INEQUALITY MEASURES APPLIED TO THE DIFFUSION OF MOBILE COMMUNICATIONS WITHIN THE EUROPEAN UNION

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ABSTRACT

This study investigates whether the evolution of mobile communications of European Union member countries has shown convergence, and whether adopting a common standard for mobile communications (GSM) or economic convergence has affected the convergence process. The evolution process is quantified by penetration rates of mobile communications subscribers. Subsequently, the annual dispersion is captured by appliance of inequality measures: It is first depicted by Lorenz curves and subsequently measured by GINI coefficients. The results of these inequality measures show that the penetration rates of mobile communications of European Union member countries do show convergence. Moreover, the common GSM standard has hastened the convergence process. The economic convergence, measured by GDP per capita, did not affect the convergence process.

Key words: Diffusion, Mobile Communications, Inequality Measures, GINI coefficient

1 INTRODUCTION

Mobile communications has recently been a popular innovation of diffusion studies: Researchers have conducted studies on a nation-level (Wright et al., 1997; Frank, 2003), a multi-nation level (Gruber and Verboven, 2001; Gruber, 2001), and on a worldwide level (Dekimpe et al., 1996).

However, although some of the diffusion studies have examined cross-country diffusion processes, there is a lack of research investigating how the disparity of diffusion processes of a given set of countries has evolved. The aim of this study is to measure, whether the diffusion of mobile communications in the European Union has converged or diverged. Further, the aim is to explore the effect of the European unification on that convergence or divergence process.

This study proceeds as follows. First, hypotheses for the aims of the study are formulated, basing on previous research diffusion research. Next, the Lorenz curve and Gini coefficient measures for disparity are introduced. This is followed by the empirical analysis, consisting of the Lorenz curves and Gini coefficients of mobile communications of the European Union member countries, and of analysing the implications of the European unification on these measures. The final section provides the conclusions of this study.

2 WHY SHOULD DIFFUSION RATES CONVERGE OR DIVERGE?

With a focus on the innovation's diffusion through time, the studying of the phenomenon started by Ryan and Gross (1943), and was subsequently continued e.g. by Griliches (1957) and Bass (1969). These studies modelled the sigmoid diffusion process of an innovation on the macro-level, investigating how an innovation diffuses within a society through time. Another research focus has been studying and modelling the adoption process, the diffusion of an innovation on the micro-level (see e.g. Rogers, 1995). Moreover, as an innovation diffuses over time, it does simultaneously diffuse through space (Mahajan et al., 1990; Mahajan and Peterson, 1979). This space dimension is also referred to as spatial diffusion. The mainstream, however, has concentrated on the time dimension.

Probably the major reason behind the lack of spatial diffusion studies is the specific scarcity of location specific diffusion data. Thus, spatial diffusion studies usually examine the diffusion process on a country level. These, multinational or cross-country studies, examine the reasons and dynamics behind the differences in the adoption or diffusion processes of a set of countries. For example, Ganesh et al. (1997) study a so-called learning effect: Whether the similarity of countries with the earlier adopted countries has an effect on the diffusion process.

Multinational diffusion studies have also noted that later adopting countries have faster diffusion (e.g. Gruber and Verboven, 2001). This is also in accordance with the diffusion theory: Communication naturally does also occur between countries, and not only within a country. Faster growth rates for later adopting countries evidently also means a catching-up process: If the first-adopted country has the slowest growth rate, it is going to be reached by other countries. This study examines the diffusion of mobile communications within the European Union, in which both the above mentioned results, the learning effect and a faster diffusion in later adopting countries, imply that:

H1: *The penetration rates of mobile communications in the European Union member countries have converged.*

