Choosing Standards

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Abstract

We study governments' choice of first generation mobile telephony standards using a 85 country data set from 1977 to 1987, and modeling the decision as a dynamic discrete choice programming problem. We find that the institutional environment of a government affects the relative weight it assigns to expected discounted producer and consumer surplus. Those surpluses, in turn, are affected by expected indirect network effects of a given standard. In addition, producer surplus is an increasing function of telecom research. Simulations reveal that…

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1. Introduction

The objective of this paper is to construct and estimate a model of standard choice, the empirical application being the decision of which first generation (1G) mobile phone standard to choose, if any. Of particular interest are the effects of the institutional environment on the decision, and the potentially ensuing welfare effects (losses). It is well acknowledged that in today's economies, standard choices are of paramount importance (For theoretical work, see Farrell and Saloner, 1988, and Farrell, 1996, who also discusses several examples of delay. For surveys that discuss standard choice, see e.g. Katz and Shapiro, 1994, Shapiro and Varian, 1999, and Gandal, 2002,); yet the existing literature on how standards are chosen seems rather thin.[1] To the best of our knowledge, no quantitative empirical research exists on the topic – in contrast to qualitative research (on mobile phone standards, see e.g. Funk and Methe, 2001, Kano, 2000, and Farrell and Shapiro, 1992 on High-Definition TV)).

The decision to look at 1G standard (i.e., technology) choice is based on the following features of that decision:

- It is well-defined, and therefore comparable over time and over countries. The choice set (see section 3 below) is unambiguous.
- During the period that we look at, effectively all countries had a government owned telecom monopoly. It is not always clear whether it is a government body (say, the Ministry for Post and Telecommunications) or the telecom monopoly that makes the decision, but for our purposes this distinction is irrelevant: both can be viewed as arms of the government.
- Unlike the second and third generation mobile phone standards, 1G was widely and rightly perceived to be a national decision. Issues like international

compatibility or roaming were not considered important. This also means that any international network effects that exist are indirect, i.e., choosing a widely spread standard may allow the population access to cheaper phones, and the telecom monopoly access to cheaper network equipment.

- There is large variation in actual decisions taken. The first government to adopt a (n analog) standard was Japan in 1978. Some advanced industrialized countries reached a (different) decision many years later (e.g. France in 1984).[2] Less developed countries introduced standards even later.

There are three major complicating factors in choosing to look at this particular decision. First, mobile telephony is a network good (Katz and Shapiro, 1994). Second, technical progress during our observation period lead to the introduction of new technologies after our observation period, in particular digital 2G. Third, governments were potentially playing a game instead of making decisions in isolation (see Gandal and Shy, 2001, for such a theoretical analysis).

As argued above, the network nature of the final good plays only a limited role in the current analysis. As any user can testify, she does not care what standard the receiver is using. The only network effects that might affect the current analysis are that phones using one standard may not operate in areas where the network is built for another standard; however, 1G phones were used nationally, and therefore this problem does not surface. Indirect network effects from economies of scale in production, and increased competition on the supply side are taken into account in the analysis.

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[1] Indeed, a recent survey on the economics of technology policy (Mowery, 1997) does not mention

Our modeling framework allows for technical progress within analog standards. We deal with these by a) allowing the cost of adoption to vary over time b) allowing the producer and consumer surpluses to be functions of (expected) installed base (to control for economies of scale and learning by doing within a standard). We end our observation period in 1987 to avoid having 1G decisions being affected by the oncoming 2G. The first 2G networks were established in 1991, and the European Union governments coordinated their 2G decision on GSM in the late 80's.

