ARE MOBILE PHONES AND FIXED LINES SUBSTITUTES OR COMPLEMENTS? EVIDENCE FROM TRANSITION ECONOMIES

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ABSTRACT

This paper addresses the issue of whether mobile telephone and fixed line telephone services are substitutes or complements in transition economies. Some studies have found that they are complements in this region, which contrasts with findings for other regions where mobile telephones and fixed line services are found to be substitutes. This study finds evidence in the support of the conclusion that complementarity and substitutability are associated with the stage of the market's development regardless of geographic region. Apparently results of previous research are predetermined by the data sample selection. The study confirms that factors positively influencing mobile telephone penetration rates are national income levels and the intensity of competition in telecommunications markets. The results suggest that by encouraging competition in mobile telephony governments can accelerate mobile phone penetration rates to the benefit of consumers. Additionally, the development of mobile telephony can put competitive pressure on incumbent fixed lines operators.

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The mistakes and inaccuracies remaining in this work are mine and only mine.

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CIS	Commonwealth of Independent States
CAGR	Compound annual growth rate
EBRD	European Bank of Reconstruction and Development
EU	European Union
ITU	International Telecommunications Union
OECD	Organization of Economic Cooperation and Development
WDI	World Development Indicators

1 INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Over the past 20 years, mobile telecommunications has undergone dramatic changes both in terms of technological sophistication and market acceptance. An ongoing issue is whether mobile telecommunications are a complement to or substitute for conventional fixed line (or land line) telecommunications. The question has particular relevance for developing countries and for countries moving from centrally planned regimes to market based economic organization. For policy makers in developing countries with weak fixed line systems the issue is whether mobile technology can provide a cost efficient substitute that would allow avoidance of heavy infrastructure investments in conventional fixed technology. For policy makers in jurisdictions moving from planned to market directed economic organization, the issue is whether privately owned mobile systems can provide effective competition to highly concentrated and previously state owned fixed line systems. If so, regulatory oversight of the fixed line systems as they move from public to private ownership can be limited.

Currently there is no general consensus at conceptual level as to whether mobile and fixed line telephony are complements or substitutes. Externalities between the two networks indicate that these services can be complements. Similarity of the products, price convergence and, in developing economies, deficiency of fixed lines telephony suggest that the services can be substitutes.

Empirical studies of this issue have produced mixed results. However, complementarity is usually found in earlier studies, and in studies at the cross country level. Later studies and studies at the micro level, based on household surveys, find more evidence of substitutability.

The issue is complicated by the lack of information on the intensity of use of mobile service and, therefore, the need to rely on proxy measures, such as penetration rates, to capture this variable. Analysis is further complicated by the fact that mobile telephony is a new technology and its adoption follows patterns reflected in the initial stages of a product cycle. Additionally, mobile and fixed line services can be strategic substitutes, which can lead to a positive rather then a negative correlation between penetration rates.

Notwithstanding data deficiencies and the complications noted above, a consensus as to the relationship between the two telecommunications services appears to be emerging. According to several researchers, the difference in empirical findings as to substitutability and complementarity may be a result of mobile phone market evolution. As the technology moves along its product cycle the substitutability effect strengthens, and ultimately dominates the complementarity effect.

One of the more recent studies dealing with the issue finds evidence that mobile and fixed line telephony are complements in Central European transition economies. This finding contradicts some of the recent anecdotal evidence from the region. The purpose of this project is to address the issue of substitutability and complementarity of the two services in transition economies by incorporating into the analysis a larger sample of countries and a longer period of market development as compared to earlier studies. Expansion of the database helps to test what will be referred to hereafter as the "market evolution" explanation, that is, the notion that in the earlier stages of its market penetration, mobile telephony is a complement to fixed line telephony, but in later stages of the product cycle, it becomes a substitute for fixed line technology.

The structure of the paper is as follows. Chapter 1 gives a brief overview of mobile technology developments and telecommunications markets in transition economies. Then, Chapter 1 reviews recent empirical findings on complementarity and substitutability between mobile phones and fixed lines. It also discusses the implications of network externalities and technology diffusion. Chapter 2 provides an overview of approaches to modelling network externalities and technology diffusion. Then, it suggests a model, and provides and discusses its estimation results. Chapter 3 presents conclusions and a discussion of policy implications.

1.2 Mobile technology

With the introduction of mobile telecommunications networks, physical connections were replaced by radio transmission. The scarce resource required for radio transmission is the spectrum. A capacity constraint resulting from spectrum scarcity has been gradually alleviated and transmission quality has been improved as the technology developed (Gruber and Verboven, 2001).

The first generation analogue mobile phone systems used the radio spectrum around 450 MHz and were very inefficient since very few consumers could be connected to the base stations at the same time. The second generation analogue systems, introduced in late 1980s, used the spectrum around 900 MHz, and this made possible the connection of many more users to a base station and the more efficient use of the spectrum. A drawback to the use of higher frequencies was the requirement for greater base station density. After the first generation digital technology was introduced in the same 900 MHz spectrum in the early 1990s, the network could accommodate three to four times more users. The second generation digital systems that operate in the 1800 MHz spectrum have allowed for even more users with even denser base station systems (Gruber and Verboven, 2001).

The first generation analogue technology did not allow a full exploitation of economies of scale in the industry. The natural monopoly argument applied. With introduction of the second generation of analogue systems, competing operators entered the market in some countries. A fundamental change, however, occurred with the introduction of digital technology. As three to four times more customers could be maintained by the digital system the scope for competition was greatly expanded (Gruber, 2001). In many mobile telecommunications markets, duopoly is the norm and the number of mobile operators in regional markets continues to increase as firms penetrate each other's markets to exploit advantages of international roaming.

1.3 Telecommunications in transition economies

For historical reasons Central European countries and the countries of the Commonwealth of Independent States (CIS) are relatively late comers to mobile telecommunications technology (Table 1). After the collapse of the communist regimes in the early 1990s all these countries had roughly similar starting conditions, especially when it concerned telecommunications. Commonly, the telecommunications sector in centrally planned economies was a state monopoly[1] and was used as an instrument to distribute benefits to different groups in society. Usually telecommunications services were underpriced, undersupplied[2] and overdemanded[3]. Moreover, price setting was dictated by political objectives and did not reflect the cost of services. This created poor incentives to maintain the fixed line system, which in turn led to a low quality of service.

It is widely recognized that telecommunications is an important factor contributing to economic growth and development (World Bank, 1994, EBRD, 1996). Many countries of the region made significant efforts to improve their telecommunications infrastructure. However, financial constraints combined with costly, but difficult to abandon social obligations (such as low cost service for low income users) frustrated attempts to increase fixed line penetration even in the most advanced economies of the region. Policies that facilitated the restructuring and deregulation of telecommunications in the West, such as tariff rebalancing between local and

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[1] There was no competition in the fixed lines markets primarily for historical reasons rather than because of the reliance on natural monopoly argument. Most industries in centrally planned economies tended to rely on monopolies.
[2] The contribution of the telecommunications to GDP was below 1% in all countries of the region, while in OECD countries it was about 2% of GDP (ITU, 1995).
[3] The average waiting time for many countries is 5 years (Carbajo, Fries, 1997).

long-distance services, and significant reductions in the workforce, were not politically acceptable in most countries. Private capital was reluctant to invest in the sector because of the social, economic and political constraints imposed on the operators.

From the perspective of policy makers, mobile telecommunications has emerged as an attractive alternative to the fixed lines telephony[4]. It is able to provide cost based telecommunications pricing to the "willing to pay" without a legacy of social obligations. Mobile telephony provides scope for competition due to low entry barriers. And, importantly for economies in transition, the installation of mobile telecommunications systems takes less time and involves much lower infrastructure costs than fixed line systems. Indeed, a nation-wide mobile network could be installed in many of the countries of the region within two years.