In Europe the first mobile communications systems were based on the analogue standard. For example, the Nordic countries implemented the NMT-standard (Nordic Mobile Telephone) in the beginning of the 1980's. However, these analogue standards were not sufficient to satisfy the increasing usage of mobile communications, and thus they were replaced by digital systems. In Europe, the European Post and Telecommunications Conference developed a digital GSM standard (Global System for Mobile Communications). This GSM standard was not only more efficient than the previous analogue standards, but it also provided new features, such as the SMS-messages. The European Union instructed its member countries to adopt the GSM standard, and simultaneously it deregulated mobile network operator monopolies. All the European Union member countries had a network operating on the GSM standard in 1993. The adoption of a common standard is hypothesized to affect the evolution as follows:

H2: *Adopting a common standard in mobile communications (GSM) has accelerated the convergence process of penetration rates.*

The integration of Europe is also expected to have economic implications. Furthermore, since the diffusion process of mobile communications is found to be affected by the GDP per capita (e.g. Gruber & Verboven 2001; Frank 2003), it is hypothesized that:

H3: *The economic integration of the European Union member countries has a positive effect on the convergence of mobile communications' penetration rates.*

3 MEASURING THE INEQUALITY OF THE DIFFUSION OF MOBILE COMMUNICATIONS

In order to depict the inequality, two measures are used in this study. Firstly, the Lorenz curve, which is a graphical representation of the proportionality of a distribution, indicating the cumulative percentage of the measured values. The Lorenz curve is constructed as follows: The measured elements are ordered first from the most important to the least important. Next, the elements are plotted according to their cumulative percentage of the measured variables X and Y. For example, if 15 EU countries were considered as X, one country would represent 1/15 % of X. The Y value of the first country is the highest in the distribution; say that the country has 82 % of mobile penetration. The second would cumulatively represent 2/15 % and its value of Y added to the first country's Y value. (For an introduction to the Lorenz curve and Gini coefficient, see e.g. Slack and Rodrigue, 2002)

After its construction, the Lorenz curve is compared with the 45-degree line of perfect equality. The 45-degree line represents a distribution where each element has an equal value in proportions of X and Y. Thus, for the 15 EU countries, perfect equality would mean that the 4th element would account for 26.7%, and the 8th element for 53.3% of cumulative X and Y. The slope of the perfect equality line is 100/N. The perfect inequality line represents the distribution of one element having the total cumulative percentage. Figure 1 gives an example of the Lorenz curve.

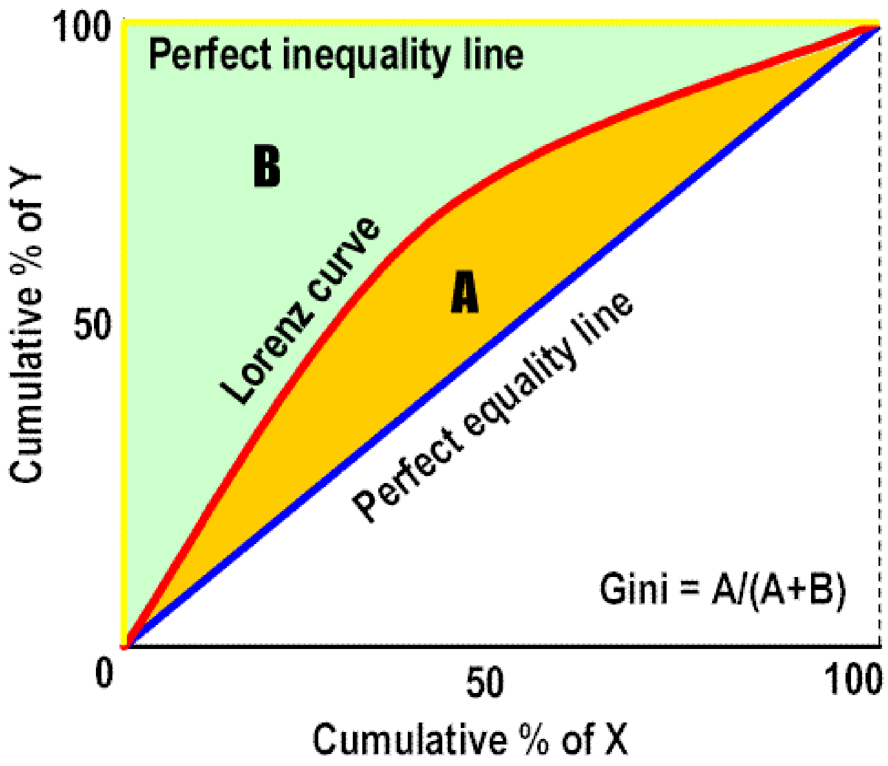

Figure 1. The Lorenz curve and Gini coefficient as inequality measures. (Slack and Rodrigue, 2002).