As is clear from above, we model the standard choice as a government decision. Unlike 2G and 3G, 1G decision were (largely) uncoordinated between governments. The main reason for that most likely is that the "mobile" phones of the late 70's and early 80's were very unlike the ones in use today. They were heavy, had limited battery life, lower quality of voice, and were mostly used from some base (such as a car). There was little expectation that they would change in nature to the extent that they have over the last 20 years.[3] One implication of this is that we will not explicitly model a game between governments (see also Timmins, 2002). As stated above, we take the view that an individual government was not affected by the decision of any other particular government, but only by the aggregate past and expected choice(s) of all the other governments, i.e., that the interdependence between governments is more alike monopolistic than oligopolistic competition

Throughout the world, governments actively affect the way markets operate. A larger literature exists (see e.g. Joskow and Rose, 1989, Laffont and Tirole, 1993) that studies how to optimally regulate markets or individual firms. Though more infrequent and the object of less research, governments' effect on markets through institutional choices is probably as pronounced. All these choices reflect the

objectives of a government. As the proliferating ”new” political economy literature stresses (this literature is surveyed and expanded in Drazen, 1999, Grossman and Helpman, 2001, and Persson and Tabellini, 2000), a fruitful way to understand government decisions is to use the standard microeconomic apparatus to governments. This literature takes the view that governments' decisions, too, are affected by the institutional setting in which they operate. In particular, the institutional setting determines by how much, and in what direction, government decisions may deviate from welfare optimizing ones. The objective of this paper is to study how governments chose a 1G standard, and to thereby shed light on what determines the weight that a particular government gives to producer and consumer surplus respectively.

It is well established that the fictitious benevolent social planner makes decisions that maximize expected welfare, consisting of the unweighted sum of producer and consumer surplus. This is the benchmark against which we will judge the actions of real governments. Various political and private interest considerations may lead to a decision that is suboptimal from the welfare point of view decision. The thesis put forward and tested in this paper is that the institutional setting in which a particular government operates will determine to what extent it can, in the pursuit of private benefits of some form, deviate from the social optimum. Anecdotal evidence suggests that (domestic) industry lobbied for one or the other standard particularly in countries where some firms saw themselves as potential producers of 1G related products, and where industry (including the telecom monopolies) had invested in telecom (mobile phone) related reseach.

[3] For example, Kano (2000) cites Financial Times, July 26, 1999, reporting that the ex-CEO of Ericsson, Kurt Hällström, stated: “When I joined Ericsson in 1984, Radio Communications was something odd happening on the outskirts of Stockholm”.

Earlier papers that combine industrial organization questions with a political economy approach and econometric analysis include several that study telecommunications:[4] Kaserman et al. (1993), and Donald and Sappington (1995) analyze US deregulation, Duso (2001) the effects of political regime within US states on the incidence and effectiveness of regulation, Duso and Röller (2001) study deregulation in OECD countries using political economy variables, and Henisz and Zelner (2001) study the effects of political institutions on telecommunications infrastructure investment using data from 147 countries.

In the next section, we discuss the technologies, i.e., the choices that goverments face(d), and characterize the environment in which these decisions were reached. In section three, we formulate the 1G standard decision as a discrete choice dynamic programming problem (Adda and Cooper, 2000, and Timmins, 2002, are examples of using a dynamic programming model for analysis of policy decisions). We estimate structurally the weight that a government facing a particular institutional environment puts on producer (consumer) surplus, while estimating the expected discounted producer and consumer surplus in reduced form. We present our data in some detail in section four. Section five contains the econometric analysis. In section six we report some counterfactual experiments, and section seven concludes.

2. Mobile Telephony

Based on earlier radiotelephony technologies, analog standards for what is now called mobile telephony began to emerge in the 1970's. The standard describes how the handset communicates with the network, and is a crucial ingredient to how the network operates. Handsets designed for a particular standard do not operate within a

[4] Several analyses exist that do not use econometrics: see e.g. Spiller and Cardilli (1997).

network designed for another standard. The first country to adopt such a standard was Japan in 1978. The adopted standard was developed in Japan, and the Japanese state telecoms monopoly (NTT) retained rights over the standard. The Scandinavian countries followed in the early 1980's with a standard of their own (NMT). Altogether, eight different standards were adopted in at least one country. The decision was one clearly made by governments. International organizations such as International Telegraph an Telephone Consultative Committee and International Telecommunications Union do not have decision making powers. For example, (see Funk and Methe, 2001), accounts exist that attribute France's and Germany's late adoption of any standard to politics (and lobbying). They were reluctant to adopt the Scandinavian NMT standard as they wanted a standard they, and their domestic firms, could dominate. Initial efforts to adopt a common standard failed, and France ended adopting its own standard (RC2000) in 1985. Germany adopted its own standard (C-450), too, in 1985. Some countries, most notably the US, did not adopt any particular standard, but instead let the firms choose their own standards.