The most advanced countries of the region had access to mobile technology by 1990 and subsequent expansion of mobile telecommunications in Central European was unprecedented. Between 1995 and 2001 compound annual growth rate (CAGR) in terms of number of subscribers in the countries of Central Europe was 100%[5], the highest among regions of the world (Banerjee and Ros, 2004). Some countries of the region were very successful in the introduction of mobile phone telephony and have caught up with neighbouring Western European countries. This is especially impressive since most of the mobile technology diffusion in these transition economies took place after 1995.

The structure of mobile telecommunications markets during the analogue phase (1992-1995) was typically characterized by monopoly. A single mobile telecommunications company

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[4] International financial institutions, seeking solutions to the bottlenecks that impede telecommunications development, see mobile telecommunications as a convenient alternative to the reform of fixed line systems (Gruber, 2001).

[5] The late introduction of mobile technology in some transition economies has allowed technological leapfrogging of several development stages and has made development easier. All countries of the region that introduced analogue technology opted for the same standard (NMT), which allowed for easy roaming. Some very late entrants skipped the analogue phase altogether and implemented a digital standard (GSM) when it was introduced in 1995-1996.

was usually owned by an incumbent fixed line monopolist. Sometimes foreign minority shareholders were accepted in order to facilitate the transfer of technology and managerial know-how. But even if foreign shareholders held a majority position, the mobile operators were heavily influenced by the fixed line monopolies. With the introduction of the digital standard of mobile telephony, several operators entered telecommunications services markets in the countries of the region. By 2001, of the 22 countries reviewed in this project, eleven were characterized by duopoly, and five supported more than two mobile telecommunications service providers (Table 1).

The lower cost of mobile telecommunications and increased competition between providers put downward pressure on the price of mobile telephone service. Mobile phone penetration substantially increased as the service became more affordable to more people. Gruber (2001) suggests that the following scenario characterizes mobile technology diffusion in the Central European countries: technological progress supports a larger number of firms in the market; competition in the market intensifies; the speed of diffusion of mobile telecommunication technology accelerates.

1.4 Literature review

Older studies in telecommunication markets are primary concerned with natural monopoly and competition issues. The findings are that competition generally improves market performance[6]. More recent studies make attempts to explain the phenomenon of mobile phone diffusion and its implications for the incumbent fixed line monopolies. A general consensus is that mobile phones operators are strong competitors to fixed line monopolies and are able to put pressure on the fixed line operators to reduce tariffs, improve the quality of service and expand the network.

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[6] See Hamilton (2003) for the summary of the studies.

The further development of fixed line telephony in transition economies will depend on the degree of substitutability between fixed line and mobile services. If they are complements, the introduction and maintenance of competition between the two services may not be sufficient to stimulate expansion and improvement of the fixed line system. In such a case, a more proactive government policy would be required in order to improve fixed line telecommunications quality and to encourage investments for development (Hamilton, 2003). When they are substitutes, competition between services can ensure adequate levels of development of both markets, and governments would not need to implement specific policies to encourage fixed line development[7]. However, until mobile phone operators are in a position to effectively constrain the market power of incumbent fixed line monopolists, government should not rely exclusively upon competition to guide development of the sector (Rodini et al., 2003).

1.4.1 Recent studies of substitutability and complementarity of mobile and fixed line telephony

There are a number of studies that address the issue of whether mobile phones and fixed line systems are substitutes or complements. Findings vary depending on the scope of the research and on the time period reviewed. Generally, a higher degree of substitutability is more likely to be found when a study is based on data in recent years (after 2000) and is based upon micro level data.

Most of the studies draw their conclusions about substitutability based on a relationship between the number of fixed line subscribers and mobile subscribers. Ahn and Lee (1999) in their study of 64 countries find that the number of fixed lines positively affects the probability of mobile phone subscription. In cross-country studies, Hamilton (2003) finds that complementarity predominated in African countries, and Gruber (2001) finds evidence of complementarity in Central European OECD member countries. However, Gruber and Verboven (2001) find that

[7] Fixed lines may even be eventually replaced by the mobile telephony.

mobile and fixed line telephony are substitutes in the EU countries. The services are also found to be substitutes by Sung and Lee (2002) in a study across regions of Korea, and in a study by Rodini et. al. (2003) based on a US household survey. Banerjee and Ros (2004), in a study based on a cluster analysis of a panel of 61 countries, find that mobile telephony diffusion takes place at a much higher rate that fixed telephony diffusion in the developing economies and it is likely to be driven by non-price factors.

Due largely to the limited availability of price data, demand estimation studies for mobile phone services are few and are just recently being undertaken (Hausman (1999) and (2000) for the US, Ahn and Lee (1999), Sung and Lee (2002) for Korea, Madden et. al. (2004) for cross country data). Some studies estimate demand for secondary fixed lines and are based on detailed household surveys. Rodini et al. (2003), using US household survey data, estimate cross-price elasticity of demand for mobile phones and second fixed lines. They find negative cross-price elasticities.

1.4.2 Factors affecting mobile telephony development

The factors affecting mobile phone penetration rates mentioned above are fixed line penetration rates and the price of fixed line service. The role of penetration rates will be extensively discussed below. Inclusion of the price variable depends on the availability of price data, and when available and used in cross country studies, most found it to be insignificant. Price information for mobile services, even when available, is very difficult to deal with because of multiple, complex pricing bundles (i.e., pricing based upon total minutes used, evening and weekend rates as opposed to daytime rates, differential roaming charges, and so forth).

In their work, Gruber and Verboven (2001) suggest using major cost and competition factors as proxies for price data. The level of urbanization and population density are believed to be important cost factors since they influence the level of required infrastructure investments.

Important factors affecting diffusion of mobile communications are technological development and competition. Gruber and Verboven (2001) show that digitalization was much more important in explaining the speed of diffusion than was the increasing number of competitors in European countries. This is supported by Parker and Roller (1997), who found that the move from monopoly to duopoly in US mobile telecommunication markets had very little effect on the rate of diffusion. On the contrary, Gruber (2001) found that in Central Europe competition factors rather than technology advancement play a stronger role in increasing the speed of mobile telecommunications diffusion[8].

There is a general consensus that mobile phone penetration rates depend on the income levels of a country. Therefore, most studies include GDP per capita as a measure of income level and it is significant in most studies (for instance, Hamilton, 2003). Fixed line penetration rates and GDP per capita are expected to be correlated. However, this correlation can be small if insufficient supply is observed in the fixed line market.

Hamilton (2003) suggests that significant factors influencing fixed line access include institutions and the political regime. A strong institutional framework is considered to be essential for network development and expansion of utilities. The general consensus of studies dealing with privatisation and competition is that simultaneous implementation of policies to encourage both tends to be associated with increased efficiency and growth, but that privatisation without the introduction of competition is not necessarily conducive to network expansion.

A major reason for substitution of mobile telephony for fixed line services in transition economies can be dismal performance of the fixed line service which is characterized by long waiting lists and poor customer care service. Gruber (2001) finds that in Central Europe mobile

[8] This appears to be consistent with some anecdotal evidence. For instance, after the second operator (Kyivstar) entered the market in Ukraine in 1997 mobile communication tariffs fell sharply and the number of mobile phone subscribers increased dramatically. By 2000 Kyivstar had captured about 50% of the market. An attempt by the original operator (UMC) to recapture market share led to even further tariff reductions in 2003.

telephony diffusion speed increases with the length of the waiting lists for access to the fixed line system.

