Does choice of contract matter for cost and quality of public goods

Ram Singh

Public Private Partnerships for National Highways

Lectures 1 and 2

PPPs for Infrastructure: Common Features

PPPs :

- pooling of resources through joint investments, by public and private sectors
- for making of provisions of public goods - roads and other infrastructure
- negotiations among participants for risk sharing
- allocation of project risks and liabilities, b/w public and private sectors
  - Public Sector - Regulatory, land related risks
  - Funding and commercial

Why PPPs?

Traditional (non-PPP) Approach:

- Delays and Cost Overruns are too frequent and too large;
- More than 80 percent of projects experience delays/cost overruns (Singh, 2010);
- Quality of assets deliver is poor

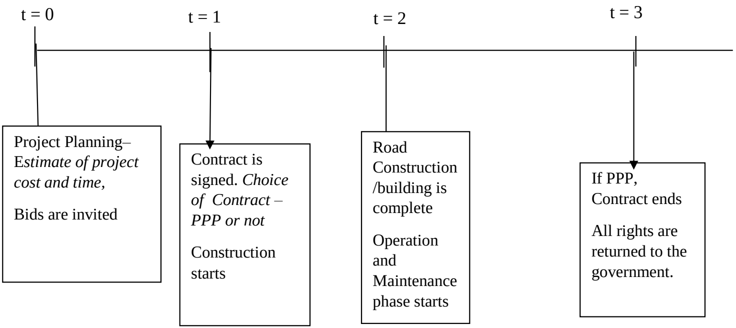
Belief in Superiority of PPPs:

- will reduce project delays
- will bring down project costs
- will deliver better quality assets

... for ensuring provision of better road services, i. e., **higher quality of construction** *and maintenance of roads and* **completion of projects without cost and time overrun**, *... (Govt of India, May 2005)*

Expectations from PPPs

Project Phases



Project Timeline

Contracts, Obligations Decision Rights

Traditional Contracts:

- No Bundling
- Most engineering decisions are taking by Govt
- Construction Cost risk (mostly) borne by the contractor
- Contractor does not bear any Operation and Maintenance (O/M) cost and related risk

PPP:

- Bundling and Greater Delegation
- Most engineering decisions are taking by Contractor
- Entire Construction cost and O/M cost Risks borne by contractor
- Contractor may bear revenue related risks
  - Toll - commercial risk assigned to contractor
  - Annuity - retained by the government

PPPs Contracts and Risk Allocations

Figure 1. Different Levels of Private Sector Engagement in PPP Contracts

	Identify Infrastructure Need	Propose Solution	Project Design	Project Financing	Construction	Operation/ Maintenance	Ownership
Bid/Build	Public Sector				Private Sector	Public Sector	
Design/Build	Public Sector		Private Sector	Public Sector	Private Sector	Public Sector	
Design/Build/Finance	Public Sector		Private Sector			Public Sector	
Design/Build/Finance/ Operate/Maintain	Public Sector		Private Sector				Public Sector

Source: Brookings analysis and expert interviews

PPPs: Incomplete Contracts

Infrastructure Assets:

- Have output features
  - Number of traffic lanes, design of the road, over and under-passes
  - Engineering Designs
- Quality of the assets during Operational phase
  - quality of construction, quality and mix of inputs used, etc.

Problem:

- Output features are observable/verifiable/contractible
- But, Quality is not observable/verifiable
  - quality shows up after several years of construction,
  - corruption can make the quality ‘non-verifiable’

Efforts, Cost and Quality

Cost reducing activities by contractor during Construction Phase:

- x denotes Observable cost reducing efforts
- y denotes Non-observable cost reducing but quality-reducing activities.