Secondly, the disparity depicted by the Lorenz curve can be quantified by utilizing Gini's coefficient. It was developed to measure the degree of concentration or inequality of a variable in a distribution of its elements. The Gini coefficient has been used for various cases, the best known being the measurement of income distribution. In geography, the Gini coefficient has been used to measure the dispersion of several spatial phenomena, for example, industrial location and concentration of traffic.

The Gini coefficient sums all vertical deviations between the Lorenz curve of a ranked empirical distribution and the perfect equality line (A) divided by the difference between the perfect equality and perfect inequality lines (A+B). Graphically, it is defined graphically as a ratio of two surfaces. Formally, it is written as follows:

$$G = 1 - \sum_{i=0}^{N} \left(sY_{i-1} + sY_i \right) \left(sX_{i-1} - sX_i \right). \qquad (1)$$

In equation (1), sX and sY are cumulative percentages of X and Y, and N is the number of observations. The Gini coefficient ranges from perfect equality, or no concentration (0), to perfect inequality, i.e. total concentration (1).

4 MOBILE COMMUNICATIONS WITHIN THE EUROPEAN UNION

A couple of alternative routes exist for the evolution of an inequality measure of the evolution of penetration between countries, for example of a phenomenon such as mobile communications: First, if the countries adopt simultaneously, in the same year, the inequality is small in the beginning. Then, if the diffusion rates vary between the countries, the inequality may increase, or if the diffusion rates are similar, the inequality stays on a low level. The alternative is that countries do not adopt simultaneously. In this case the inequality starts at a high level. Now, only if the later adopted countries have faster diffusion rates in comparison to the early adopters, the inequality decreases with time. If the later adopting countries have a similar diffusion rate, or if they have a slower diffusion rate, the inequality stays on a high level.

The data for the analysis is from the EMC database. It consists of annual mobile communications penetration rates of the 15 EU member countries, measured by the amount of mobile phone subscriptions. The annual penetration rates were first summed together, wherefrom every individual country's percentage rate was calculated. The calculated percentage rates were ranked from the largest to the smallest, and used to calculate the cumulative percentages. The Lorenz curves representing the annual cumulative percentages of mobile communications penetrations of the European Union member countries are depicted in Figure 2.