1.4.3 Role of network externalities in market development

Sung and Lee (2002) endorse the "market evolution" explanation for the nature of complementarity and substitutability in mobile and fixed line markets. Hamilton (2003) seems to independently support it in her study. Starting as complements mobile phones become more of substitutes as their number increases.

Traditionally fixed line telephony and mobile telephony were believed to be complements. An explanation for this is what is known as cross-network externalities[9] which are additional to own network externalities (e.g., network externalities associated with the fixed line system) and are more likely to be encountered when there is easy interconnection between the networks. When mobile phone technology is introduced, mobile phones are very few in number and do not have much use without the fixed line networks. Calls from mobile phones are commonly made to fixed lines as opposed to other mobile phones (Jha and Majumdar, 1999). Therefore, at this stage mobile phones are strong complements to fixed lines. Increases in the quantity of mobile phones demanded not only increases their attractiveness[10], but also, through network externalities, increases attractiveness of the fixed lines. As penetration rates increase, the attractiveness of both networks is enhanced.

As mobile telephones reach higher penetration rates, more and more calls remain within mobile network. The demand for mobile services increases due to both price and network effects. The diffusion of mobile phones speeds up as they become more popular among users[11]; eventually they achieve a critical mass and become self-sustaining and less of a complement to

[9] Cross network externalities are also referred to as call externalities.
[10] Complements tend to increase the value of each other.
[11] A technology diffusion phenomenon to be discussed below.

the fixed lines. When the markets for mobile phones approach their saturation levels, the diffusion rates slow down.

There are two main lines of reasoning for the view that the mobile phones are substitutes for fixed line services. First, access to the fixed lines is as expensive as access to the mobile phones in high-income countries. The price of mobile phones falls due to technological advances and competition. When the price of a mobile phone approaches the price of a fixed line they are expected to become substitutes. The price of fixed lines in transition economies remains relatively stable, since this service was traditionally underpriced and is regulated[12]. Therefore, a low price for fixed line service can significantly discourage mobile phone substitution for fixed lines at the initial stage of market development and the argument hardly applies.

Second, unlike developed economies, in transition and developing economies access to the fixed lines is restricted by supply constraints and is discouraged by the low quality of the fixed line system. This is the major reason why mobile phones could be substitutes for fixed lines in these countries.

1.4.4 Inference about complementarity vs. substitutability

An expansion of a mobile phone network is expected to be positively associated with an expansion of the fixed line network when they are complements, and negatively associated, when they are substitutes. Sung and Lee (2002) find that the number of Korean mobile subscribers is positively correlated with the number of fixed-line disconnects, but it is negatively related to the number of new fixed-line connections, thus, suggesting net substitution between the two services.

When micro level data are not available it becomes more difficult to disaggregate complementarity and substitutability effects. Mobile phones and fixed lines remain complements

[12] In transition economies the prices can even increase due to tariff rebalancing.

and substitutes at the same time. The demand for each can increase due to independent factors, own network externalities or cross network externalities.

While mobile and fixed line telephony can be consumption substitutes (economic substitutes), they can also be strategic substitutes (Hamilton, 2003) or technological substitutes (Banerjee and Ros, 2004). Strategic substitution arises when an incumbent operator believes that increasing fixed line access is the best response to the competition from mobile operators. Therefore, for strategic substitutes the correlation between penetration rates of fixed lines and mobile phones will be positive. Technological substitution takes place when consumers increasingly turn to the mobile service as a substitute for fixed network service despite relatively higher mobile service prices. For technological substitutes the correlation between penetration rates of fixed lines and mobile phones will be negative.

Sometimes both mobile phones and fixed lines markets are influenced by the government controlled monopoly operator. Therefore, the number of mobile phones and fixed lines is jointly determined by the same decision maker. The endogeneity problem can arise. To deal with it Hamilton (2003) suggests private credit as an instrumental variable for mobile penetration rates. Private credit is defined as the ratio of private sector credit to GDP. Fixed line operators are usually publicly owned while mobile operators are privately owned. Therefore, private sector credit is more likely to be channelled into mobile telephony rather than into fixed line systems.

1.4.5 Technology diffusion

The definition of network externalities is very broad. According to Katz and Shapiro (1985) "there are many products for which the utility that a user derives from consumption of the good increases with the other agents consuming the good". This can include networks where the users are physically connected (for instance, telecommunication networks) and networks with positive consumption externalities (for instance, computer software or automobile repair). The first type of network effect is referred to as a direct network effect and the second type is referred to as an indirect network effect. Where the network involves physical connection, the externalities may fail to be internalized, and then market failure can arise (Liebowitz and Margolis, 1994).

Mobile phones may have both direct and indirect network effects. In both cases the decision of a consumer to join the network is influenced by the current number of network users. The direct and indirect network effects should not necessarily be differentiated for the purposes of this paper. Both types of network effects can be modelled as S-curves following models of technology diffusion that rely on the indirect network effects.

Technology diffusion is defined as "the process through which innovation, that is a new idea, is communicated through certain channels over time among the members of a social system" (Rogers, 1995). Usage of new technology over time typically follows an S-curve and the most common ways to model it are the epidemic and the probit models. The first model builds on the premise that what limits the usage of new knowledge is the lack of information available about a new technology. The second model assumes that different consumers with different goals and abilities are likely to want to adopt the new technology at different times (Geroski, 2000). An early S-curve diffusion model of innovation was proposed by Griliches (1957). An epidemic model of technology diffusion was suggested by Bass (1969) and later significantly developed.

A logistic function generates an S-shape diffusion curve (Griliches, 1957), but its weakness is that it fails to explain where the initial group of users comes from. Recent models of technology diffusion describe the process as being transmitted from two sources. "Hardware"[13] is transmitted from a common source and follows an exponential function. "Software" knowledge is transmitted through a word of mouth diffusion process and follows a logistic function. A

[13] Rogers (1995) draws a distinction between the "hardware" and "software" aspects of new technology. The "hardware" is the physical object that embodies a technology and "software" is the information base needed to use if efficiently. It is assumed that software cannot be transmitted from a common source as users need to build up experience from using the tool.

combined model of exponential and logistic functions can adequately describe the process of diffusion through the two sources and allows the diffusions with different inflection points (Geroski, 2000).

2 THE MODEL AND THE DATA

2.1 Introduction

As can be seen from the literature review the problem of complementarity and substitutability cannot be solved on a conceptual level, since the aggregate effect depends on a number of directly conflicting effects. Early and recent attempts at empirical investigation lead to different conclusions. The major difference between those studies appears to be the time period considered, and the number of jurisdicitions included in the analysis. However, all the different findings are consistent with the "market evolution" framework for explaining the relative change in substitution and complementarity effects.

This paper exploits a more robust data set (both in terms of country coverage and the time period considered) to investigate whether the "market evolution" framework is applicable in the case of transition economies. According to Gruber (2001) mobile telephony and fixed lines are found to be complements. The "market evolution" framework suggests that with time they will become more of substitutes.

Following a market development paradigm and based on inspection of the data a proper model and estimation methodology can be identified. The most current studies suggest what variables are important in explaining mobile phone penetration rates. Omitted variable problems will be addressed by estimation of the model using panel data estimation with fixed effects.

2.2 The data

In 2001 the highest mobile phone penetration rate in the region was achieved by Slovenia (760 phones per a thousand people) in 11 years of development (Figure 2, Table 2). In Tajikistan the penetration rate remained as low as 0.2 mobile phones per 1000 people after 6 years of development. The cumulative annual growth rates (CAGR) decline with higher levels of penetration achieved. According to Gruber (2001) those introduced mobile telephony later should be faster growers, thus closing the gap. Indeed, in the same year, those who have introduced mobile phones later grow faster (Figure 4).