Let

- q denote quality of road during O/M phase
- effort y is quality-shading but x is not

$$q_y(.) < 0 \quad q_x(.) = 0$$

C^a denotes the **Actual Construction** costs, known at the end of Construction phase

$$C^a(x, y) = c_0^a - c_1(x) - c_2(y),$$

The First Best I

Let,

- M denote the operation and maintenance (repair) costs of the project, and
- B denote the Social Benefit from the road.
- M is incurred during the $O\&M$ phase, during dates $t = 2$ and $t = 3$.
- Similarly, B accrues in the $O\&M$ phase.

$$\frac{dB(y)}{dy} < 0 \ \& \ \frac{dM(y)}{dy} > 0.$$

Now, the net social benefit can be written as:

$$B(y) - M(y) - [c_0^a - c_1(x) - c_2(y)] - [x + y].$$

The First Best II

Therefore, the social optimization problem is:

$$\max_{x,y}\{B(y) - M(y) - c_0^a + c_1(x) + c_2(y) - x - y\} \tag{0.1}$$

Assume optimization problems are concave. The first order conditions are:

$$\frac{dc_1(x)}{dx} \leq 1 \tag{0.2}$$

$$\frac{dB(y)}{dy} + \frac{dc_2(y)}{dy} - \frac{dM(y)}{dy} \leq 1 \tag{0.3}$$

Let x^*, y^* solve these equations, respectively and simultaneously. We assume

$$x^* > 0 \text{ However,} y^* = 0, i.e.,$$

The First Best III

the gains from quality reducing effort y are more than offset by the social costs in terms of increased maintenance costs and reduced benefits.

- Let q^* denote the socially optimum level of quality, i.e.,

$$q^* = q(y^*).$$

- $c_1(.)$, $c_2(.)$, $q(.)$, $M(.)$ and $B(.)$ are all non-contractible.

Traditional Contracts

- There is no bundling
- Contractor does not care about Maintenance costs
- Contractor focuses only on minimizing construction costs

Under TC, the contractor solves

$$\max_{x,y} \left\{ P^{TC} - [C_0^a - \alpha^{TC} c_1(x) - c_2(y) + x + y] \right\}, i.e.,$$

$$\min_{x,y} \left\{ \alpha^{TC} c_1(x) + c_2(y) - x - y] \right\}, i.e.,$$

$\alpha^{TC} < 1$

$$\begin{cases} x^{TC}(\alpha^{TC}) < x^* & . \\ y^{TC} > y^* = 0 & . \end{cases} \tag{0.4}$$

PPP: Contracts

- There is bundling
- Contractor cares about Maintenance costs
- Contractor focus on construction as well as Maintenance costs
- P^{PP} can be fixed or $P^{PP} = \gamma B(y)$

Under PPP, the contractor solves

$$\max_{x,y}\{P^{PP} - [M(y) + C_0^a - \alpha^{PP} c_1(x) - c_2(y) + x + y]$$

When P^{PP} does not depend on y,

$$\min_{x,y}\{M(y) + \alpha^{PP} c_1(x) + c_2(y) - x - y]$$

$$\alpha^{TP} < \alpha^{PP} \Rightarrow x^{TC} < x^{PP}$$
$$0 \leq y^{PP} < y^{TC}$$

Quality and Construction Costs

Proposition

Quality $q^{PP} > q^{TC}$

The Construction Cost Ratio:

$$CO = \frac{C^a}{C^e}$$

where C^a is the actual construction cost and C^e is the expected construction cost of the project.

Proposition

For any given project cost estimates, C^e*:*

$$x^{TC} = x^{PP} \Rightarrow [(\frac{C^a}{C^e})^{PP} > (\frac{C^a}{C^e})^{TC}$$

However, $x^{TC} < x^{PP}$ and $y^{TC} > y^{PP}$. Therefore, $(\frac{C^a}{C^e})^{PPP} >$ or $\leq (\frac{C^a}{C^e})^{TC}$ is possible

Bidding and Contract Choice

Let

- The government gets estimates of costs and revenue from toll
- Bids are invited with these estimates
- A project becomes PPP it investors find it commercially attractive.

Bid=Asking Price

- For non-PPP, it is the price asked for construction works
- For non-toll-PPP, it is the asked price for construction and maintenance tasks
- For toll-PPP, it is the asked price for construction and maintenance tasks **over and above toll receipts**

Note

- For toll-PPP, bid can be **positive or negative**
- Toll rates are uniform across the country
- No provision for contract renegotiation if cost are high

Data

Data Source: NHAI

- Start Dates: December 1997- December 2012
- Completion Dates: December 1998- December 2015

Table : Category-wise Number of Projects

Project Category	Number of Projects
Toll-PPP	66
Non-toll-PPP	38
PPP (toll + non-toll)	104
Non-PPP	209
All projects (PPP + non-PPP)	313