All in all, eight different analog standards have been adopted by 1998 by at least one country. Other standards may have been considered, but were never adopted. We therefore restrict the choice set to those standards that were in existence by 1987 (concerning analog standards). Of these eight standards, the Scandinavian NMT, AMPS and TACS dominate with adoption shares of 38, 38 and 13 per cent respectively. All other five standards were adopted by at most three countries (by 1998), and in the empirical analysis we therefore group them together with TACS (which is only adopted by one country in the whole world during our observation period).

No quantitative analysis of these decisions exist, and the qualitative analyses all underline the political nature of the process. It is also commonly argued that lobbying for one or the other standard was sometimes pronounced. For example, Funk and Methe (2001) mention that the "initial sponsors" for NMT were the four Scandinavian PTTs; that of RC2000 France Telecom only, and so on. Nobody however mentions lobbying by consumer organizations. Discussions with technical experts suggest that although there are technical differences between standards, these are not drastic from consumers' point of view. Also, it is probably fair to state that at the time when decisions on standards (both analog and digital) were made, consumers were more or less ignorant (indifferent) about the matter. As the short description above already suggests, domestic industry may have inserted a considerable influence on the decision.

3. The Model

A. The dynamic framework

Consider the following standard dynamic stochastic discrete decision problem (DDP) of the optimal stopping type. A decision maker (government) makes in each period t one of mutually exclusive discrete choices in order to maximize discounted expected utility. Once a decision is made, the decision maker stays with that decision forever. Utility is time separable and $u(s_t, a_t)$ represents the one-period utility function, where s_t is a vector of state variables, and a_t is the decision variable. β denotes the discount factor.

Under certain regularity conditions (Stokey et al., 1989, Rust, 1988) it is well known that Blackwell's theorem applies, and we can define the optimal choice as a function of the state variables as:

(1) $\delta(s) = \arg\max_a \left\{ u(s,a) + \beta \int V(s')p(ds' \mid s,a) \right\}$

where *s´* is the vector of next period's state variables, and V(.) is the unique solution to the Bellman equation

(2) $V(s) = \max_a \left\{ u(s,a) + \beta \int V(s')p(ds' \mid s,a) \right\}.$

In this paper, we follow the existing empirical literature on DDP (see Ecsktein and Wolpin, 1989, Rust, 1994, and Miller, 1997, for a surveys, and e.g. Rust 1987, Slade, 1998, and especially Adda and Cooper, 2000, and Timmins, 2002, for applications) and employ assumptions that guarantee that the dynamic problem is well-behaved (see Stokey et al. 1989, Rust, 1988). We next discuss the parameterization of the model.

B. The One-Period Problem

We assume that the one-period utility function *u(s,a)* is a weighted sum of expected producer and consumer surplus, net of adoption costs. The weights are determined by variables that measure the institutional environment in which a particular government operates. We normalize these weights (see later) to obtain consistency. That is (dropping country and period subscripts),

(3) $u(s,a) = \Phi^{PS}(\gamma, x)PS(\delta, z, a) + \Phi^{CS}(\gamma, x))CS(\alpha, y, a) - F(\theta, w, a, \varepsilon)$

where $\Phi^{PS}(.)$ ($\Phi^{CS}(.)$) is the weight that government i in period t gives to expected discounted producer surplus PS(.) (CS(.), the expected discounted consumer surplus), and F(.) is the cost of implementing a particular standard. Implementation costs include costs to build the network, training of personnel, drafting of necessary legislation and regulations etc.. x, z, y, and w are vectors of observed state variables (subsets of s), a is the decision, ε is the unobserved (by econometrician) state variable which is assumed to be distributed i.i.d. extreme value (see e.g. Rust, 1987). We also

assume – in line with Rust (1987), Aguirregabiria (1999), Slade (1998), Hotz and Miller (1993), and others - that the conditional independence assumption holds (see Rust, 1994). Finally, $\{\gamma, \delta, \alpha, \theta\}$ are parameter vectors to be estimated.