The Kyrgyz Republic, Turkmenistan and Armenia were the last countries to introduce mobile telephony, 1998-1996 respectively (Table 1). The Kyrgyz Republic and Armenia introduced digital mobile technology at the outset, skipping an analogue standard and as a result have moved ahead of several countries of the region in terms of the sophistication of the technology employed. Given the very short period of time since introduction of the digital technology, it is not possible to say whether these late adopters will maintain a technological lead. Some countries of the region have moved into the category of fast growers, like Georgia and Azerbaijan (Figure 4). However, the correlations between the time of introduction of mobile telephony and the CAGR in the 4^{th} year and the 9^{th} year of mobile telecommunication market development are 0.01 and 0.12 respectively. This suggests that later introduction of mobile telecommunication does not increase the rate of diffusion notwithstanding the expectation that the introduction of better, lower cost technology, and costs of switching from analogue to digital would advantage late-comers.

The fixed lines penetration rates in the countries of the region do not exceed 0.4 fixed lines per person, which is substantially lower than mobile phone penetration rates in the most advanced countries of the region in 2001 (Figure 1). When Figure 1 and Figure 2 are compared one can notice that the most advanced countries of the region in terms of mobile phone penetration also had a dramatic increase in fixed lines penetration (Hungary, Poland, Czech Republic, and Slovenia). The correlation coefficient between them is 0.58 (Table 3). It should be noted that these are the countries that were in the sample used by Gruber (2001). High correlation between the penetration rates led to his conclusion regarding complementarity of the services. It is possible that penetration rates in these countries are driven by a common third factor, for instance, income levels. This is something to be investigated. In some countries at the higher level of fixed line market development the penetration rates show a downward turn (Estonia, Lithuania, and the Slovak Republic). This might be a sign of a higher substitution with the mobile phones.

Mobile and fixed line penetration rates tend to be higher in higher income economies, the correlation coefficients are 0.49 and 0.63 respectively (Table 3). The penetration rates are also higher in countries with more extensive reform of the telecommunications sector (unbundling, privatization, regulation), the correlation coefficients are 0.53 and 0.58 for mobile phones and fixed lines (Table 3). Mobile phone penetration rates are also negatively correlated with the length of waiting lists for fixed line service, the correlation coefficient is -0.41 (Table 3). This may be explained by some third factor influencing the variables. For example, countries that have taken steps to reduce fixed line waiting lists are also more active in the introduction of mobile phone technology. Fixed line penetration rates are positively correlated with the level of urbanization of a country, the correlation coefficient is 0.56 (Table 3). Therefore, unlike mobile telephony, the fixed cost of infrastructure plays a more significant role in explaining fixed line penetration rates.

Studying the data one can see that mobile phone penetration follows an S-shaped curve (Figure 2). More advanced markets are already approaching their maximum penetration levels, which can be around 0.8 for Slovenia or around 0.6 for Estonia. However, most countries are only at the stage of sustained growth and it cannot be observed when they would level off. Most countries seem to achieve critical mass in their 8^{th} or 9^{th} years of development.

Several countries (Russian Federation, Ukraine and Kazakhstan) have a very late take off (Figure 3). There should be some explanation as to why these countries, with an early introduction of mobile telephony, failed to rapidly reach high levels of penetration. On one hand those countries are the largest in territory in the region, which may be a barrier for nationwide coverage. On the other hand those countries are resourceful and ambitious, but not consistent reformers; a failure to reform the economy or the sector in a timely fashion could have slowed mobile phone penetration.

2.3 The model

When studying substitution and complementarity, demand system estimation would be the best approach. Unfortunately, it requires detailed information on prices and expenditure shares, which is not available; and even if it is available, the measurement error is high, since telecommunications take a small share of consumers' budgets[14].

Alternatively, a system of supply and demand equations could be estimated. It would include demand and supply equations for mobile and the fixed line telecommunications, since these are the two major alternatives. Estimation of a system of simultaneous equations faces a serious information constraint as well. First, information on the intensity of telephone use is not available; it can be only approximated by information on telephone subscriptions. Second, mobile communication operators are very inventive in pricing their services. Usually there are several alternative pricing schemes, which make it virtually impossible to obtain some average price of mobile telecommunications. The available price information is not reliable due to huge price distortions in countries of the region due to government interventions.

Thus, this paper follows the most straightforward way of estimating the demand equation for mobile telecommunications including all the relevant explanatory variables - the price of mobile communications is replaced with several proxies.

[14] The information on expenditure shares is not likely to be reliable as telecommunications are about 2% of GDP in Western Europe and about 1% of GDP in Central Europe and the CIS (and this is likely an overstatement given the size of the shadow economy in this region).

Quantity and price of the mobile telecommunications can be described by a system of equations:

$$q^m{}_d = f_1(p^m, p^f, q^f, q^m, X) \qquad (1)$$

$$q^m{}_s = f_2(p^m, W) \qquad (2)$$

$$q^m{}_d = q^m{}_s \qquad (3)$$

where the demand for mobile telecommunication services, q^m, is approximated by the number of users or the penetration rate. X and W are the explanatory variables that are described below. It is assumed that telecommunication services produce positive consumption externalities, therefore $q^m{}_d$ is a function of the number of users of mobile and fixed telecommunication services q^m and q^f.

We can express p^m as function of $q^m{}_s$ from equation (2) and plug it in equation (1):

$$q^m{}_d = f_3(q^m{}_s, W, p^f, q^f, q^m, X) \qquad (4)$$

Since $q^m{}_d = q^m{}_s = q^m$ we can rearrange (4) with the restriction that the left hand side of the equation cannot be zero.

$$q^m{}_d = f_3(W, p^f, q^f, X) \qquad (5)$$

Equation (5) can be estimated for a panel of countries.

2.3.1 Alternative functional forms

The models of product diffusion follow an approach suggested by Bass (1969). Probability of purchase at time t ($P(t)$) depends on the number of purchases made during the period ($Y(t)$). $Y(t)=mF(t)$, where m is potential saturation level and $F(t)$ is cumulative density function.

$f(t)/(1-F(t)) = P(t) = p+q/mY(t) = p+qF(t)$, where $f(t)$ is the likelihood of purchase at t.

Solving the equation with the initial condition $F(0)=0$

$$F(t)=(1-exp(-pt-qt))/(1+(q/p)exp(-pt-qt)) \qquad (6)$$

The cumulative adoption function is $Y(t)=mF(t)$.

Bass (1969) estimates the model using ordinary least squares. Schmittlein and Mahajan (1982) improve the estimates of the model using maximum likelihood estimation. Srinivasan and Mason (1986) propose a nonlinear least squares approach, which improves standard error estimates compared to the maximum likelihood estimation for the diffusion models, where the cumulative adoption can be expressed as an explicit function of time.

Griliches (1957) proposes a logistic growth curve model of technology diffusion in a simple model for hybrid corn in the US:

$$P=K/(1+exp(-a-bt)) \qquad (7)$$

where P is the percentage planted with the hybrid corn, K the ceiling equilibrium value, t the time variable, b the rate of growth coefficient, and a the variable which places the curve on the time scale.