Measuring Quality

Proposition

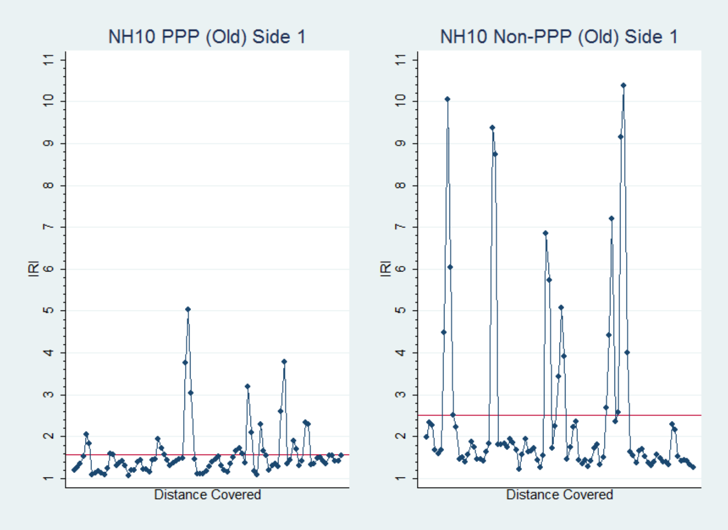
Quality $q^{PP} > q^{TC}$

Data on road (quality) roughness

- collected using an *App* called **‘Roadroid’**.
- The App uses the ‘accelerometer’ built-in Samsung smart-phone to measure road roughness.
- Recodes GPS coordinates of the site, time and speed
- Vibration data is uploaded on the platform to covert it in excel format

Measuring Quality using Roadroid

Measuring Quality



Quality Data

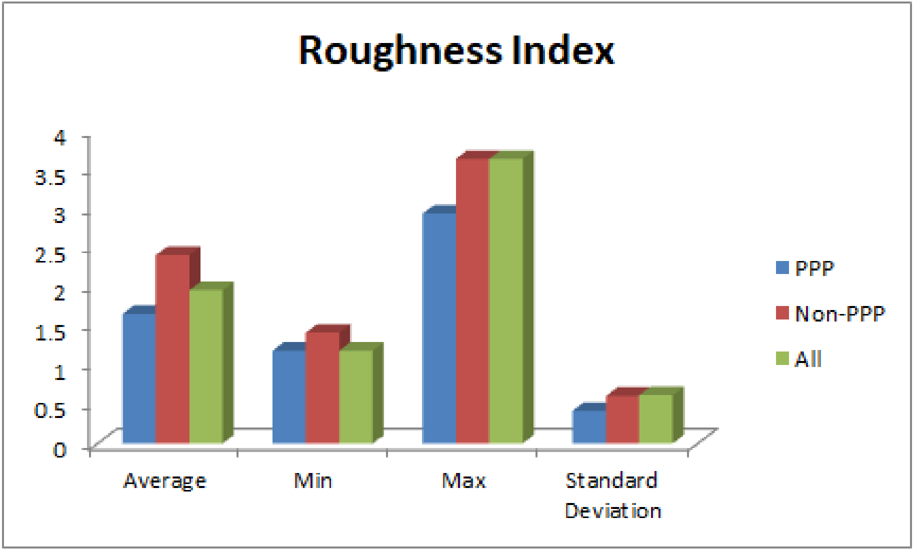
Table : Projects with Quality Data

Category	Number of Projects
Toll-PPP	44
Non-toll-PPP	4
PPP (toll + non-toll)	48
Non-PPP	36
All projects (PPP + non-PPP)	84
Boundaries Covered	54

Table : Roughness Index-Summary Statistics

Project Type	Average	Min	Max	Standard Deviation
PPP	1.66	1.19	2.94	0.42
Non-PPP	2.41	1.42	3.64	0.61
All	1.96	1.19	3.64	0.62

