Mobile investment and traffic per capita tend to increase with license duration*

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Abstract

Using source WCIS (World Cellular Information Service) for the tangible investments of mobile operators and mobile spectrum licenses, we are able to build a database matching the level of investment per capita with average license duration for 14 countries (representing more than 75% of the number of mobile subscribers of the EEA area) during 15 years. The statistical analysis of the data base proves a strong positive correlation between license average duration and tangible investment per capita. More precisely, we observe an increase of 5.36 € in average investment per capita per year for each additional year of license duration. This feature also holds at operator level. Using Data traffic from Telecom Market Matrix at country level, we also observe that each additional year of license duration corresponds to about 10% additional yearly growth of data traffic.

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1 Introduction

This paper analyses the statistical relations between the duration of spectrum licenses of mobile operators, their level of tangible investment and the outcome in terms of traffic growth, in a sample of European representing 75% of European mobile subscribers. It shows that globally, the average investment per year increases by more than 5 Euros per capita and that data traffic growth is increased by about 10% per additional year of average license duration. An econometric modeling of investment at operator's level confirms the positive effect of longer licenses.

The question of whether mobile license durations should be globally extended in order to foster investment in new mobile infrastructure has been hotly discussed during the legislative debate of the future European Electronic Communication Code which will rule telecom markets in Europe after 2020. To put it in a simplified way, the debate was based on the following arguments:

- On the one hand, advocates of longer license durations insisted on the fact that installing tens of thousands of antennas with associated equipment and network upgrades implied that operators engage in tens of billions of sunk investment costs for which reduced uncertainty and enhanced security were necessary.
- On the other hand, opponents insisted on the role of competition by new entrants and disruptive technologies to foster investment, and on that long license durations could hinder both.

From an economic point of view, as both arguments mentioned above could be true in principle, the question is whether a quantitative analysis based on real data may decide which effect is the strongest and should be given priority from a policy purpose. As this specific question had not yet been directly addressed in the literature, we have developed the present analysis to fill the gap, using simple and straightforward statistical techniques on a sufficiently large dataset. We have also extended our analysis from impact on license duration on tangible investment to impact on data traffic growth. Indeed, although a very rich and large economic literature has analyzed multiple aspects of mobile license allocation, whether they should be

subject to auctions or beauty contests, how auctions should be designed, how many licenses should be attributed in a given market, what it the impact of license fees on market outcomes, the specific question of the impact of license duration on investment had not yet been empirically analyzed.

The rest of the paper is organized as follows: Section 2 indicates how this paper takes place in two streams of literature: one on mobile license design and one on the impact of policies on investment in the telecom industry. Section 3 describes the dataset and provides some descriptive statistics. Section 4 studies the global statistical analysis of the relation between the average license durations and the level of tangible investment per capita and provides the main result of the paper. Section 5 elaborates an econometric model of investment per capita as a function of licence duration at operator's level. Section 6 elaborates an econometric model of the growth of traffic as a function of investment at country's level. Section 7 derives policy implications of these outcomes and concludes.

2 Literature review

Although spectrum allocation plays a crucial role in wireless industry, the impact of license duration, to our knowledge, has not been specifically studied. Economic literature on spectrum license mainly addresses the issue of spectrum concentration or spectrum auction.

Competition and sectoral authorities have early suspected that spectrum concentration could harm competition and, therefore proposed measures aiming to limit spectrum concentration (1927 Radio Act in the USA). However, recent empirical literature finds little correlation between spectrum concentration and downstream concentration in wireless services, Israel & Katz (2013), or between spectrum concentration and consumer welfare, Faulhaber *et al.* (2011).

The impact of license fees on competition is also well known, the higher the license fee, the lower the number of operators sustained by the market Gruber (2001). Considering that more spectrum allocation improves transmission capacities, theoretical literature highlights that it improves service quality perceived per consumers and tends to reduce marginal costs. Loertscher & Marx (2014) found that a transfer of spectrum from a low-quality or inefficient operator toward

a high-quality or a more efficient one increases consumer surplus. Lhost *et al.* (2015), considering the lack of spectrum as a capacity constraint showed that a spectrum allocation where the more efficient operators do not hold more spectrum than least efficient ones was unsuitable and could hamper competition and increase prices. To find out more about spectrum concentration and its impact on the performance of wireless industry, see Woroch (2018).