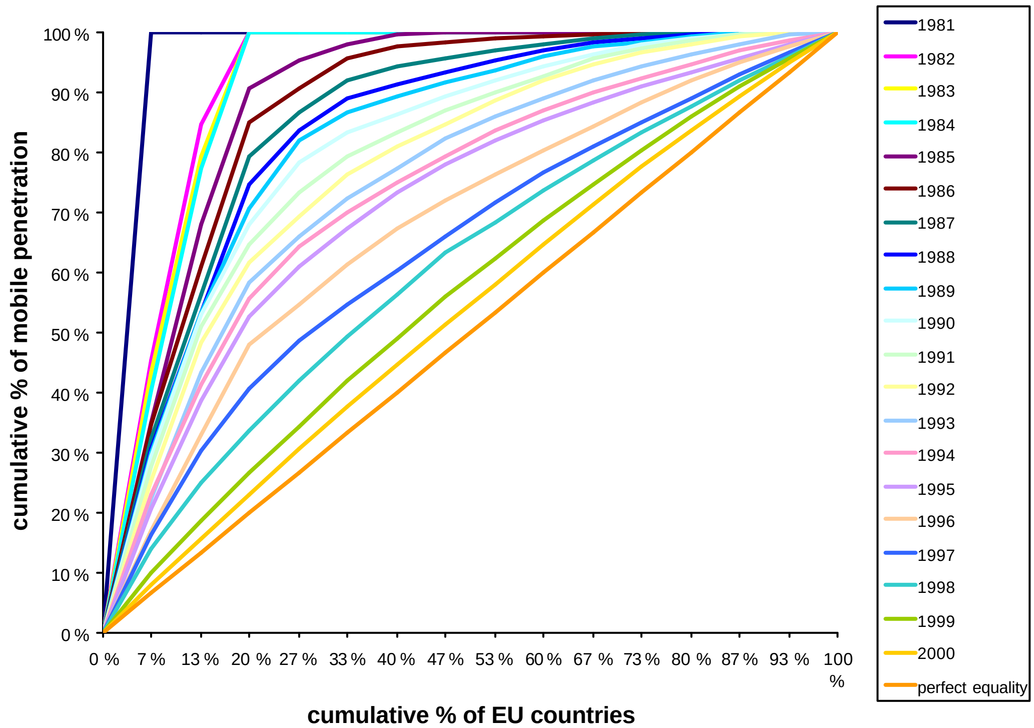

Figure 2. The Lorenz curves of the equality of mobile phone penetrations in the European Union from year 1981 to 2000.

The Lorenz curves in Figure 2 show that the dispersion of mobile communications penetrations within the EU has moved from perfect inequality in 1981 (the line follows the frame of the figure) towards perfect equality. *This finding is supporting H1, hypothesizing that the diffusion rates of the EU member countries should have converged.*

Indeed, every year shows a more equal distribution of mobile communications penetration: In 1981, only Sweden had implemented mobile communications, thus the high inequality: One country accounted for 100% of mobile communications in the EU. Afterwards, the dispersion has been getting more equal because more countries implemented mobile communications. Greece was the last to build a mobile communications system in 1993. Thus, the equalization of the distribution after this is not more due to more countries joining, but solely due to the convergence of the penetration rates.

The evolution of the dispersion depicted in Figure 2 can be quantified by means of the Gini coefficient presented in Equation (1). The annual Gini rates showing the amount of dispersion of mobile communications penetration in the EU are presented in Table 1.

Table 1. Gini coefficients of the evolution of mobile communications penetrations in the EU.

YEAR	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
GINI	0,93	0,84	0,83	0,82	0,78	0,75	0,71	0,67	0,65	0,62

YEAR	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
GINI	0,59	0,55	0,50	0,47	0,43	0,36	0,28	0,22	0,13	0,07

The time series of Gini coefficients in Table 1 show the process even clearer: The coefficient declines every year, meaning that the countries have become more equal in terms of mobile communications penetration. The time series of Gini coefficients is depicted in the following figure.