Producer surplus is the expected producer surplus from choosing a particular mobile telephony standard. In particular, a government is interested in the expected discounted value of domestic producers' share of global producer surplus. Dividing this into domestic firms' share of domestic and non-domestic producer surplus and (for simplicity) assuming identical firms, homogenous products, constant marginal cost and a welfare (price = marginal cost) maximizing telecom monopoly, the former is given by:

(4) $$PS_d(.) = \sum_{t=1} \sum_k \beta^{t-1} (P_t^* - c_k) q_{kt}^* .$$

In (4), P_t^* is the equilibrium price, q_{kt}^* the equilibrium quantity of each of the identical firms k, and c is the firm specific constant margincal cost, and it is understood that k is period specific. The subscript d refers to domestic. The domestic firms' share of non-domestic producer surplus is given by

(5) $$PS_{nd}(.) = \sum_t \sum_{j \neq i} \sum_k \beta^{t-1} \left[P_{jt}^* q_{jkt}^* - c_k \sum_j q_{jkt}^* \right].$$

In (5) we have assumed that firms can only produce to the standard adopted in their home country, i.e., j indexes those countries that have adopted the same standard as country i in period t, and k is country and period specific. Prices and quantities are country specific.

The government also takes into account expected discounted consumer surplus from adopting a particular standard. For simplicity, let's abstract for the moment from the reality that there are several 1G standards among which the government chooses. Consumers in a country that has adopted a 1G standard face a discrete-continuous

dynamic programming problem: taking the standard as given, they have to decide when to buy a 1G mobile phone, if at all, and after purchase, how much to use it. Assuming that they have a binding (static) budget constraint, their problem is

(6) $$V^c(s) = \max_{q_c, a} \left\{ u_0(s, q_c, a) + \beta \int V(s') p(ds' \mid s, q_c, a) \right\}$$

$$\text{s.t. } a \quad p_c q_c + p_p \quad + p_0 q_0 = W$$

sufficient for our purposes to just measure expected discounted producer and consumer surplus from a given standard choice with sufficient accuracy.

We model (with slight abuse of notation, and dropping country, standard, and time subscripts) the producer surplus as

(8)

$$PS_h(.) = \frac{\beta}{1-\beta} PS(Pop, GDPcap, telmain, indva, telpatD, telpatw, wstock, wpot)\ .$$

That is, we assume that the expected per period (average) producer surplus from standard h is a function of domestic population, GDP per capita and the penetration rate of fixed line telephones. These are included to capture the domestic demand curve. In addition, producer surplus is a function of industry value added, a dummy for telephone-related US patents, a quality-weighted measure of those patents, the world stock of users of standard h, and the number of potential users of standard h. Industry value added is a composite measure of the size and technological level of the country's manufacturing sector. In choosing a particular standard a government creates a market for all levels of goods needed to deliver the product to consumers. The larger the manufacturing sector, and the higher its technological level, the better positioned the country's own firms are to supply these goods. At the same time, high value added could be a sign that the domestic industry has allocated its resources well, and it would be suboptimal to readjust towards 1G related manufacturing. The US patent measures are there to capture the idea that 1G related manufacturing is not possible without some know-how. US patents offer a reasonably homogenous measure of how much know-how a country has in telecoms. The world stock of users of mobile phones of standard h is included to capture first-mover advantages of existing manufacturers. The larger this number, the farther down they are the learning

curve, and the better they are able to benefit from economies of scale etc. Finally, the number of potential users (measured by the population of those countries that have already adopted standard h) is included to capture the size of the non-domestic market in standard h.

Similarly to (8), we model expected discounted consumer surplus as

$$(9)\quad CS_h(.) = \frac{\beta}{1-\beta} CS(Pop, GDPcap, telmain, wstock, wpot)$$

Consumer surplus is determined by the size of the population, GDP/capita, the amount of main (fixed) line telephones in use, and the (expected) size of the world market for mobile phones in standard h. Fixed line telephone penetration measures on the one hand revealed preferences for phone services, and on the other, availability of substitutes to mobile phones. In addition, the two measures of the number of (potential) users already introduced earlier are assumed to affect consumer surplus. The number of current users is assumed to increase consumer surplus through two channels. First, through indirect network effects (economies of scale in production, learning by doing), and secondly, through being a measure of the perceived quality of the standard (the final good that the standard delivers). Similarly, the larger is the potential number of users of a particular standard, the larger are the indirect network effects going to be in the future.

