a few assumptions (for details see Appendix II). The estimated average road freight rate is converted to 2007-08 prices by using *Road Freight Index of Transport Corporation of India Limited* (TCIL) (Figure 2). In Table 6, we have estimated the demand for road freight transport in physical unit for 2009-10 to 2011-12 using the I-O Table of 2007-08.

Figure 1: Road Freight Index of Transport Corporation of India Limited (TCIL): 2000-01 to 2012-13



Data Source: http://www.tcil.com/tcil/indian-road-freight-index.html (accessed on 7 October 2014)

Table 6: Estimation of Demand for Road Freight Transport based on I-O Table 2007-08

Description	2011-12
Demand for Road Freight Transport (in Rs. Crore) (Prices in 2007-08) (A)	248,936
Road Freight Index (RFI) Deflator (B)*	1.048
Road Freight Rate (Rs. Per tonne Km.) (Respective year's prices) (C)#	2.275
Road Freight Rate (Rs. Per tonne Km.) (Prices in 2007-08) (D) [C*(1/B)]	2.171
Demand for Road Freight Transport (in Billion Tonne Km.) (E) [A/(D*100)]	1,147

Note: * - e.g., $RFI_{2011-12}/RFI_{2007-08}$
- For details estimation method see Appendix II
Source: Estimated by authors

3.3 Estimation of Unaccounted GDP for India: 2011-12

In this section, we compare the physical demand and supply of road freight transport (in billion tonne kilometer) and estimate the unaccounted supply of road freight transport (Row G in Table 7). Corresponding to this unaccounted supply of road freight transport, we have also estimated unaccounted GDP (Row H in Table 7) and it is 25 percent for 2011-12.

Table 7: Estimation of Unaccounted GDP for India (based on I-O Table 2007-08)*

Description	2011-12
Demand for Road Freight Transport (in Rs. Crore) (Prices in 2007-08) (A)	248,936
Demand for Road Freight Transport (in Billion Tonne Km.) (B) (source Table 6)	1,147
Gross Domestic Product (in Rs. Crore) (Prices in 2007-08) (C)	6,143,246
GDP Supported by Per Unit of Road Freight Transport (F) (Rs. Crore/Billion Tonne Km.) (Prices in 2007-08) (D) [C/B]	5,355.93
Estimated Supply of Road Freight Transport (in Billion Tonne Km.) (E)	1,537.51
Unaccounted Supply of Road Freight Transport (F) [(E-B)/E] (Percent)	0.25
Estimated GDP (Rs. Crore) (Prices in 2007-08) (G) [D*E]	8,103,515
Estimated Share of Unaccounted GDP (H) [(G-C)/G] (Percent)	0.25

Source: Computed by authors

4. Sensitivity Analysis

Since the analysis is based on some assumptions, it would be useful to examine the sensitivity of the estimates to changes in the assumptions. Table 8 presents these results. Since often studies suggest higher values for average distance travelled and average carrying capacity, the table considers cases where these parameters are increased by ten percent. On the other hand, since fuel efficiency is based on weighted average declared fuel efficiency of different varieties of goods carriages, for older vehicles, the fuel consumption would be higher – so we consider a ten percent decrease in fuel efficiency. Table 8 shows that 10 percent increase in average daily distance covered by goods carriages will increase the estimated unaccounted income by 9.26 percent. On the other hand, an increase in average daily distance travel will support a smaller stock of goods carriages and at the same time it will result in larger supply of road freight transport (in billion tonne Km.). The rise in supply of road freight transport exceeds the fall in stock of goods carriages and it results in larger supply of road freight transport implying an increase in unaccounted GDP. Similarly, 10 percent fall in average fuel efficiency will lead to

22.47 percent fall in estimated unaccounted income. 10 percent increase in average carrying capacity will result in 26.65 percent increase in estimated unaccounted income. In other words, if one incorporates any estimate of overloading of vehicles, the estimates of unaccounted incomes would increase.