After the transformation, parameters of the model can be estimated directly by least squares.

$$ln(P/(K-P))=a+bt \qquad (8)$$

Gruber and Verboven (2001) and Verboven (2001) estimate a model more complicated than that of Griliches (1957). Gruber (2001) estimated equation (9) by non-linear least squares adding the error term to the equation (9).

$$y_{it}= y^*_{it}/[1+\exp(-a_{it}-b_{it}t)] \qquad (9)$$

y_{it} denotes the number of agents that have adopted the new technology in country i at time t. This can be adequately approximated by a mobile telephone line penetration rate in a country i at time t. y^*_{it} denotes the number of potential adopters of the new technology in a country i at time t. The number of potential adopters can be assumed to evolve proportionately to the total population in a country i at time t (pop_{it}):

$$y^*_{it}=\gamma pop_{it}$$

a_{it} is a location variable, which depends on a set of explanatory variables Z:

$$a_{it}=\alpha^F_i+Z`_{it}\boldsymbol{\alpha}$$

where α^F_i are fixed effects for each country i and captures the technology adoption lag or lead relative to an average country. $\boldsymbol{\alpha}$ measures instantaneous effects of the variables.

b_{it} is a parameter for a speed of diffusion. It depends on a set of explanatory variables for a country i at time t ($Z`_{it}$). It includes a coefficient β on a time trend (t), which captures own network externalities of mobile phones market development. $\boldsymbol{\beta}$ measures effects of the variables on the diffusion speed.

$$b_{it}=\beta+Z`_{it}\boldsymbol{\beta}$$

The variables of $Z`_{it}$ include income per capita, a size of the fixed network, a waiting list for a fixed line connection, the quality of telecommunications, a level of urbanization of a country population, a population density, competition in the market, digitalization, institutional environment.

2.3.2 The model to be estimated

Following the models of technology diffusion this paper estimates the model similar to that proposed by Griliches (1957) using the factors proposed by Gruber (2001). The advantage of the model is that it can be linearized and estimated with fixed effects OLS. The disadvantage that γ cannot be estimated explicitly can be overcome by sensitivity analysis of γ. Studying the data it is found that the most advanced country in the region asymptotically approaches 80% of total population. The initial potential adopters value for γ is 0.8. Since the dependent variable is a number of mobile phones, the cross network effects are captured by the coefficient on the number of fixed lines and own network effects are captured by the logistic functional form incorporating a time trend.

Following Gruber (2001) the specification includes a variable responsible for an instantaneous effect of introduction of the mobile technology (*gsm*):

$$ln(y_{it}/\gamma/(1-y_{it}/\gamma))=\alpha^F_i+\alpha^D gsm_{it}+(\beta+Z`_{it}\beta)t+e_{it}$$

$Z`_{it}$ includes:

- income per capita, real GDP per capita in constant USD (*gdppc*)
- size of the fixed network, number of fixed telephone lines per capita (*fixed*)
- price of fixed line communication, includes monthly fee plus communication fee of 100 minutes of talk, expressed in constant USD (*fixedprice*)
- waiting list for a fixed line connection, ratio between registered applications for a fixed line and the number of connected fixed line subscribers (*wait*)
- level of urbanization of a country population in percent (*urban*)
- population density in a country, persons per square kilometer (*popdens*)
- monopoly operator, one licensed operator in the market, basis dummy variable (*mon*)
- duopoly operators, two licensed operators or more licensed operators, but the market is dominated by only two operators, dummy variable, 1 if duopoly (*duo*)
- competition, dummy variable, more than two licensed operators with similar shares of the market, 1 if competition (*comp*)

- level of development of regulatory framework, EBRD telecommunications sector infrastructure indicator (*trans*).

The variables were constructed based on information obtained from the World Development Indicators by the World Bank, the International Telecommunication Union World Telecommunication Indicators Database and infrastructure indicators of the European Bank of Reconstruction and Development. Information on market characteristics, competition and digitalisation were obtained from corresponding company websites (www.gsmworld.com).

2.4 Discussion of the estimation results

Table 4 presents fixed effects OLS estimation of the model for a panel of data. All the countries of the region were included[15] and all had similar recent transition histories. This adds variability and eliminates the selection bias. The estimation of the model is done for the panel available from 1990 to 2001 (Column 1) and for a panel from 1993 to 2001, where the price of fixed lines is included (Column 2). Column 3 presents the estimations of the model for a dataset similar to the one used by Gruber (2001). Column 4 shows the relationship between the number of fixed lines and three dummies - one for the first four years of market development, one for the next three years of market development, one for the last five years of market development. This allows drawing a conclusion about the evolution of substitutability of mobile and fixed lines directly from the estimations of the coefficients on fixed lines throughout the market development cycle.

An introduction of the digital standard of mobile communication (GSM) appears to be a statistically significant factor explaining both when mobile telecommunications are introduced and the dynamics of mobile penetration rates (Columns 1 and 2). The introduction of the digital standard has substantially increased the spectrum capacity and has both reduced the cost of a

[15] States of the former Yugoslavia, which were in the midst of civil conflict during the 1990s, were excluded.

telephone call and has allowed more operators to be in the market. According to the estimations the availability of digital technology makes a positive instantaneous impact on the penetration rates of mobile phones, but negatively affects the speed of their diffusion. This may be explained by the fact that introduction of digital technology leads to higher levels of penetration, where the diffusion rates are slower due to market saturation.

The time variable is statistically significant and positive in the sample (Columns 1 and 2). This suggests that mobile penetration rates follow their own paths predetermined by own network externalities. The penetration rates of fixed lines are statistically significant and have a negative sign. This leads to a conclusion that the substitution effects overweigh the complementarity effects in the sample. However, the sensitivity analysis for the maximum level of market penetration (γ) below shows that the substitutability effect becomes lower when the maximum level of penetration is lower. As it was expected and found by other authors at aggregate level, the price of fixed telephony is not statistically significant (Column 1).

Country income levels appear to be statistically significant and have a positive effect on the penetration rates growth (Columns 1 and 2). This corresponds to the expectations and findings of other authors. Other factors accelerating mobile phone penetration are population density and level of competition. Greater population density reduces the cost of the service, since fewer towers per 1,000 subscribers would be required to provide the country's population with the service. Competition makes operators reduce prices.

The level of urbanization does not affect mobile phone diffusion. Coupled with the significance of population density this may suggest that operators are worried about nationwide coverage rather than coverage of the most populated areas. As mobile telecommunications are important for travellers, the mobile phone networks normally cover major travelling routes outside urban areas.

The effect of unsatisfied demand (waiting lists) on diffusion of mobile phones is positive and statistically significant in the samples (Columns 1 and 2). Unexpectedly, the quality of the fixed line communication (number of faults) is statistically significant and has a negative sign. On one hand this relationship may reflect a complementarity between the fixed lines and the mobile phones. On the other hand there can be an endogeneity problem when factors impeding the improvement of the fixed line system also slow down the development of the mobile network.

Surprisingly, the infrastructure indicators, which represent institutional reform efforts of the government in the sector, are not statistically significant (Columns 1 and 2). The mobile phone market may not be sensitive to government regulations since the incumbent monopoly fixed line operators are the object of most of these regulations. It may be more sensitive to the general investment climate in the countries, which should be captured by the fixed effects. It is also difficult to draw conclusions here, since the infrastructure indicators may be deficient by themselves[16].

Estimations based on the Gruber's sample of 10 countries between 1990 and 1997 (Column 3) support the conclusions drawn above that competition is a significant factor of infrastructure development and that infrastructure reforms are not significant. Similarly, waiting lists have a significant positive impact on mobile phone penetration rates. Gruber (2001) does not find any support for own network effects but does find support for cross network effects, which leads to a conclusion of service complementarity. In contrast to his finding, this paper finds evidence of positive own network effects but insignificant cross network externalities, which can lead to a conclusion that complementarity and substitutability have a similar importance. Unlike Gruber (2001), this paper finds evidence that country income levels are significant. This is in line with other studies, which reach a consensus that a region's income level is an important factor. It

[16] For a discussion of this issue see Dodonov et al. (2001).

can be inferred that Gruber (2001) does not find support for significance of the income variable because of a selection bias; countries in his sample are all high-income countries of the region.