As population, GDP per capita, and fixed line penetration attempt to capture the (domestic) demand curve, we restrict their coefficients to be the same in the producer and consumer surplus function. In contrast, the actual and potential adopter stocks have potentially different effects, and we therefore estimate separate parameters for these variables in the PS(.) and CS(.) functions. This assumption is important also because it allows us to identify the parameters of the weight function. Further, as we only have a limited number of countries adopting a particular standard

(see next section), we restrict all the coefficients to be identical over standards; thus, any differences between standards are derived from the network variables.

Turning then to the weight that a government gives to PS(.) respectively, we model that as

$$(10) \qquad \Phi^{PS}(.) = \gamma_0 POLR_{it} + \sum_{m=1}^{4} \gamma_m L_{mi} ,$$

where POLR is a measure of the political rights of the citizens of country j, and L_{mi} are indicator variables for different legal origins (La Porta et al., 1997).[6] The former is a direct measure (used by e.g. Rodrik, 2000) of how "democratic" a given government is; the latter are measures of the institutional (legal) setting in which a government operates. We model the weight attached to consumer surplus as

$$(11) \qquad \Phi^{CS}(.) = 1 - \gamma_0 POLR_{it} - \sum_{m=2}^{4} \gamma_m L_{mi} ,$$

In other words, we normalize the coefficient of L_1 to unity. What this means is that countries with legal origin one (the French legal system) attach a weight of $1 - \gamma_0 POLR$ to consumer surplus, and $\gamma_1 + \gamma_0 POLR$ to producer surplus. The coefficients of the other legal origin indicator variables then measure deviations from this (assuming similar political rights).

What this means is that the weights do not (necessarily) sum up to one. The great benefit of specification is that it allows a linear weight function. One can normalize these weights to one by dividing them by $1 + \gamma_1$. To recover the true cost of adoption, the cost function should also be divided by this number. The downside of this is that either of the weights can become negative. We will interpret negative weights as weights of zero in simulations.

[6] The legal origin variables have been used extensively in cross country analysis: for a recent application, see Djankov et al. (2001).

The final ingredient is the cost function. We specify simply that the cost of adopting a standard is given by

(12) $F(.) = F(Year) + \varepsilon$.

Here, year measures naturally time (base year 1977); We will assume that F(.) is a quadratic function of time. ε is a country and period specific cost shock.

We assume that none of the parameters is standard-specific. This is to economize on the number of parameters to be estimated. Finally, we assume that the government makes a decision at the end of the period (year in our data), and that the decision takes effect in the following period. This completes the description of the model.

4. The Data

Our data comes from a variety of sources. The key standards and other mobile telephony data come from EMC. The country level economic and demographic variables come entirely from the World Bank's World Development Indicators. The legal origin – variables come from La Porta et al. (1997), and the political rights data from Freedom House (2000). All other variables are standard; the Freedom House variables are on a seven point Likert scale (1 = full rights, 7 = smallest possible rights).

The US patent data is from NBER (Hall et al., 2001). We first computed the number of US patents per country in three patent categories: 178 (Telegraphy), 379 (Telephonic Communications), and 455 (Telecommunications), assuming that all patents are held for their maximum number of years (20). We do not discount patents by their, age, the idea being that the patent stock is a measure of both the amount of accumulated human capital in telecoms, and a measure of intellectual property rights in possession. In addition to the patent count, we calculated averages for two

measures of the quality of the patent, both devised by Trajtenberg et al. (1997): originality, and generality. Both are Herfindahl-type measures that use citations. Originality uses citations made by a patent. Originality is increasing in the number of patent fields to which citations are made. Generality uses citations received by a patent, and is increasing in the number of fields from which a patents receives citations. We use the values reported in the NBER data file, and calculate averages for yearly country-level stocks of patents. We use two measures of human capital/intellectual property rights in the analysis. First, a simple dummy for a country having telecom patents; second, a quality weighted average of the number of patents (wpat). It is defined as the number of telecom patents times average originality times average generality.