Road Quality Comparisons



Road Quality Comparisons

Table : Road Roughness: PPPs Vs non-PPPs

	(1) Difference in Roughness Index
Difference in age (in months)	0.00167
	(1.21)
Difference in PPP-Non-PPP status (adjacent)	-1.102***
	(-6.25)
Constant	-0.0221
	(-0.18)
N	54
R^2	0.500
adj. R^2	0.480

t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Construction Costs

Construction Costs Ratio (CO):

$$\frac{C^a}{C^e}$$

where C^e denotes the **Estimated Construction** costs

Recall, Contractor can reduce construction costs

- Through cost cutting activities denoted by y
- Through innovations denoted by x

Proposition

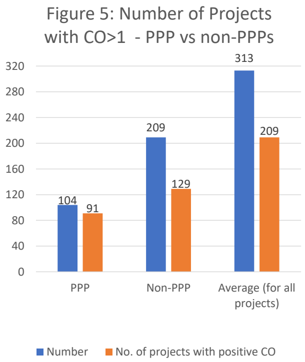
For any given project cost estimates, C^e:

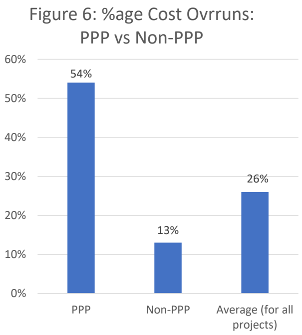
$$x^{TC} = x^{PP} \Rightarrow \left(\frac{C^a}{C^e}\right)^{PP} > \left(\frac{C^a}{C^e}\right)^{TC}$$

However, $x^{TC} < x^{PP}$ and $y^{TC} > y^{PP}$. Therefore,

$$\left(\frac{C^a}{C^e}\right)^{PPP} > \text{or} < \left(\frac{C^a}{C^e}\right)^{TC}$$

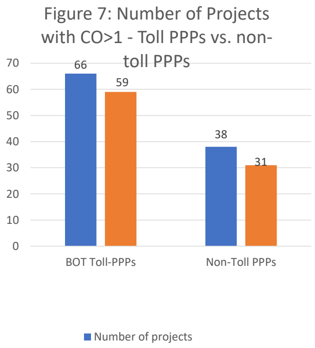
Construction Cost Ratio: PPPs Vs Non PPPs

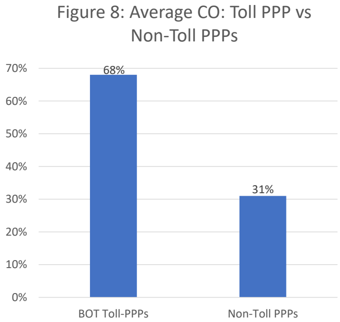




1

Construction Cost Ratio: Toll Vs Non-toll PPPs





1

Correlates of Cost Ratio

Table : Correlates of Cost Ratio - PPP vs Non-PPP. OLS estimates

	(1)	(2)
Dependent Variable	CO	CO1
PPP	0.543***	0.448***
	(9.36)	(7.99)
Length (in 100 km)	0.0812	0.0698
	(0.89)	(0.79)
Implementation Phase	0.00379	0.00378
	(1.89)	(1.95)
Time Overrun	0.123*	0.122**
	(2.55)	(2.62)
Local population (in millions)	0.0409**	0.0389**
	(2.64)	(2.60)
Distance (in 100 km)	0.00900	0.0103
	(0.24)	(0.28)
Constant	0.740***	0.747***
	(6.03)	(6.30)
N	304	304
R^2	0.307	0.250
adj. R^2	0.293	0.235

t ratios in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The 2005 Policy

Between 1997 and 2005:

- potentially viable projects were offered to investors
- no clear legal and contractual framework to govern the PPPs

The 2005 Policy, launched several initiatives in order to attract PPPs.

> *... contracts based on BOT model are inherently superior to the traditional EPC contracts. Accordingly, it was decided that for NHDP Phase-III onwards, all contracts for provisions of road services would be awarded only on BOT basis... (Govt of India, May 2005)*

- Standardization of Bidding and Concession Documents
- MCA, a standard contract document governing PPPs
- India Infrastructure Finance Company Limited (IIFCL) was set up
- Capital grant called 'Viability Gap Funding' (VGF) for toll PPPs.