Investment in information technologies in general and in telecommunications in particular are considered, in economic literature, to provide a major contribution to economic growth. Roller & Waverman (2001) found a causal link between telecommunication infrastructure and economic growth in OECD countries and Waverman *et al.* (2005) extended this result to developing countries for the wireless network roll out. Moreover, Jeanjean (2015) showed that investment in wireless industry is mainly responsible for the data traffic growth by the mean of installed capacities.

Theses considerations do not explicitly take the duration of the licenses into account. However, considering that licenses constitute a right to install and use transmission capacities, it is natural to assume that the longer the duration, the higher the value of the license. In this context, what is written for spectrum allocation in general remains valid for the duration of the licenses. In order to approach the specificity of the duration, and its impact on investment, we can look at the literature about investment and uncertainty. Investment in transmission capacities depends on a license granted for a fixed period. The longer the period, the lower the uncertainty on the investment. Economic literature clearly states that uncertainty tends to delay or reduce investment Ingersoll Jr & Ross (1992) Dixit & Pindyck (1994). On the other hand, licenses can be viewed as entry barriers that could prevent more efficients entrants from entering the market. In this perspective, lowering the duration of the licenses may allow new entry more frequently and should reduce incumbents market power. Leyton-Brown *et al.* (2017). There is thus a trade-off in the duration of the licenses between allocating radio spectrum to most efficient operators who will make better use of it and the resulting market power. This trade-off should be solved empirically. This is the purpose of this paper.

3 The Data

We combine three datasets for 14 European countries[1]. The two first dataset come from WCIS (World Cellular Information Service) for which sufficient data on both the license term and the investment are available . The first dataset contains the population at country-level and the quarterly tangible investments [2] mobile operators from Q1 2002 to Q3 2017 (796 observations for 63 quarters with 86 missing values).Summary statistics at country level are reported in table1. The statistics at operator level are reported in table3. For the calculation of CAPEX per capita, we divide the sum of quarterly CAPEX of all operators in 14 countries by the total population of the 14 countries[3]. We obtain then 63 values of quarterly CAPEX per capita with a mean value of 10.90 euros per capita per quarter, variable "total-capex_cap" in Table 2 below. The second dataset contains mobile spectrum licenses granted in the 14 countries. More specifically, for each mobile license, the dataset provides the mobile technology or frequency (2G, 3G, 900MHz, 1800 MHz, 2.6GHz...), the begin date and the end date. So that we calculate, for each quarter and each country, the number of active mobile licenses. Then we calculate the duration of each license (duration is equal to end year - begin year). The average duration at country-level is obtained by dividing the sum of all active licenses duration by the number of active licenses with a mean value of 17.4 years. Finally, the average duration for all 14 countries is calculated for each quarter with a mean value of 17.35 years: "total-duration_m" in Table 2. The total population of 14 countries is around 399 millions which represents more than 75% of European population. For 86 quarters in some countries, the CAPEX values are missing. In that case, only the active licenses and the population of countries in which we have CAPEX value are taken into account in order to have a homogeneous point of comparison [4] The third dataset comes from the Telecom Market Matrix provided by Analysys Mason in the version of 6 april 2018. It provides the total cellular data traffic per country and per quarter. Traffic experiences a quasi exponential growth. Traffic data are not available before 2006 which means that the 22

[1]Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom.

[2]excuding license fees

[3]When there are missing data for some countries for a quarter, we use only the population corresponding to available countries.

[4]This is the reason why the total population varies from 1.11e+08 to 3.99e+08 in the summary statistics.

first quarters do not have any traffic information.

Table 1: Summary statistics at country level

Variable	Obs	Mean	Std. Dev.	Min	Max
year	796	2010.43	4.45555	2002.25	2017.75
population (country-level)	796	2.84e+07	2.70e+07	4541175	8.30e+07
density (inhabitant per km^2)	796	162.581	116.419	14.006	409.853
number of licenses (country-level)	796	6.572864	4.618363	1	19
duration_mean (year, country-level)	796	17.4023	3.211188	8	29
capex (million €, country-level)	796	313.4585	299.0421	23	2666
GDP per cap (€ per year)	796	45875.91	17238.63	12888.65	104512.8
nb_firms	796	3.678	.759	2	5
HHI	796	.354	.066	.227	.587
traffic (Megabyte)	634	5.16e+10	9.32e+10	$6e+07$	6.03e+11