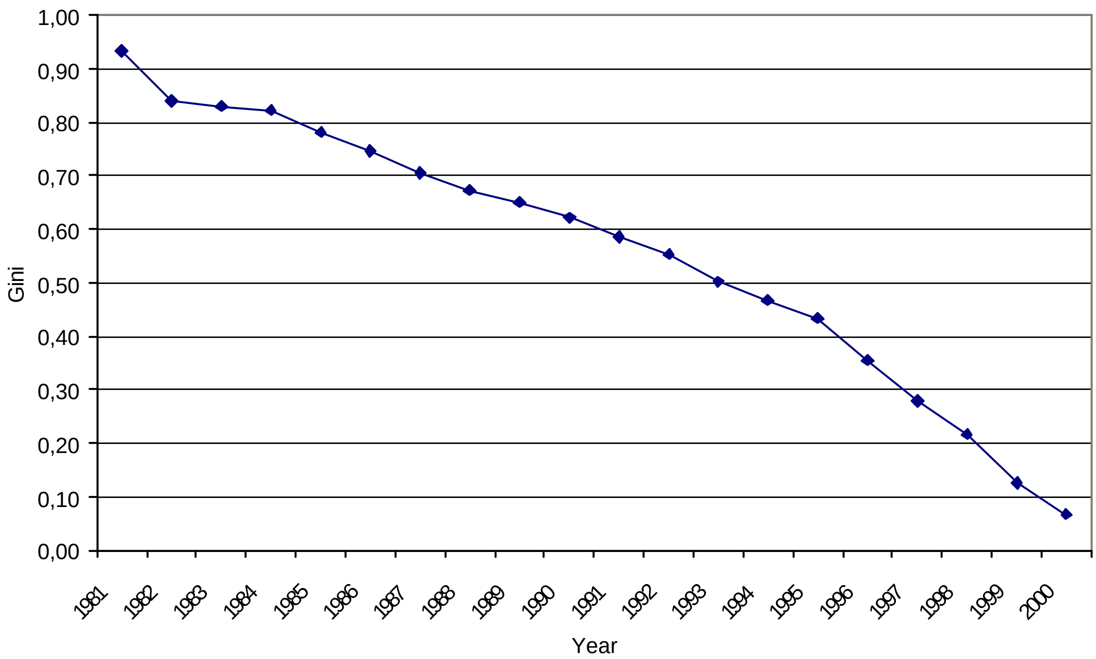

Figure 3. The annual Gini coefficients of mobile communications penetrations in the EU, ranging from year 1981 to 2000.

5 ANALYSIS AND RESULTS

The graph in Figure 3 shows clearly the decline of the Gini coefficient in the observed time period. A slight deepening of the slope is visible after year 1993, which was the year when the digital GSM system was introduced, and also Greece introduced mobile communications as the final EU country. Thus, it could be the case that introducing a common standard of mobile communications would have hastened the convergence process as hypothesized in H2. In order to test the correctness of the hypothesis, a multiple regression of the following form is carried out:

(2) $GINIMC = a + b \cdot GSM + c \cdot TIME + d \cdot MULT + e \cdot QUAD + f \cdot QINT + e$.

In Formula (2), *GINIMC* is the time series presented in Table 1. Dependent variables include *GSM*, which is a dummy variable capturing the effect of the introduction of GSM on the level of the regression line. *TIME* is a variable measuring the years. *MULT* is the product of the *GSM* dummy and *TIME*, and thus measures whether the angle of the regression line differs after the introduction of GSM. In other words, the parameter of *MULT* indicates whether the convergence has increased significantly after the year 1993. Furthermore, *QUAD* is the quadrant of *TIME*, a parameter measuring whether the relationship between the convergence and time is rather cubic than linear. Next, *QINT* is a combination of *QUAD* and *GSM*, indicating whether the convergence of the regression has been accelerating after the introduction of GSM, and whether the convergence in both of the time periods (before and after introduction) has had a cubic relationship. Finally, *a* is the intercept of the regression, and *b, c, d, e* and *f* are the coefficients of dependent variables, and ε is the error term of the regression. The regression presented by equation (2) was estimated using the stepwise method of the SPSS software. The resulting model is presented in Table 2.

Table 2. Estimation results of multiple regression using time as an explanatory variable.

Variable	Coefficient	Std. Error	Significance
Constant	0.935	.009	.000
TIME	-0.032	.001	.000
MULT	0.022	.000	.000
QINT	-0.002	.002	.000

The estimation with the stepwise method resulted in the exclusion of the *GSM* and *QUAD* variables. The coefficient of determination was $R^2 = 0.997$. The exclusion of