In order to investigate whether fixed line and mobile telephony substitutability changes as a result of the market evolution the paper studies the effects of fixed lines during three time periods – for the first four years of the market development, the next three years and the last five years (Column 4). The last sample contains the least observations, since not many countries have reached that stage of the development. For the 12^{th} year there is only one observation. The coefficients are estimated to be negative and statistically significant in the second and the third time periods. This supports the hypothesis that substitutability increases as the market matures. An inconsistency is that the power of the substitutability in the last time period is somewhat lower than in the second time period. This may be due to the fact that most countries of the region are underrepresented in this sample, since only few countries have achieved that level of development.

The sensitivity analysis of the level of potential adopters reveals that as γ gets lower, that is as the number of potential adopters gets smaller, fixed lines no longer affect the diffusion of mobile phones. Thus, the relative power of substitutability declines. Gruber estimates γ to be about 0.2 for the sample prior to 1997, which is too low by any measures. The estimated γ for European Union countries in 1997 (when GSM had just been introduced) was 0.6 (Gruber and Verboven, 2001). Slovenia approaches 0.8 and eight countries are currently above 0.2 in 2001. Thus, if one estimates the models for lower levels of potential adopters evidence of complementarity is more likely.

3 CONCLUSIONS

3.1 Overview

This paper explores the hypothesis that mobile and the fixed line telecommunication services can be complements and substitutes at the same time and that the relative importance of complementarity and substitutability changes with the market evolution. This is done based on the estimation of complementarity and substitution effects in transition economies and by comparing them at different stages of market evolution. This study has benefited from a more robust data set (in terms of country coverage and time period) than was used in earlier studies. Since substitutability manifests itself with the passage of time, this should affect the estimations and confirm or reject the idea of a changing relative importance of complementarity and substitutability.

As the market matures the substitution effect dominates. The market develops, first, due to network externalities and technology diffusion and, second, due to technological advances and falling costs of the service. After a critical mass in the market is achieved the mobile technology becomes self-sustaining and it becomes more independent of fixed line telephony. Later it starts competing for new users. When the price of a mobile phone approaches the price of a fixed line it also increasingly plays the role of a substitute. It is not necessary that the prices of the alternative modes of telecommunications are the same. Mobile phones have a number of attractive features that increase their value relative to the value of the fixed lines.

According to the earlier cross country research mobile telephony was found to be a complement to fixed line telephony in developing countries. Later research found evidence of substitutability between mobile and the fixed line telephony. Gruber (2001) studied the relationship between mobile and fixed line telecommunications services in Central European countries and concluded that they are complements rather than substitutes. This paper, using a more robust data set, allows for a critical appraisal of Gruber's findings. This paper also provides information relevant to the "market evolution" framework for explaining the relationship between the two types of telecommunications services.

3.2 The estimation results

The analysis of the data suggests that mobile phone diffusion follows an S-curve. There are several functional forms developed to represent such a market development process. This paper takes a logistic function, which can be linearized. This model is computationally easier and allows fixed effects panel data estimation, which is recommendable to avoid omitted variable bias. The disadvantage of the inability of the model to estimate the potential level of the mobile phone users is dealt with by sensitivity analysis of this parameter.

The prices of fixed lines between 1993 and 2001 for all the countries of the region appear to be statistically insignificant. The fixed line penetration rates negatively influence mobile phone diffusion and are statistically significant when the potential level of mobile telephony users is high. The substitutability is found to manifest itself at later stages of market development. This lends support to the conclusion that mobile phones are substitutes for rather than complements to fixed lines as the mobile phone market matures. The significance of cross network effects appears to be sensitive to the assumed maximum penetration level; it turns from negative into insignificant when a lower maximum penetration level is assumed.

Other factors important for mobile technology diffusion are found to be country income levels, population density and the levels of competition between the operators. Surprisingly, the infrastructure reforms indicator is not found to be significant. This can be attributed either to an insignificant role of the sector reforms or to the deficiency of the indicator. It is difficult to reach a firm conclusion on this issue, but the deficiency of the indicator is likely to play a role. On the other hand, mobile operators should not be constrained by the majority of telecommunication market regulations since most of them deal with the incumbent monopolist fixed line operators.

A model estimated for the Gruber's sample of countries between 1990 and 1997 does not support his finding that mobile phones and fixed lines are complements, although it finds more complementarity than in the longer 1990 to 2001 sample. His results could be attributable to his sample selection, since the chosen 10 countries of the region have higher income levels, are advanced reformers and have higher penetration rates in both mobile phones and fixed lines. Therefore, the relation between the penetration rates is not necessarily a result of complementarity of the services; it may also be a manifestation of a selection bias. Other conclusions of Gruber (2001) are mainly supported. Competition is an important factor of mobile technology diffusion and technological advancements are not, unlike the finding for the European Union countries.

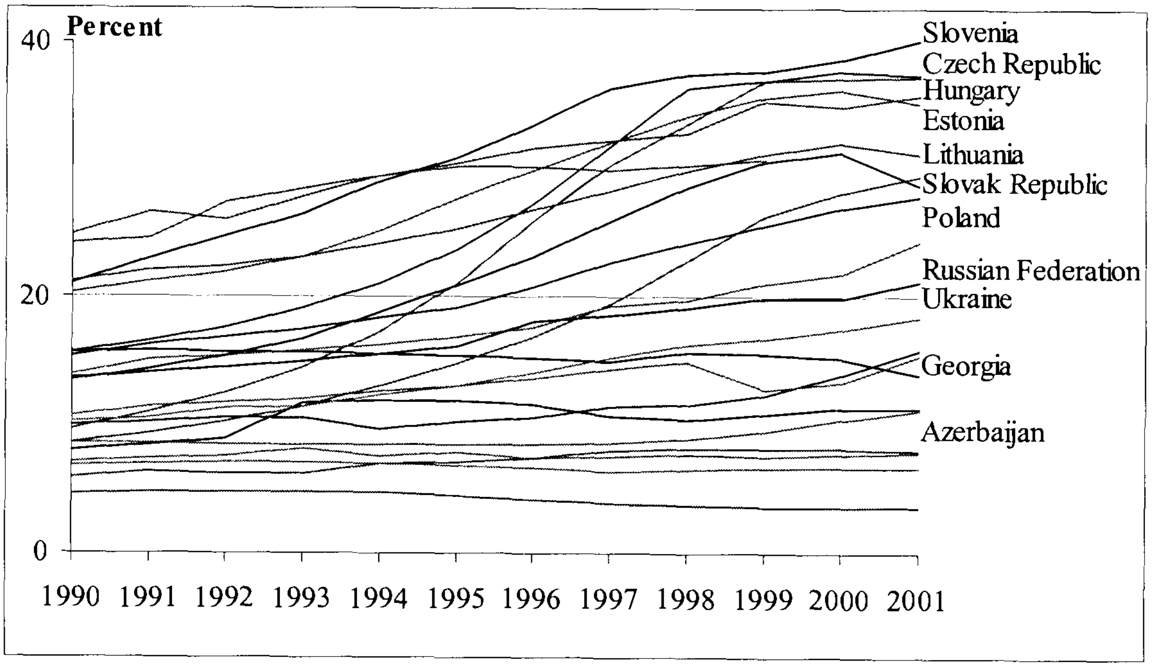
3.3 Policy implications

It has become widely recognized that if fixed lines and mobile phones are substitutes then competition policy should play a major role in the reforming of the telecommunications sector and that direct regulation should play a lesser role. Direct regulation of the fixed line monopolist becomes less crucial if competing mobile phone operators can put pressure on telecommunication tariffs. However, it is premature to suggest that telecommunications markets can rely exclusively upon competition to achieve high levels of performance. It remains to be seen how effectively mobile telephone services will constrain incumbent fixed line monopolists in transition economies.