Table 2: Summary statistics at global level (14 countries)

Variable	Obs	Mean	Std. Dev.	Min	Max
total-duration_m (year, 14 countries)	63	17.35014	0.97924	16.15579	19.36396
total-capex_cap (€, 14 countries)	63	10.89814	2.431975	4.548172	17.17618
total-population (14 countries)	63	3.58e+08	6.22e+07	1.11e+08	3.99e+08

Table 3: Summary statistics at operator level

Variable	Obs	Mean	Std. Dev.	Min	Max
CAPEX per capita	1872	32.095	349.541	0	9839.31
duration_mean	1872	17.666	3.140	5	29
MarketShare_sub	1872	.298	.142	.0002	.708
lic_sum	1872	2.761	1.371	1	7

4 One additional year of average license duration corresponds to more than 5 euros more of investment per year per capita

To get an insight of the relationship between tangible investment and license duration, we first observe it at the aggregate level of the 14 countries. The graph in figure 1 below, shows the relationship between the average license duration and the CAPEX per capita. Each point corresponds to a quarter. The x and y axis represent respectively the average license duration and the average CAPEX per capita for the 14 countries. We observe a highly statistically significant correlation between Capex per capita and license duration, with a coefficient of determination (R^2=0.29). We observe an increase of 1.34 Euros in average investment per capita per quarter for each additional year of license duration, or 5.36 Euros per year. This strong correlation suggests a positive link between licenses duration and investment. A better visibility offered to operators benefits to investment.

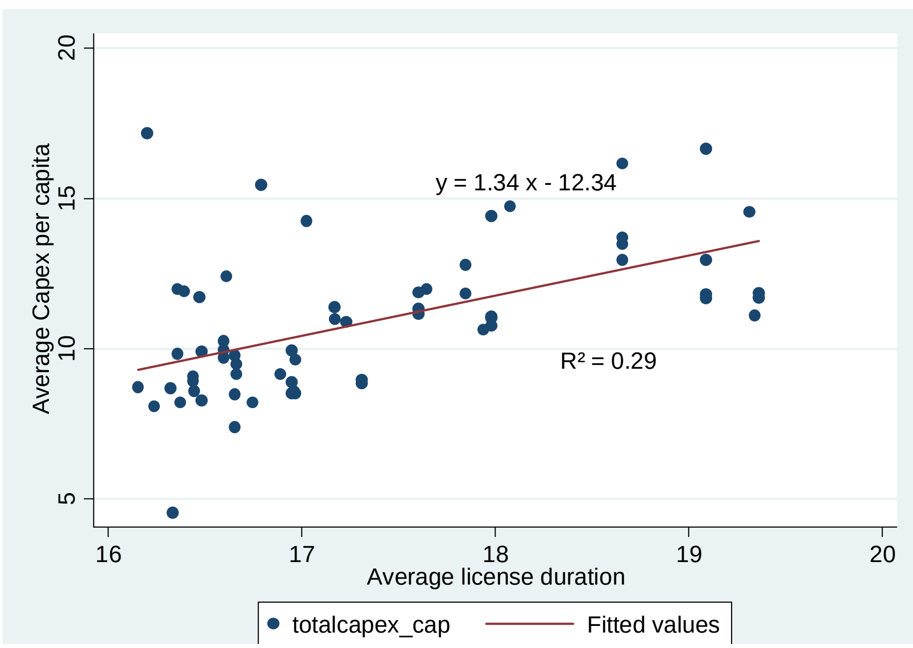

Figure 1: Capex per capita as a function of license duration

The table below shows the strong positive correlation between average license duration and

the average investment per capita in the 14 countries during the 63 quarters. The positive coefficient associated with the license duration is highly significant. However, given the aggregation level of the data and the relatively low number of observations (63 quarters), this result must be consolidated with a more detailed econometric model at operator level.

Table 4: Positive correlation between license average duration and average tangible investment per capita in the 14 countries

total-capex_cap	coef.	Robust Standard Error	95%	confidence interval
total-duration_m	1.3396***	0.2901	0.7594	1.9198
Constant	-12.3436**	5.1078	-22.5573	-2.1298
Observations	63			
R-squared	0.2909			
*** p<0.01, ** p<0.05,	* p<0.1			

To get further in the analysis, we need to build an econometric model at operator level, which allows to control for the differences among countries in terms of consumers characteristics or market structure.