GSM indicates that the declining convergence rate did not show a level shift after 1993, the introduction of GSM. The exclusion of *QUAD* means that the time series of the GINI coefficients is not of cubic form. The included variables were *TIME*, *MULT* and *QINT*. The negative and significant parameter of *TIME* simply indicates that the GINI coefficients have been declining over time. A positive and significant *MULT* parameter means a change in the regression slope after the year 1993: *This supports hypothesis H2, stating that convergence has been faster after the introduction of GSM.* Additionally, a negative and significant coefficient of *QINT* indicates that the time series of GINI coefficients has been of cubic form, before and after the introduction of GSM. This means that before and after the GSM, the penetration rates of mobile communications have not been dropping steadily, but with an increasing rate. If the resulted equation is used to calculate the time when *GINIMC = 0*, that is when convergence is achieved, the resulting *TIME* is 20.88. This means that the mobile communications penetration rates should have converged in the end of the year 2000. Figure 3 illustrates the actual Gini coefficients and the resulted regression estimations.

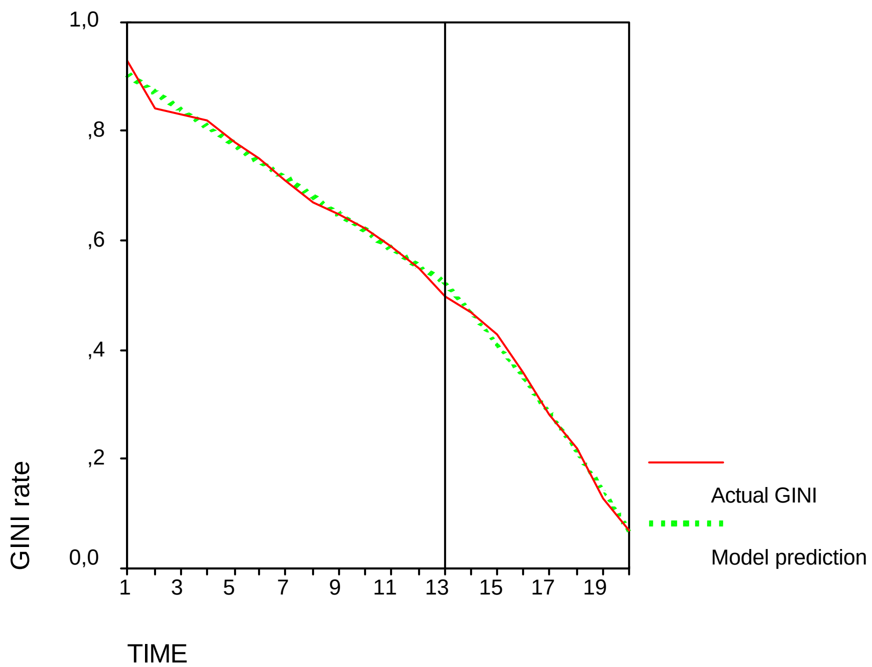

Figure 3. Actual and model prediction of GINI coefficients.

Hypothesis 3 was tested using GDP per capita data of the 15 EU member countries. Similarly as for the mobile communications penetration data in chapter 4, a time series of GINI coefficients was calculated also for the GDP per capita data. The corresponding figure is presented below.