For transition economies this issue is also important in another respect. Governments in these countries seek ways to raise telecommunications penetration rates, since they expect this would positively influence the economic environment and would accelerate the economic growth. The competition between mobile and fixed line telephony can guarantee adequate levels of development of the both markets. Governments may want to avoid expensive over investments in fixed line infrastructure. Therefore, they should be more cautious in pursuing extensive fixed line investment programs, which is not uncommon. For instance, in Ukraine instead of tariff rebalancing the government owned fixed line operator invests profits in the construction of telecommunications lines. If mobile telephony is potentially a lower cost substitute for fixed line systems, as is suggested by this paper, then decision makers should take this into consideration when evaluating expensive investments in fixed line infrastructure.

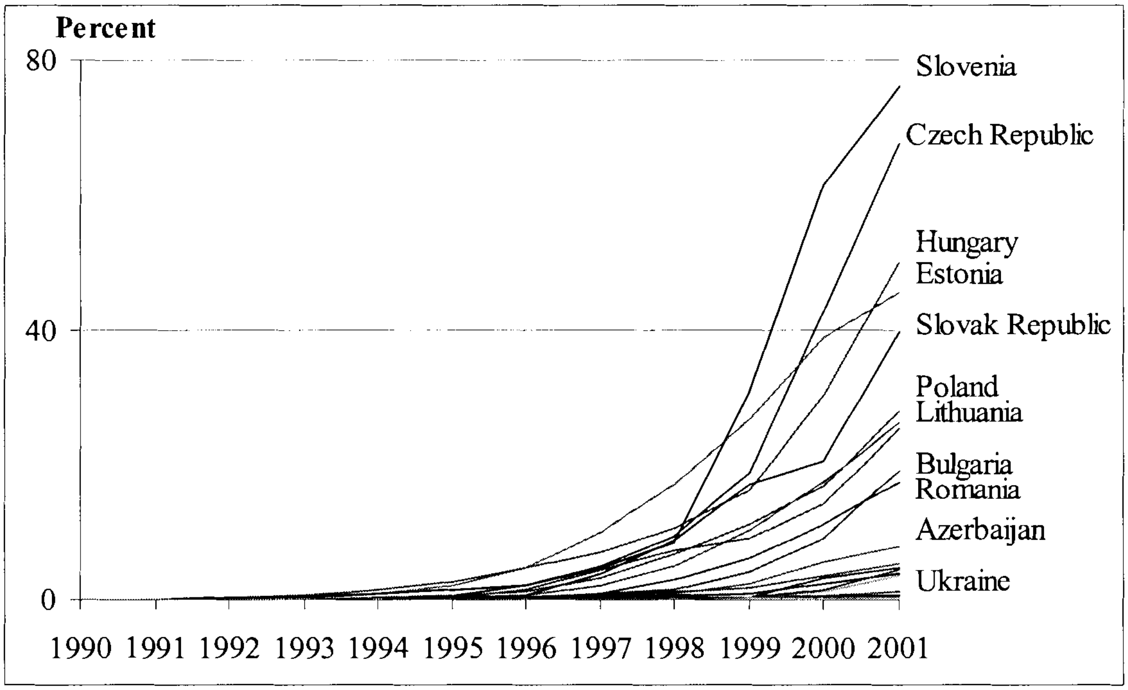
APPENDIX:
FIGURES AND TABLES

Figure 1: Fixed lines penetration rates by year.



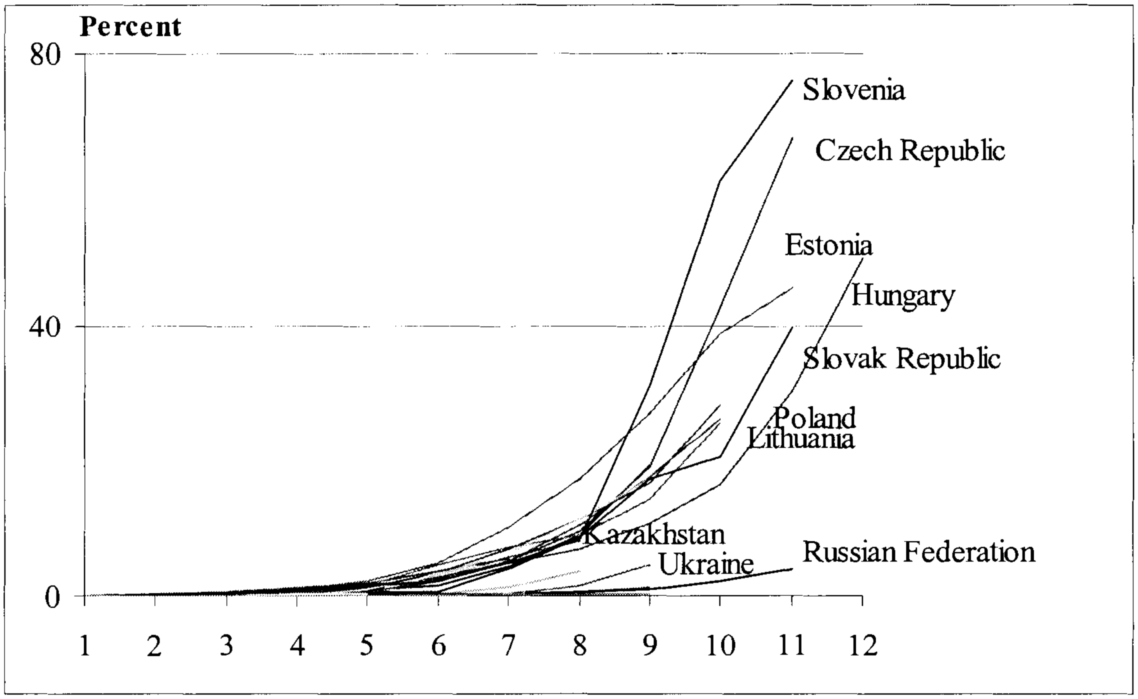
Data source: WDI.

Figure 2: Mobile phones penetration rates by year.