5 Positive correlation between license average duration and tangible investment for individual mobile operators

To estimate the relationship between operator's investment and the duration of license, we calculate firstly the average duration of license. Since each operator owns several licenses, the average duration of license is calculated by dividing the sum of all active licenses duration by the number of active licenses owned by each operator.

We propose a linear equation to study the relationship between operator's investment and the mean duration of licenses:

$$CAPEX\_pc_{it} = \alpha\, duration\_mean_{it} + \beta\, X_{ct} + \varepsilon_{it} \tag{1}$$

Where $CAPEX\_pc_{it}$ is the quarterly investment per capita of operator i in the quarter t,

calculated by dividing the quarterly CAPEX by the number of operator's subscribers (population*market share). $duration\_mean_{it}$ is the mean duration of license. The vector of X_{ct} corresponds to control variables for country c in the quarter t. These control variables are market share, GDP per capita, population density and the number of licenses. ϵ_{it} is error term.

Table 5: Positive correlation between license average duration and tangible investment at individual operator level

	(1)	(2)	(3)	(4)
VARIABLES	capex_pc	capex_pc	capex_pc	capex_pc
duration_mean	3.0278**	2.6687**	2.4422**	2.3122**
	(1.183)	(1.116)	(1.048)	(0.980)
gdppcap		0.0007**	0.0007**	0.0008**
		(0.000)	(0.000)	(0.000)
density			-1.0875**	-0.9567*
			(0.540)	(0.489)
lic_sum				-2.4290
				(2.081)
operator dummies	Y	Y	Y	Y
quarter dummies	Y	Y	Y	Y
Constant	-35.5097*	-48.2769**	61.4486	54.3256
	(19.817)	(22.862)	(44.517)	(42.668)
Observations	1,872	1,872	1,872	1,872
R-squared	0.379	0.379	0.379	0.379

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5 displays the estimation results using ordinary least-squares regression. First of all, in Column (1), we observe a positive and statistically significant effect of the mean duration of license. The next columns (2) and (4) then introduce sequentially the controls. We see the results are rather stable across the additional specifications. GDP per capita has positive effect on investment. This effect shows that a higher income country is in favor of investment. The negative coefficient of population density suggests that the deployment cost is lower for higher density country. The number of active licenses affects investment negatively but not significantly. All those effects have the expect signs and the model appears to provide reasonable outcomes. The sign of the impact of license duration on investment per capita is very robust and

independent of the list of control variables. Therefore, we can conclude that operators invest more when mobile licenses durations are longer. The values of coefficients at operator level are consistent with the value of the coefficient found at aggregate level given the confidence interval.

6 Increased investment triggered by one additional year of license duration converts into around 10% more traffic growth.

As noticed above, traffic growth is mainly driven by investment which allow to install new capacities. Cost of capacity decreases exponentially following the pace of technical progress. Jeanjean (2015) developed a model of traffic growth, detailed in the annexes, that we will estimate in the following for the panel of 14 countries :

$$ln\Delta T_{it} = \alpha_i + \beta\ lnCapex_{it} + t\ ln(1+\theta) + \gamma X_{it} + \nu_t + \epsilon_{it} \tag{2}$$

where $ln\Delta T_t$ is the logarithm of the increase in traffic during a quarter, lnCapex is the logarithm of investment, α_i is a constant depending of each country, β is a coefficient depending of the efficiency of investment which is expected to be close to one, X_{it} is a set of control, ν_t, time fixed effects and ϵ_{it} the residuals. However, in this equation, there may be a concern about identification. Capex may be endogenously determined by the increase in traffic. Indeed, a growth in traffic which is higher than expected should reduce the ratio λ between data traffic and capacity under a level where congestion may occur. This urges telecom operators to increase their investments. This could lead OLS to underestimate coefficient β. We can use the average license durations per country or more precisely the logarithm of average license durations as an instrumental variable to solve the problem. Furthermore, this allows to show that the increase in capex induced by the channel of license duration actually contributes to increase traffic. In order to improve the precision of the result, we can add a second instrument which is the logarithm of the country's population.