Data

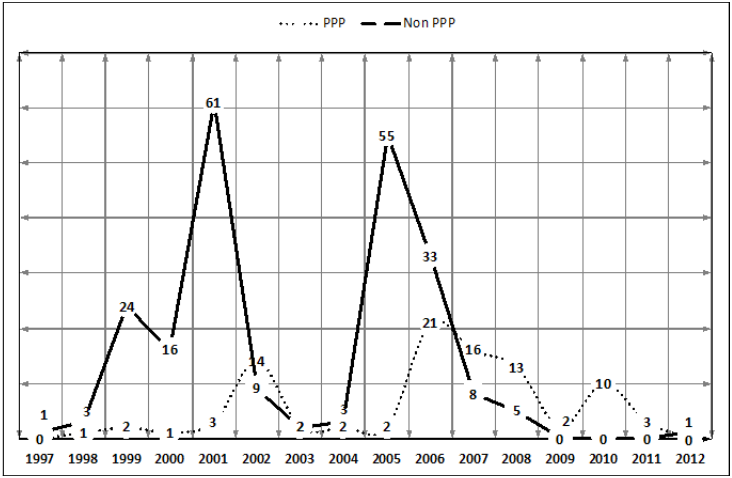


Figure : Year-wise number of PPPs and non-PPPs projects started during 1997 - 2012

Determinants of PPP relative to non-PPP status

Table : Determinants of PPP relative to non-PPP. Logistic Regression

	(1) PPP	(2) (odds ratio)
Start Year Dummy (=1 in/after 2006)	2.664***	14.35***
	(7.72)	(7.72)
Length (in 100 km)	2.711***	15.05***
	(4.31)	(4.31)
Implementation Phase	-0.0175	0.983
	(-1.52)	(-1.52)
Distance from nearest mega city (in 100 km)	-0.278	0.758
	(-1.11)	(-1.11)
Local Population around project (in millions)	0.149	1.160
	(1.38)	(1.38)
Constant	-2.523***	0.0802***
	(-4.79)	(-4.79)
N	304	304
pseudo R^2	0.312	0.312
Log Likelihood	-130.0	-130.0

t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Correlates of Cost Ratio

Table : Correlates of Cost Ratio - Start Year Dummy (OLS estimates)

	(1)	(2)
Dependent Variable	CO	CO1
Start Year Dummy(=1 in/after 2006)	0.520***	0.464***
	(9.01)	(8.48)
Length (in 100 km)	0.227*	0.183*
	(2.55)	(2.16)
Implementation Phase	-0.00348	-0.00270
	(-1.61)	(-1.31)
Time Overrun	0.0332	0.0516
	(0.72)	(1.18)
Local population (in millions)	0.0376*	0.0345*
	(2.40)	(2.32)
Distance (in 100 km)	-0.0152	-0.01000
	(-0.40)	(-0.28)
Constant	1.068***	1.022***
	(8.85)	(8.93)
N	304	304
R^2	0.295	0.266
adj. R^2	0.281	0.252

t ratios in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Determinants of Cost Ratio - TSLS estimates (PPP Vs non-PPP)

	(1)	(2)
Dependent Variable	CO	CO1
PPP	1.08***	0.96***
	(8.11)	(7.50)
Time Overrun	0.27***	0.26***
	(4.27)	(4.32)
Implementation Phase	0.0040	0.0039
	(1.77)	(1.82)
Local population (in millions)	0.020	0.019
	(1.13)	(1.10)
Distance (in 100 km)	0.029	0.029
	(0.68)	(0.71)
Length (in 100 km)	-0.17	-0.17
	(-1.47)	(-1.54)
Constant	0.48**	0.50***
	(3.24)	(3.47)
N	304	304
Uncentered R sq	0.89	0.89
Centered R sq	0.11	0.040
Underidentification	73.0	73.0
Weak identification(Cragg-Donald Test)	93.8	93.8

t ratios in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Instrument=Start Year Dummy