Table 8: Comparative Static Results

Parameter (Assumption)	Supply of Road Freight Transport (in BTKM)		Demand for Road Freight Transport (in BTKM)	Unaccounted Income (percent)		
	Present	After Change (10%)		Present	After Change	% Change
(A)	(B)	(C)	(D)	(E) = [(B-D)/B]	(F) = [(C-D)/C]	(G) = [(F-E)/E*100]
Average Daily Distance Travel (M&HCVs: 151 Km.; LCVs: 55 Km.) (Increase)	1,537.51	1,587.58	1,147	0.25	0.28	9.26
Fuel Efficiency (Km./Litre) (M&HCVs: 3.2; LCVs: 8.5) (Decrease)	1,537.51	1,428.24	1,147	0.25	0.20	-22.47
Average Carrying Capacity (tonne/vehicle) (M&HCVs: 22.05; LCVS: 3.99) (Increase)	1,537.51	1,690.96	1,147	0.25	0.32	26.65

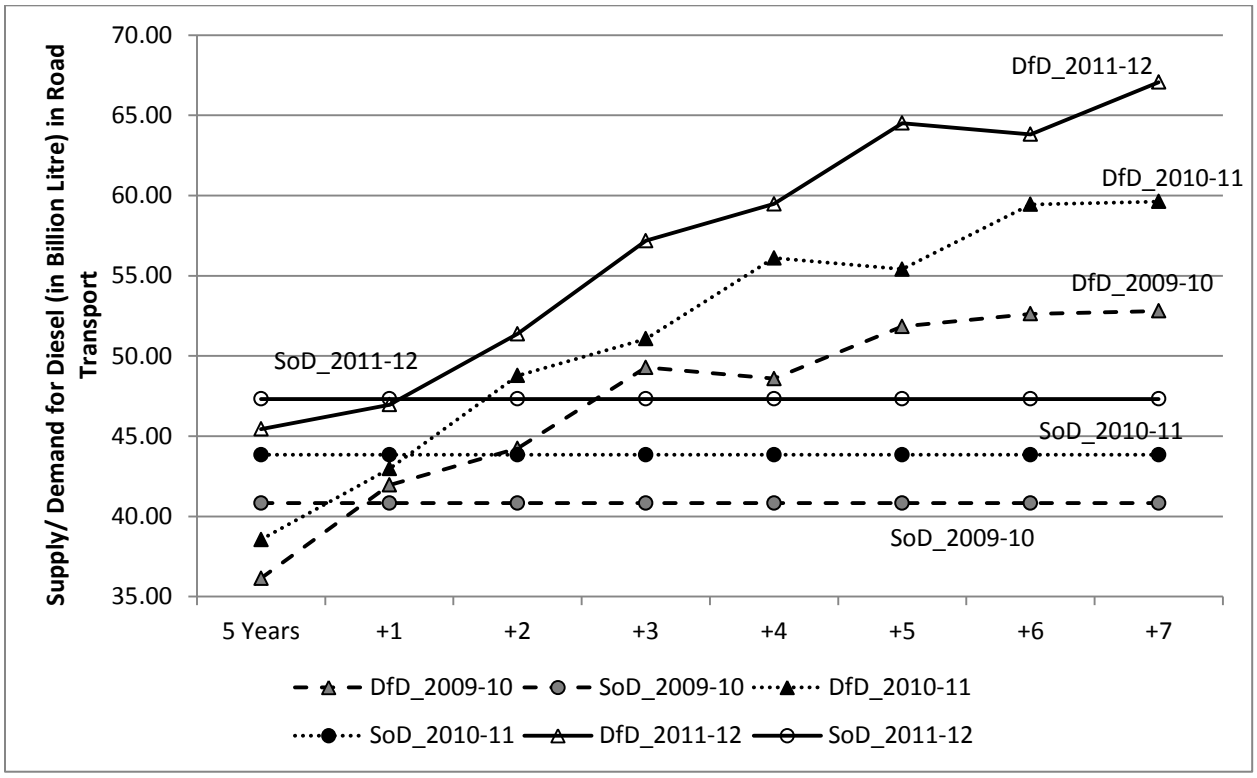
Source: Estimated by authors

5. Robustness of the Estimates

To check the robustness of our estimates with reference to change in structural composition of the economy and transport intensity of the sectors, first, based on availability of information we have extended our analysis to cover another two years 2009-10 and 2010-11. This helps rule out the possibility that the results obtained for 2011-12 are an aberration relevant to a single year. Second, we have estimated the results with reference to two successive I-O Tables of 2003-04 and 2007-08 released by CSO (CSO 2012, 2008). It is expected that with changes in the economy as reflected in the I-O tables, the measure of unaccounted incomes too would change. However, if with change in the I-O tables, there is a very dramatic change in the results for any given year, then the methodology and the results would be viewed with a degree of suspicion.