The table 7 below, summarizes the results:

Table 6: Growth of traffic explained by investment spurred by license average duration at country level

VARIABLES	(1) $ln\Delta T$	(2) $ln\Delta T$	(3) $ln\Delta T$	(4) $ln\Delta T$	(5) $ln\Delta T$
lnC	0.4941**	0.4095**	0.3963*	0.9629	0.7667**
	(0.222)	(0.179)	(0.186)	(0.655)	(0.371)
quarter	0.1829***	0.1824***	0.1822***	0.1792***	0.1802***
	(0.004)	(0.005)	(0.005)	(0.006)	(0.005)
density		0.0575**	0.0592***	0.0532***	0.0552***
		(0.019)	(0.019)	(0.013)	(0.010)
hhi			-1.4480	-0.8058	-1.0282
			(3.388)	(1.413)	(1.181)
quarter dummies	Y	Y	Y	Y	Y
Constant	8.1133***	-1.1766	-1.4833		
	(1.137)	(3.405)	(3.371)		
Observations	569	569	569	569	569
R-squared	0.880	0.889	0.889	0.884	0.887
Number of countries	14	14	14	14	14
First stage F-statistic				17.25	18.51

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

(1), (2) and (3) are OLS estimations. (4) is a IV/2SLS estimation using the logarithm of duration_mean as instrumental variable. (5) is a IV/2SLS estimation using two instruments: (the logarithm of duration_mean and the logarithm of the population). Those two instruments for a single instrument requires an over-identification test. Let H0 be the hypothesis of over-identification.The Hansen J statistics for the test is 0.139 which provides a p-value of 0.7096, thus Hypothesis H0 can be rejected. The first stage F-statistic for weak identification test (Cragg-Donald) in both IV/2SLS regressions provides quite high values meaning that instruments are strong enough to correctly identify the equation. First stage regression results are reported in the annexes.

In the OLS estimations, The coefficient for lnC is positive and significant. In the IV/2SLS estimations, the coefficient comes closer to 1 even if it is not significant with only one instrument. The second instrument increases the precision and makes the coefficient quite significant.

The coefficient associated to quarter, $ln(1+\theta)$ provides the rate of technical progress in the wireless industry: taking the coefficient of regression (5), 0.1802, $\widehat{\theta} = 19,74\%$. This means a near doubling annual performances of the data transportation technology [5]. In other word, an investment undertaken one year increases the traffic twice as much as the same investment the previous year. The coefficient associated to density, as expected is positive and very significant. This is consistent with the result in table 5 where density reduces the cost of investment. The coefficient associated to hhi is negative as expected, but not significant.

As a robustness check, it is possible to calculate the evolution of traffic. Traffic $T_t = \sum_{i=1}^{t} Capex_i(1+\theta)^i$ which can be rewritten:
$T_t = \sum_{i=1}^{t-1}(Capex_i - Capex_t)(1+\theta)^i + Capex_t \sum_{i=1}^{t}(1+\theta)^i$. The first term of the right hand side can be neglected compared to the second because capex are relatively steady over time. As a result, we can estimate the following equation:

$$lnT_{it} = \alpha_i + \beta\ lnCapex_{it} + t\ ln(1+\theta) + \gamma\ X_{it} + \nu_t + \epsilon_{it} \tag{3}$$

The table 7 below, summarizes the results:

[5] A growth of 19,74% per quarter corresponds to $(1+19.74\%)^4 - 1 = 106\%$ per year, which means more than a doubling

Table 7: Traffic explained by investment spurred by license average duration at country level

VARIABLES	(1) *lnT*	(2) *lnT*	(3) *lnT*	(4) *lnT*	(5) *lnT*
lnC	0.2977*	0.2356*	0.2233*	0.5959*	0.9706***
	(0.161)	(0.116)	(0.121)	(0.326)	(0.242)
quarter	0.1981***	0.1948***	0.1940***	0.1946***	0.1952***
	(0.009)	(0.006)	(0.005)	(0.007)	(0.009)
density		0.0553**	0.0567**	0.0536***	0.0504***
		(0.020)	(0.021)	(0.007)	(0.006)
hhi			-1.1826	-0.7012	-0.2171
			(2.759)	(0.820)	(0.806)
quarter dummies	Y	Y	Y	Y	Y
Constant	10.3197***	1.5358	1.8161		
	(1.124)	(3.549)	(3.642)		
Observations	596	596	596	596	596
R-squared	0.966	0.973	0.974	0.972	0.966
Number of countries	14	14	14	14	14
First stage F-statistic				22.53	19.45

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7 with a similar structure, confirms the results of table 7 R-squared are higher, as we estimate the logarithm of traffic rather than the logarithm of the increase in traffic. However, we had to make approximations to build equation (3). The results are qualitatively similar has those of table 7, however, We can notice that, in specification (4), the coefficient of lnC is significant even with only one instrument and in specification (5), the coefficient of lnC is highly significant. The Hansen J statistics for the over-identification test is 2.292 with p-value of 0.13 which allows to reject over-identification hypothesis. First stage regression results are reported in the annexes.