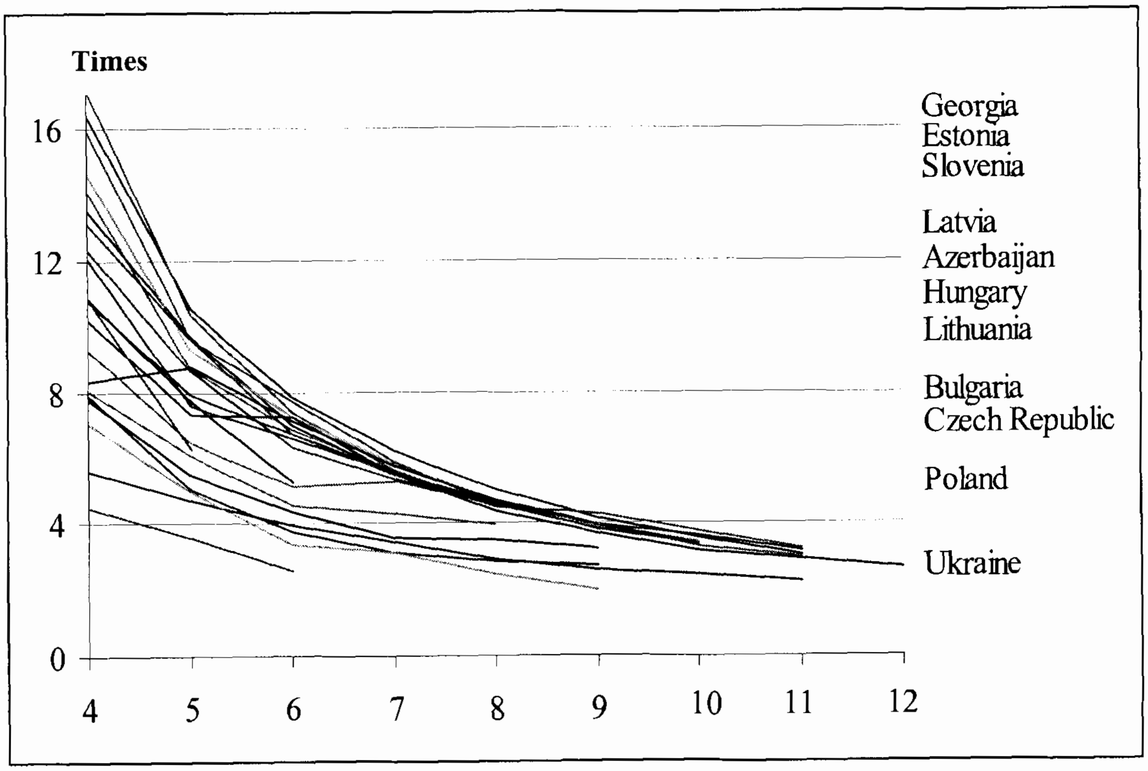
Data source: WDI, ITU.

Figure 3: Mobile phones penetration rates by the time of markets evolution.



Data source: WDI, ITU.

Figure 4: Mobile phones CAGRs by the time of markets evolution.



Data source: WDI, ITU

Table 1: Dates of major changes in mobile phones markets structure prior to 2001.

	NMT standard	GSM standard	Monopoly	Duopoly	Competition
Armenia		1996	1996		
Azerbaijan	1994	1996	1994	1999	
Belarus	1993	1999	1993		
Bulgaria	1993	1995	1993	2001	
Czech Republic	1991	1996	1991	1996	2001
Estonia	1991-2000	1994	1991	1995	2001
Georgia	1995	1996	1995	1997, 2001	1998-2000
Hungary	1990	1993	1990	1994	
Kazakhstan	1994	1999	1994	1999	
Kyrgyz Republic		1998	1998		
Latvia	1992	1995	1992	1997	
Lithuania	1992-2000	1995	1992	1995	2000
Moldova	1995	1998	1995	2000	
Poland	1992	1996	1992	1996	1998
Romania	1993	1997	1993	1997	
Russian Federation	1991	1994	1991		1997
Slovak Republic	1991	1997	1991	1997	
Slovenia	1991	1996	1991		
Tajikistan	1996	2000	1996		
Turkmenistan	1997	2000	1997		
Ukraine	1993	1996	1993	1998	
Uzbekistan	1993	1997	1993	1997	

Data source: GSM Association, ITU.

Table 2: Descriptive statistics for major variables in a panel of countries in 2001.

	Mobile phones penetration	Fixed lines penetration	Fixed lines price	GDP per capita	Infrastructure indicator	Faults per fixed line	Waiting list per fixed line
Observations	22	22	22	22	22	22	22
Mean	0.1940	0.2236	5.2176	2649.03	2.7590	0.4070	14.7030
Median	0.0670	0.2275	4.4824	1647.18	2.8500	0.2855	10.1500
Standard Deviation	0.2298	0.1163	4.2099	2640.69	0.8427	0.3251	14.4790
Minimum	0.0002	0.0360	0.1923	420.19	1.0000	0.0311	0.5000
Maximum	0.7600	0.4010	13.7261	11970.66	4.3000	1.2500	50.9246

	Percentage of urban population	Population density per sq km	Mobile phones monopoly	Mobile phones oligopoly	Mobile phones competition	NMT standard	GSM standard
Observations	22	22	22	22	22	22	22
Mean	0.5722	72.4545	0.2727	0.5000	0.2272	0.8181	1.0000
Median	0.5900	72.5000	0	0.5	0	1	1
Standard Deviation	0.1327	42.3058	0.4558	0.5117	0.4289	0.3947	0.0000
Minimum	0.2800	6.0000	0	0	0	0	1
Maximum	0.7500	136.0000	1	1	1	1	1

Data source: WDI, ITU.

Table 3: Correlation coefficients between the major variables, panel of 22 countries between 1990 and 2001.

	Mobile phones penetration rate	Fixed lines penetration rate	GDP per capita	Infrastructure indicator
Mobile phones penetration rate	1			
Fixed lines penetration rate	0.5816	1		
GDP per capita	0.4906	0.6295	1	
Infrastructure indicator	0.5329	0.5836	0.2414	1
Faults per fixed line	-0.2394	-0.4833	-0.2850	-0.3062
Waiting list per fixed line	-0.4140	0.0125	-0.0475	-0.1225
Urbanization	0.1076	0.5631	0.1630	0.3651
Population density	0.1523	0.1683	0.2985	0.1947
Monopoly	0.1065	0.0523	0.1586	-0.0528
GSM standard	-0.1781	-0.0979	-0.1344	-0.0511

Source: WDI, ITU, own calculations.

Table 4: .Estimation results. Logistic function, FE OLS regression. Dependent variable: mobile phones penetration rate[a].

Variable / Sample	1993-2001	1990-2001	1990-1997 10 countries	1990-1997
	No.obs. 177	No.obs. 193	No.obs 64	No.obs. 193
	1	2	3	4
Constant	-10.5771***	-10.326***	-9.68492***	-10.4268***
	(0.000)	(0.000)	(0.000)	(0.000)
GSM	1.5915***	1.2832***	0.3301	1.2446***
	(0.000)	(0.001)	(0.649)	(0.004)
Time	0.6725***	0.7735***	1.3850***	0.7487***
	(0.000)	(0.000)	(0.000)	(0.000)
Fixed *Time	-0.9181**	-0.7092*	-0.8085	
	(0.019)	(0.062)	(0.432)	
Fixed*Time*First				-0.3844
				(0.437)
Fixed *Time*Second				-0.7593*
				(0.058)
Fixed *Time*Third				-0.6769*
				(0.073)
Fixed Price*Time	-0.0019			
	(0.688)			
GDPpc*Time	0.00003***	0.00002**	-0.00002	0.00002**
	(0.006)	(0.043)	(0.225)	(0.040)
Faults*Time	-0.1560**	-0.1428**	-0.0356	-0.1383**
	(0.015)	(0.030)	(0.796)	(0.035)
Wait*Time	0.0023**	0.0023**	0.0007	0.0026***
	(0.034)	(0.016)	(0.679)	(0.007)
Popdens*Time	0.0029***	0.0020***	0.0010	0.0019***
	(0.000)	(0.000)	(0.354)	(0.000)
Urban*Time	0.3322	0.2218	-0.0082	0.2434
	(0.271)	(0.438)	(0.991)	(0.392)
Trans*Time	0.0448*	0.0190	-0.0720**	0.0159
	(0.088)	(0.435)	(0.037)	(0.516)
Duo*Time	0.0926***	0.0697**	0.1076**	0.0753**
	(0.005)	(0.034)	(0.047)	(0.022)
Comp*Time	0.0797*	0.0834**		0.0822*
	(0.053)	(0.050)		(0.053)
GSM*Time	-0.3737***	-0.2760***	-0.0769	-0.2527**
	(0.000)	(0.002)	(0.646)	(0.012)
R-sq	0.7971	0.7856	0.7608	0.7989

a) p values are in parentheses

*) 10% significance level **) 5% significance level ***) 1% significance level

Source: own calculations.

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