Before going into the estimates for unaccounted supply of road freight transport, it would be worthwhile to check the physical demand and supply of diesel for road freight transport for all three years of our analysis. In Figure 2, we present the estimates of supply and demand for diesel in road freight transport across cumulative stock of goods carriages. Across all estimates, we find that the availability of diesel could meet demand for upto 6 years cumulative stock of goods carriages.[12] It means that if the actual stock of vehicles in operation is higher, then either the vehicles would be running fewer kilometers per day or there is not enough diesel to run them.

Figure 2: Matching of Supply and Demand for Diesel in Road Freight Transport



Note: DfD implies demand for Diesel and SoD implies Supply of Diesel

Source: Estimated by Authors

[12] By matching availability and demand for diesel, additional supply of road freight transport of 24.51 and 62.22 billion tonne Km. is gained for 2011-12 and 2010-11 (with reference 6 years' stock of goods carriages). For 2009-10, we have a reduction in supply of road freight transport by 80.26 billion tonne Km. due to unavailability of diesel to meet 6 years' stock of goods carriages.

The estimates for various years corresponding to two I-O Tables are presented in Table 9. It shows that the estimates of unaccounted income do vary across I-O tables and year of estimation, but the variation is not large. Estimates based on 2003-04 I-O Table show that unaccounted incomes vary from 29 percent (in 2011-12) to 35 percent (in 2009-10). On the other hand, estimates based on 2007-08 I-O Table vary from 25 percent (in 2011-12) to 30 percent (in 2009-10). Variation in estimates across I-O tables is only 3 to 5 percent.

Table 9: Estimation of Unaccounted GDP in India

Description	Prices in	2011-12	2010-11	2009-10
Estimated Share of Unaccounted GDP (Percent)	2003-04	0.29	0.30	0.35
	2007-08	0.25	0.27	0.30

Source: Computed by Authors

5.1 Impact of additional supply of diesel

It is often argued that diesel in the country is adulterated with a number of other products, primary among them being kerosene. It is therefore interesting to ask what happens to the estimates of unaccounted demand for road freight transport and corresponding unaccounted GDP, if the effective supply of diesel was higher say by five percent (Scenario I) or ten percent (Scenario II). Table 10 presents baseline scenario and two alternative scenarios - Scenario I where the fuel supply for goods carriages is higher by 5 percent, and Scenario II where additional 10 percent fuel is available for road freight transport.

Table 10: Estimation of Unaccounted Supply of Road Freight Transport (I-O Table 2007-08)

	2011-12	2010-11	2009-10
Baseline Scenario	0.25	0.27	0.30
Scenario I (5% additional Diesel Supply)	0.32	0.34	0.36
Scenario II (10% additional Diesel Supply)	0.38	0.39	0.41

Source: Computed by Authors

6. Conclusions

This paper develops a methodology for estimation of unaccounted GDP based on road freight transport as a universal input. To capture the dynamics of the relationship between inputs and outputs and structural changes of the economy, the methodology is tested for India by using two different I-O Tables (2007-08 and 2003-04) and estimating the results for 3 consecutive years (2009-10 to 2011-12). The results show that for reasonable assumptions, fairly consistent estimates of unaccounted GDP can be derived. The actual level of unaccounted incomes in the country can be calibrated by incorporating estimates of the adulteration in diesel and estimates of overloading in trucks.