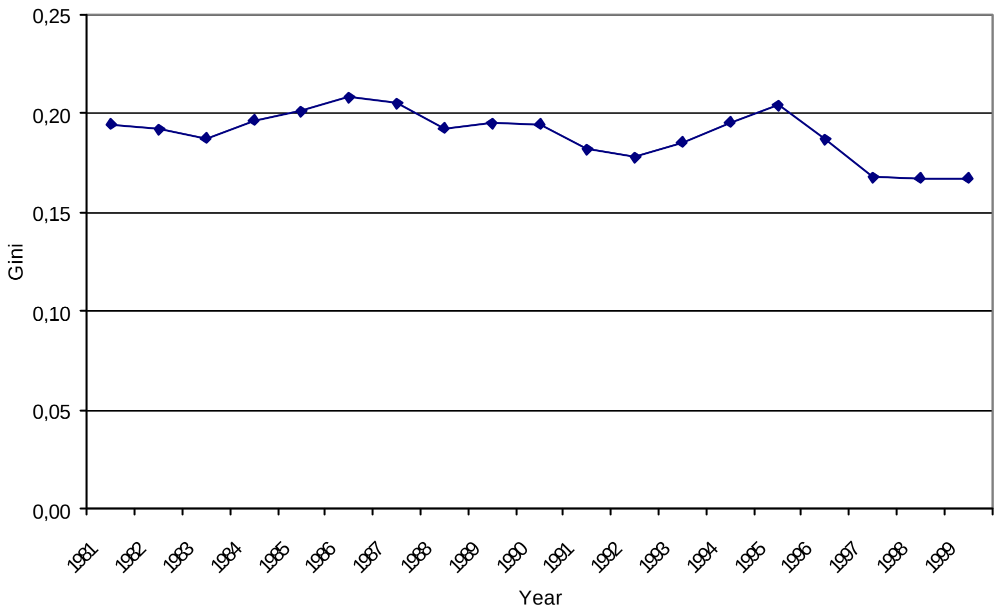

Figure 3. The annual Gini coefficients of GDP per capita in the EU, ranging from year 1981 to 2000.

Next, the calculated Gini values for the GDP per capita were used instead the variable *TIME* in Equation (2):

(3) $GINIMC = g + h \cdot GSM + i \cdot GDPCAP + j \cdot MGDP + k \cdot QGDP + l \cdot QINTGDP + e$.

Equation (3) is testing whether the occurred convergence of mobile communication is not a result of lapsed time, but rather because of the convergence in GDP per capita rates within the EU. *GDPCAP* is the Gini coefficients of the GDP per capita rates. *MGDP* is the product of the *GSM* dummy and *GDPCAP*, with a similar interpretation as *MULT* in Equation (2). Furthermore, *QGDP* is the quadrant of *GDPCAP*, and *QINTGDP* is the product of *QGDP* and *GSM*. Equation (3) was also estimated using the SPSS stepwise procedure. The results are presented in Table 3.

Table 3. Estimation results of multiple regression using GDP per capita as an explanatory variable.

Variable	Coefficient	Std. Error	Significance
Constant	-,71	,417	,109
GSM	-,33	,049	,000
GDPCAP	7,47	,417	,109

As Table 3 shows, the stepwise method left two variables additionally to the constant. The coefficient of determination was $R^2 = 0.718$. However, the *GDPCAP* variable is insignificant on the 5% level, and thus can also be left out of the model. If compared to the first model, with the *TIME* variable, the results are worse. *Thus, the result for testing H3 is that the economic convergence of the EU member countries, measured by the per capita GDP convergence, did not affect the convergence of mobile communications penetrations.*

6 CONCLUSIONS

In this paper, the evolution of the dispersion of mobile communications penetration rates in the European Union is studied. The calculated Lorenz curves and Gini coefficients show a clear tendency of equalization: The European Union member countries have converged in terms of mobile communications penetration, as is foreseen by the learning effect. Also, Gruber and Verboven (2001) get convergence of the EU countries as a result, but they do predict it using a diffusion model to occur in year 2006. The model used in this study predicts the convergence to have already occurred in the end of year 2000.

Additionally, two hypothesized reasons behind the convergence were studied: The effects of the adoption of a common mobile communications standard (GSM), and of economic convergence of the EU member countries. It seems that adopting the common GSM standard, and the simultaneous instruction of multiple network operators within a country, have facilitated the convergence of mobile communications penetrations. Gruber and Verboven (2001) get a similar result, as they show that the introduction of GSM has significantly sped up the diffusion rates of mobile communications. The results of this paper also show that the convergence process is rather due to time than to the economic convergence of the EU member countries.

Considering the result of a common standard speeding up the equalization of mobile communications penetrations has also implications on the third generation (3G) of mobile communications. Although mobile communications penetration rates start to be somewhat equal in the EU member countries, and thus further reduction of inequality is not possible, the decision of choosing a common standard probably causes the inequality to continue to be on a low level. This is, of course, assuming other factors affecting the diffusion of mobile communications do not change.

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