Equation (2) and the results of Table 7 show that the coefficient associated with lnC is slightly lower than one (0.7667 in specification (5) of table (7). This means that 1% increase in capex leads to around 0.8% increase in Traffic. In section 4, we showed that a one year increases in the license duration leads to a capex increase, in average, of 5.36 € per capita per year. This corresponds to about 12% of the average capex per capita (10.9 € per capita per quarter in table

2 and thus 43.6 € per capita per year)[6]. As a result, one year increases in the license duration leads to about 10% ($0.8 * 12\% = 9.6\% \approx 10\%$) increase in traffic growth.

7 Conclusions of the statistical analysis and policy implications

Using source WCIS (World Cellular Information Service) for the tangible investments of mobile operators and mobile spectrum licenses, we are able to build a data base matching the level of investment per capita with average license duration for 14 countries (representing more than 75% of the number of mobile subscribers of the EEA area) during 15 years. The statistical analysis of the data base proves a strong positive correlation between license average duration and tangible investment by mobile operators. More precisely, we observe an increase of 5.36 Euros (5.36 Euros = 1.34 Euros * 4 quarters) in average investment per capita per year for each additional year of license duration. This global statistical result is plainly confirmed by an econometric analysis at operators' level showing that the function explaining operators investment includes a linear term of license duration with a significant positive coefficient. Moreover increased investment associated with longer license duration also results into higher data traffic growth: around plus 10% of traffic growth per additional year of license duration.

The results of the statistical analysis presented in this paper provides an unambiguous answer to the policy question exposed in the introduction. As for now and for mobile markets in the European Union, longer license durations goes with high levels of investment. It would therefore be appropriate to extend the average duration of individual licenses of mobile operators if increased investment is considered as a relevant policy objectives. Further research is however required to understand the mechanisms which underline this outcome. In the meantime, we cannot ensure that the same rule would apply everywhere and in any circumstances.

[6] Indeed, $5.36/(4 * 10.9) = 12,29\%$

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Appendix

■ **Appendix 1: Model of traffic growth: Jeanjean (2015)** Let A_t be the capacity available for a given amount of investment at time t. Let θ be the rate of technical progress. At time t+1, $A_{t+1} = (1+\theta)At$ and thus $A_t = (1+\theta)^t A_0$. The increase in capacity at time t is the investment at time t times the capacity A_t. We denote λ, the ratio between data traffic and capacity, the increase in traffic at time t can be written:

$$\Delta T_t = \lambda Capex_t A_t \tag{1}$$

which can be rewritten in logarithmic form:

$$ln\Delta T_t = ln\lambda + lnA_0 + lnCapex_t + t\ ln(1+\theta) \tag{2}$$

Assuming λ is constant, $ln\lambda + lnA_0$ is a constant that depends on each country.

■ **Appendix 2: First stage regression of equation** (2) and (3)

VARIABLES	equation(2) lnC	equation(2) lnC	equation(3) lnC	equation(3) lnC
logdur	**0.5674***** **(0.137)**	**0.4086***** **(0.137)**	**0.6243***** **(0.132)**	**0.4851***** **(0.133)**
logpop		**4.4236***** **(1.012)**		**3.9960***** **(0.983)**
quarter	0.0054*** (0.001)	0.0045*** (0.001)	-0.0037 (0.007)	-0.0056 (0.008)
density	0.0124*** (0.003)	-0.0014 (0.004)	0.0107*** (0.003)	-0.0018 (0.004)
hhi	-1.0185** (0.113)	-0.5811 (0.466)	-1.1393** (0.457)	-0.6960 (0.448)
Observations	569	569	596	596
R-squared	0.449	0.468	0.442	0.458

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The first and the second columns represent the first stage regression of equation(3). The first column uses the logarithm of country average duration as instrument (logdur), the second

column uses logdur and the logarithm of the population (logpop) as instruments.