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Appendix I

Estimation of Average Freight Transport Capacity and Fuel Efficiency of M&HCVs and LCVs

First, from the data on the category-wise number of registered vehicles, we estimate the stock of goods carriages (multi-axle/articulated vehicles/trucks and lorries/light motor vehicles (goods)), and passenger carriers (buses, taxis, three-wheelers, passenger cars, Omni vans, etc.). The latest data available for state-wise, category-wise registered motor vehicles is as on 31 March 2012. Since, average vehicle weight-wise information on stock of goods carriages is not available from the data released by the Ministry of Road Transport and Highways, we have relied on category-wise domestic sales data released by magazines like *Motor India* (May 2011 and May 2012 Issue) and *Commercial Vehicle* (May 2012 Issue) (Table A2). Since all domestic sales of vehicles required registration, ideally, domestic sales figure should match the number of registrations of vehicles in a year. Second, from available data on category-wise (based on gross vehicle weight) domestic sales of commercial vehicles, we estimate the weighted average maximum weight for Light Commercial Vehicles (LCVs: maximum weight up to 7.5 tonne) and Medium and Heavy Commercial Vehicles (M&HCVs). The estimated maximum weight for LCVs is 3.99 tonne, and that of M&HCVs is 22.05 tonne (Table A1).

Third, since data on fuel efficiency across varieties of goods carriages are not available in the public domain, to estimate the fuel efficiency of the vehicles, we depend on company product brochures where, for a few models, we found the fuel efficiency figures. The available information is placed according to their category based on Gross Vehicle Weight (GVW), and we estimate the weighted average fuel efficiency of the vehicles. Average fuel efficiency for LCVs comes to 8.5 km per litre, and that of M&HCVs to 3.2 km per litre. We found that fuel efficiency figures as put up by Government of India (2010) for LCVs (light trucks) and M&HCVs (heavy trucks) are 4.5 km per litre and 3.6 km per litre, respectively. The estimate of average mileage provided by the Transport Corporation of India (TCI) and the Indian Institute of Management Calcutta (IIMC) (2012) for major freight across India is 4.06 km per litre for 2011−12. The estimated average fuel efficiency for M&HCVs is 3.2 km per litre, and for LCVs it is 8.5 km per litre (Table A1), and we have considered these numbers for estimation. The rationale behind the numbers put up by Government of India (2010), and TCI and IIMC (2012) is not clear.

Table A1: Category-wise domestic sales of commercial goods carriers in India: 2009−10 to 2011−12

Sl. No.	Category of Commercial Vehicle	Min. Mass (in tonne)	Max. Mass (in tonne)	Domestic Sales (in Nos.)			Gross Vehicle Weight (in tonnes)	Weighted Average Vehicle Weight (in tonne)	Fuel Efficiency (in Km./Litre)	Weighted Average Fuel Efficiency (in Km./Litre)
				2009-10	2010-11	2011-12				
	(A)	(B)	(C)	(D)	(E)	(F)	(G)=(C*F)	(H)=(G/F)	(I)	(J)
	Light Commercial Vehicles (LCVs) (Goods Carrier)									
1	Maximum mass upto 3.5 tonne		3.5	212,943	272,995	361,192	1,264,172		8.5	
2	Maximum mass exceeding 3.5 tonne but not exceeding 7.5 tonne	3.5	7.5	40,421	44,035	50,268	377,010			
	Total LCVs (Goods Carrier) (1 to 2)			**253,364**	**317,030**	**411,460**	1,641,182	**3.99**		**8.5**
	Medium & Heavy Commercial Vehicles (M&HCVs) (Goods Carrier)									
3	Maximum mass exceeding 7.5 tonne but not exceeding 12 tonne	7.5	12	43,679	55,411	67,056	804,672		5.1	
4	Maximum mass exceeding 12 tonne but not exceeding 16.2 tonne	12	16.2	48,605	60,686	60,955	987,471		3.5	
5	Maximum mass exceeding 16.2 tonne but not exceeding 25 tonne	16.2	25	76,556	85,503	78,185	1,954,625			
6	Maximum mass exceeding 25 tonne		25	14,348	44,471	64,644	1,616,100		2.7	
	Haulage Tractor (Tractor-Semi Trailer/ Trailer)									
7	Maximum mass exceeding 16.2 tonne but not exceeding 26.4 tonne	16.2	26.4				-			
8	Maximum mass exceeding 26.4 tonne but not exceeding 35.2 tonne	26.4	35.2	8923	12,839	10,871	382,659			
9	Maximum mass exceeding 35.2 tonne but not exceeding 40 tonne	35.2	40.0	338	562	1,017	40,680			
10	Maximum mass exceeding 40 tonne but not exceeding 49 tonne	40.0	49.0	7918	13,165	14,638	717,262			
11	Maximum mass exceeding 49 tonne		49	1494	2,484	1,943	95,207			
	Total M&HCVs (3 to 11)			**201,861**	**275,121**	**299,309**	6,598,676	**22.05**		**3.2**