We have the needed telecoms data for 207 countries but, as is to be expected, we do not have all the other data for all the countries. Concentrating on the analog standard prior to the introduction of first digital standards in early 1991 and on those countries on which we have the needed data from the above sources leaves us with 85 countries, and a total of 842 country-year observations.

These are naturally very heterogenous with respect to demographics and economic indicators, as the sample descriptive statistics in Table 1 reveal. Notice especially that only slightly more than twenty per cent of our observations are ones where the country in question had US telecom patents in force in a given year. Table 2 reports the descriptive statistics of our measures of political institutions. Political rights is commonly used in the macro/growth literature (e.g. Rodrik, 2000) to capture observed and unobserved differences in the institutional setting in which governments operate. As can be seen, 60% of our observations are from countries with French legal origin, and only 1.2% from countries with German legal origin.

[TABLES 1 AND 2 HERE]

Of the 85 countries, 24 adopt an analog standard by end of our observation period. Table 3 gives the descriptive statistics both for our sample, and the whole world. Only nine countries that adopted an analog standard within our observation period are excluded; the number of countries that did not adopt but are excluded is naturally much higher. Of the 24 adopting countries in the sample, 14 adopted the Nordic NMT standard, 3 the AMPS standard, and 5 each a unique standard (e.g. France RC200, Germany C-450 and so on). In addition, Sweden adopted (simultaneously) both NMT and a standard of its own (Comvik). We will treat this incidence of double standard adoption as adoption of NMT only.[7]

As can be seen from Table 3, the average adoption times are very similar for the three possibilities (NMT, AMPS, other). Note that the number of users of mobile phones of a given standard, and the number of potential users are both calculated using world, not sample, figures.

[TABLES 3 AND 4 HERE]

Table 4 reports the average adoption years conditional on legal origin, with some sample descriptive statistics.[8] Countries with German legal origin are on average fastest to adoption, closely followed by countries with Scandinavian legal origin. All countries with Scandinavian and German legal origin also adopt a standard; the proportion of English (French) legal origin countries adopting are 25.7% (16.7%). There seems to be a clear pattern in that countries with Scandinavian and German legal origin adopt, and adopt early, relative to countries with other legal origins.

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[7] The reasons for this are that i) Comvik never took off: in our sources (ITU, EMC), it is always reported to have zero adopters, ii) this modeling decision restricts the choice set by one choice (that was only ever chosen once).

[8] There are no countries with socialist legal origin in our data set.

5. Econometric Results

We estimate the model using Hotz and Miller's (1993) Conditional Choice Probability (CCP) estimator; specifically, utilizing the simplification that the optimal stopping property allows for (for a discussion, see Hotz and Miller, 1993, Miller, 1997, and Aguirregabiria and Mira, 2002). We follow the standard two-stage approach and first estimate nonparametrically the conditional choice probabilities (using multivariate Gaussian kernels), and then maximize a pseudo-likelihood function in the second stage (for details on estimation of DDPs, see Hotz and Miller, 1993, Aguirregabiria and Mira, 2002, and Rust, 1994). We have already made two of the three standard assumptions (additivity of observed and unobserved state variables; conditional independence of the error term). To fulfill the third assumption (finite domain of observed state variables), we follow e.g. Rust (1987), Aguirregabiria (1999) and Slade (1998) and discretize our continous explanatory variables (we use a grid of seven per variable).

The estimation results are presented in Table 5. Looking first at the terms that capture demand, we find that population, Gdpcap, and the mainline penetration all have a positive effect on domestic demand for mobile phones. These results are otherwise in line with research on mobile phone diffusion (Gruber and Verboven, 2001a, 2001b, Liikanen et al., 2002), but for the positive effect of fixed line telephones. The aforementioned papers found mobile phones and fixed line phones to be (net) substitutes. Our results suggest the contrary.

The parameters determining expected discounted producer surplus are given in section two of the table. We find that industry value added has a nonlinear effect on producer surplus. Having telecom patents increases producer surplus, but the

interaction term with industry value added is negative. Same applies to the quality weighted number of telecom patents. Existing stock of mobile phones of a given standard has a nonlinear effect. At mean of existing mobile stock (over standards and years), the total effect is positive, but already less than one standard deviation above the mean it turns negative. Recall that a negative effect was expected. The linear effect of potential stock of adopters is negative, but the quadratic term positive. The total effect is positive at two thirds of the mean. That is, the larger the potential market, the larger is expected discounted producer surplus.