Correlates of Cost Ratio -Toll-PPP vs non-toll PPP vs non-PPP. OLS estimates

	(1)	(2)
Dependent Variable	CO	CO1
Toll PPPs	0.739***	0.633***
	(11.00)	(9.73)
Non-Toll PPPs	0.294***	0.212**
	(4.00)	(2.99)
Length (in 100 km)	0.00653	-0.000837
	(0.07)	(-0.01)
Implementation Phase	0.00399*	0.00397*
	(2.08)	(2.14)
Time Overrun	0.149**	0.146**
	(3.21)	(3.26)
Local population (in millions)	0.0318*	0.0303*
	(2.13)	(2.09)
Distance (in 100 km)	0.0162	0.0171
	(0.45)	(0.49)
Constant	0.723***	0.731***
	(6.14)	(6.40)
N	304	304
R^2	0.365	0.310
adj. R^2	0.350	0.294

t ratios in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Correlates of Cost Ratio -Toll-PPP vs non-toll PPP vs non-PPP. OLS estimates

	(1)	(2)
Dependent Variable	CO	CO1
Toll PPPs	0.739***	0.633***
	(11.00)	(9.73)
Non-Toll PPPs	0.294***	0.212**
	(4.00)	(2.99)
Length (in 100 km)	0.00653	-0.000837
	(0.07)	(-0.01)
Implementation Phase	0.00399*	0.00397*
	(2.08)	(2.14)
Time Overrun	0.149**	0.146**
	(3.21)	(3.26)
Local population (in millions)	0.0318*	0.0303*
	(2.13)	(2.09)
Distance (in 100 km)	0.0162	0.0171
	(0.45)	(0.49)
Constant	0.723***	0.731***
	(6.14)	(6.40)
N	304	304
R^2	0.365	0.310
adj. R^2	0.350	0.294

t ratios in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Determinants of Cost Ratio: Toll-PPPs with VGF Vs others

	(1)	(2)
Dependent Variable	CO	CO1
Non-toll PPPs Dummy	0.284^{***}	0.205^{**}
	(3.91)	(2.90)
Toll-PPPs-with-VGF Dummy	0.753^{***}	0.648^{***}
	(9.63)	(8.55)
Length (in 100 km)	0.0186	0.00869
	(0.20)	(0.10)
Implementation Phase	0.00400^{*}	0.00401^{*}
	(2.08)	(2.15)
Time Overrun	0.137^{**}	0.137^{**}
	(2.97)	(3.05)
Local Population around project (in millions)	0.0229	0.0221
	(1.42)	(1.41)
Distance from nearest mega city (in 100 km)	-0.00493	-0.00267
	(-0.13)	(-0.07)
Constant	0.760^{***}	0.762^{***}
	(6.45)	(6.68)
N	285	285
R^2	0.325	0.273
adj. R^2	0.308	0.255

t ratios in parentheses; $^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$

Cost Ratios for PPPs - VGF Grant

Dependent Variable	(1) CO	(2) CO	(3) CO	(4) CO1	(5) CO1	(6) CO1
Length (in 100 km)	0.407*	0.0821	0.0591	0.432*	0.0872	0.0628
	(2.33)	(0.36)	(0.20)	(2.33)	(0.36)	(0.20)
Implementation Phase	0.00217	0.0156	0.0141	0.00230	0.0166	0.0150
	(0.46)	(1.48)	(0.95)	(0.46)	(1.48)	(0.95)
Time Overrun	0.177	0.229	0.207	0.188	0.244	0.220
	(1.29)	(0.96)	(0.66)	(1.29)	(0.96)	(0.66)
Local population (in millions)	0.0665*	0.0836*	0.0885	0.0706*	0.0888*	0.0940
	(2.36)	(2.33)	(1.66)	(2.36)	(2.33)	(1.66)
Distance (in 100 km)	-0.0730	0.0447	-0.125	-0.0776	0.0475	-0.133
	(-0.89)	(0.36)	(-0.81)	(-0.89)	(0.36)	(-0.81)
BP1	-0.337*			-0.358*		
	(-1.99)			(-1.99)		
BP2		0.00993			0.0105	
		(0.04)			(0.04)	
BP3			-0.574			-0.610
			(-0.88)			(-0.88)
Constant	1.079***	0.712	1.060	1.146***	0.757	1.127
	(3.59)	(1.46)	(1.46)	(3.59)	(1.46)	(1.46)
N	91	56	35	91	56	35
R^2	0.185	0.161	0.231	0.185	0.161	0.231
adj. R^2	0.126	0.058	0.066	0.126	0.058	0.066

t ratios in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Thanks!

Thanks!