Source: *Motor India* (May 2011, May 2012), *Commercial Vehicle* (May 2012),[13] and Planning Commission (2011)

[13] These are Magazines available online at: *http://www.motorindiaonline.in/ and http://www.commercialvehicle.in/*

Appendix II

Estimation of Average Tariff for Road Freight Transport

To determine a reliable and representative average tariff of road freight transport per tonne-km, we worked with road freight tariff across Indian cities.[14] We have found that the average tariff across cities varies, and the average tariff per tonne per km of road freight transport is Rs. 1.75 (minimum Rs. 1.1 to maximum Rs. 4.6) for medium and heavy commercial vehicles (M&HCVs).[15] To estimate the average tariff for light commercial vehicles (LCVs), we have relied on informal discussions with a few transporters and local traders, and find that the average tariff for LCVs is higher than for M&HCVs. The reason for this difference is that LCVs mostly operate for shorter distances, and within city limits. Traffic restrictions on the movement of goods carriages within the city, as well as various factors influence the higher average tariff for LCVs. The weighted average of road freight tariff is estimated to be Rs. 2.275 per tonne-km for 2011-12 (see Table A2).

Table A2: Estimation of average tariff per tonne-km: 2011−12

Sl. No.	Alternative estimate for demand of diesel in the freight transport sector	Unit	Amount	Data source
1	Average vehicle weight of medium and heavy commercial vehicle (M&HCV) under full load (capacity)	tonne	22.05	Estimated (see Table A1)
2	Average vehicle weight of light commercial vehicle (LCV) under full load (capacity)	tonne	3.99	-do-
3	Average road freight tariff for medium and heavy commercial vehicle (M&HCV)	Rs. per tonne-km.	1.75	Estimation based on data provided in http://www.infobanc.com/logistics/logtruck.htm
4	Average revenue for light commercial vehicle (LCV)	Rs. per tonne-km.	7.00	Estimated (4*Av. Rev. for

[14]The data on truck freight rate (in Rs. per tonne km for 16 tonnes vehicle) between 4 metros (Kolkata, Mumbai, Chennai, and New Delhi), and 26 major cities, is taken from *http://www.infobanc.com/logistics/logtruck.htm* (last accessed on 10 April 2012); and the data on distance between cities (in km.) are taken from *http://www.distancebetweencities.co.in/*

[15] This is a simple average of the rates computed for different pairs of destinations within India. Similar rates are reported in a study by TCI and IIMC (2012).

Sl. No.	Alternative estimate for demand of diesel in the freight transport sector	Unit	Amount	Data source
				M&HCVs)
	Average monthly distance travelled			
5	M&HCV	km per month	4,592.92	Assumption based on Government of India (2010)
6	LCV	km per month	1,672.92	-do-
	Stock of goods carriages (as on 31March 2012)			
7	No. of multi-axle/articulated vehicles/ trucks and lorries (age ≤7 years) (M&HCVs)	Nos	13,38,288	Estimated based on state-wise, category-wise vehicle registration data released by the Ministry of Road Transport and Highways, Government of India, New Delhi
8	No. of light commercial vehicles (goods carrier) (age ≤7 years) (LCVs)	Nos	22,88,585	-do-
	Average annual road freight transport			
9	M&HCVs [(5*1)]*12Months]	Tonne−km per vehicle	12,15,285.75	Estimated
10	LCVs (6*2)*12 months	Tonne−km per vehicle	80,099.25	-do-
	Average annual road freight transport			
11	M&HCVs [(9*7)/10^9]	Billion tonne−km	1,626.40	Estimated
12	LCVs [(10*8)/10^9]	Billion tonne−km	183.31	-do-
13	Total (11+12)	Billion tonne−km	1,809.71	
	Share in total road freight transport			
14	M&HCVs (11/13)		0.90	Estimated
15	LCVs (12/13)		0.10	-do-
16	Weighted average revenue for road freight transport (14*3+15*4)	Rs per tonne−km	2.275	Estimated

Source: Computed based on data sources as shown in last column.