Turning then to consumer surplus parameters, we find that the expected discounted consumer surplus from standard h is increasing in the actual stock of adopters of standard h up to 1.3 times the mean. Both the linear and quadratic potential adopter terms carry positive and significant coefficients; thus the potential market size (capturing future indirect network effects) has the expected positive effect.

The cost function terms reveal that adoption costs are decreasing in time, but at a decreasing rate. Estimated adoption cost in 1977 (year=1) is 22.481, whereas in 1987 the cost is 4.462, just 20% of the initial adoption cost. This decrease in adoption cost is important as it may explain why immediate adoption is not optimal.

Let's then turn to the parameters of the weight function. Recall that we normalized to unity the weight that French legal origin countries put on consumer surplus. The estimated weight that these countries put on producer surplus is 4.335 (s.e. 0.0004, i.e., significantly different from unity). The coefficient of political rights is 0.668; a high value of the variable indicates fewer political rights, and the positive coefficient thus that countries with fewer political rights give a higher weight to producer surplus. These results together imply that a country with best possible political rights (polr

value one) and French legal origin puts 94% weight on producer surplus. Countries with French legal origin already reach the 100% constraint if their political rights are classified as two on the seven-Likert scale (mean political rights value is 4.01). English legal origin countries put significantly less weight on producer surplus than countries with French legal origin: the coefficient on the English legal origin dummy is –0.305, indicating that with best political rights these countries put 76% weight on producer surplus. German and Scandinavian legal origin countries, in contrast, obtained very large negative coefficients. These were so large that the estimated weights attached to consumer surplus exceed unity for all values of political rights. It seems thus that the differences observed in the conditional adoption decisions (Table 4) carry strongly over to the structural parameters. German and Scandinavian legal origin countries adopt both early and with high (in the sample, 100%) probability, and this drives the estimation results. This is slightly surprising, given that all anecdotal evidence (including Scandinavian countries) suggested a priori that any lobbying that took place was one-sided and would have diverted the decision towards producer surplus maximization. On the other hand, this is in line with recent work (Björkroth, 2002) that shows, using data from 1917-1998, that the Finnish telecom monopoly maximized (short-run) welfare in long-distance (fixed line) calls.

6. Counterfactual experiments

To be completed…

7. Conclusions

The objective of this paper was to study standard decisions empirically: to the best of our knowledge, despite the acknowledged importance of standard decisions in industries with network effects, no previous paper studies actual standard decisions

quantitatively. We chose to study 1G standard decisions as this displays several attractive features: a well defined and internationally comparable decisions, clear decision making authority (governments), little or no (achieved) coordination between decision makers, and large variation in outcomes.

We cast the question in a discrete choice dynamic programming framework, and estimated in reduced form both the expected discounted producer and consumer surplus, and structurally the weight and cost functions. The former function measures how much weight a government (or its arm, like the nationally owned telecom monopolies) put on producer and consumer surplus. We used variables on citizens' political rights, and legal origin of the country to measure the extent to which a government can deviate from first best decisions.

We find that population, GDP per capita, and fixed telephone penetration rate all increase domestic demand; that industry value added and telecom human capital (measured through US patents) increase producer surplus; and that the existing number of users of mobile phones of a particular standard decrease (after a threshold) producer surplus, but increase consumer surplus. The expected size of the market for a given standard has a positive effect on both producer and consumer surplus. Adoption cost is strongly decreasing over time.

We find that the institutional environment has a strong influence on the weights that governments put on producer and consumer surplus. Using a linear approximation, we find that countries with French and English legal origin put a minimum weight of 75% on producer surplus; and that this weight reaches 100% for all countries that have less than highest possible political rights of citizens.

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Table 1
Sample Descriptive Statistics

Variable	Mean (s.d.)
Population (Millions)	26.838 (83.677)
GDP/Capita (1000 USD/year PPP)	3200.765 (3098.433)
Industry Value Added (% of GDP)	30.257 (11.128)
Main Telephone Lines/ 1000	69.661 (116.653)
Telpat. Indicator variable taking value one for a country having US telecom patents, zero otherwise.	0.212 (0.409)
Wpat. Quality weighted number of US telecom patents registered in country i in year t. Defined as # pat x avg. originality x avg. generality x 100000	0.885 (57.500)

NOTES: there are 85 countries and 842 country-year observations in the data. Data from World Bank's World Development Indicators (Population, GDP/Capita, Industry value added, ITU publications (Main telephone lines), and NBER (telpat, wpat).

Table 2
Institutional Environment of Government

Variable	Mean (s.d.).
Political Rights	3.991 (2.122)
English legal origin	0.342 (0.475)
French legal origin	0.601 (0.490)
German legal origin	0.012 (0.107)
Scand. legal origin	0.033 (0.180)

NOTES: Political Rights data from Freedom House (2000); Legal origin data from La Porta et al. (1997).

Table 3
Descriptive Statistics of Standard Adoption and Within Standard Diffusion

Standard	NMT	AMPS	Other
Number of countries adopting by end of 1987 in sample (world)	14 (22)	3 (6)	6 (9)
Average year of adoption in sample (world)	1983.643 (1983.647)	1985.333 (1983.833)	1983 (1983.444)
First/last adoption within sample (world)	1981/1986 (1981/1986)	1984/1986 (1979/1986)	1978/1985 (1978/1985)
Stock of adopters in world (s.d.). Defined as worldwide number of mobile phone connections (millions) using standard h in period t-1 .	4.738 (15.613)	19.369 (63.958)	0.160 (0.396)
# Potential adopters in world (s.d.). Defined as population (millions) in countries that have adopted standard h by t-1.	49.700 (99.159)	110.836 (133.030)	241.984 (438.032)

NOTES: Adoption year is defined as the year with the first recorded mobile phone users in country i-1. The difference between the sample and year average adoption times, and the first adoption year for AMPS are explained by Brunei which is excluded from the sample, and adopted AMPS in 1979.

Table 4
Standard Adoption and Legal Origin
1977-1987 Data

Variable	English	French	German	Scand.
# countries	28	49	2	5
Prop. of obs. (%)	34.2	60.1	1.2	3.3
Avg. year of adoption	1984.6	1984.9	1981	1981.8
# countries adopting NMT Prob. of adoption by 1987	3 .115	5 .104	1 .50	5 1.00
# countries adopting AMPS Prob. of adoption by 1987	2 .071	1 .021	0 .000	0 .000
# countries adopting other standards Prob. of adoption by 1987	2 .071	2 .042	1 .500	0 .000

Table 5
Estimation Results

Demand Function	Coefficient (s.e)
Pop	14.939
	0.003
Pop^2	0.225
	0.006
GDPcap	31.763
	0.007
$GDPcap^2$	0.090
	0.004
Telmain	7.383
	0.005
$Telmain^2$	0.240
	0.004
Producer Surplus	
Indva	1.589
	0.005
$Indva^2$	-0.788
	0.003
Telpat	2.405
	0.004
Telpat*indva	-1.5718
	0.005
Wpat	0.157
	0.005
Wpat*indva	-0.025
	0.003
Stock	2.682
	0.004
$Stock^2$	-1.658
	0.003
Potential	-0.027
	0.002
$Potential^2$	0.014
	0.001
Consumer Surplus	
Stock	4.335
	0.0004
$Stock^2$	-3.316
	0.004
Potential	0.456
	0.005
$Potential^2$	0.331
	0.003

NOTES: Coefficients and standard errors for all other coefficients but those in the Weight function have been multiplied by 1000.

Table 5 c'ed

Estimation Results

Cost of Adoption	
Const.	25091.109
	10.228
Year	-2670.498
	0.777
Year2	60.762
	0.034
Weight Function	
Political Rights	0.685296
	0.000853
French	4.733055
	0.001643
English	-0.304922
	0.000060
German	-11.439500
	0.005348
Scand.	-17.766705
	0.009319
LogL.	-100.8493

NOTES: Coefficients and standard errors for all other coefficients but those in the Weight function have been multiplied by 1000.