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Modelling and forecasting national introduction times for successive generations of mobile telephony

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ABSTRACT

An accurate prediction of the timing of a country's introduction of a new generation of mobile telephony benefits numerous agents including suppliers of network and consumer equipment, regulators, and network planners. We consider the estimation and prediction of the time interval between the international introduction of a generation of mobile telephony and its introduction into a specific country when a decision maker judges the introduction of a newer technology a worthwhile investment. Using literature-based socio-economic and geographical variables, we examine how well variation in international introduction times of four generations of mobile telephony in 172 countries can be explained and forecast. We model and forecast introduction times at two levels of granularity: we use Cox's proportional hazards model for the introduction time; we partition countries into introduction time-based segments and model segment membership using multinomial logistic regression. Our modelling of each generation considers three subsets of explanatory variables: *All variables*, socio-economic *Covariates only*, *Regional dummies only*. Over successive generations, the *Covariates only* models reveal the changing relevance of each socio-economic covariate. Model-based forecasting of the introduction time of the next generation is performed under three hypotheses making different uses of the information available at the time the relevant generation is launched internationally. However, changing socio-economic environments coupled with changing models impair forecasting accuracy, the lower accuracy of modelled introduction times is concentrated in 20% of countries. We speculate about the nature of the unobserved factors affecting these countries' decision processes.

1. Introduction

Cellular telephony is one of the most globally significant innovations of the past 40 years, in 2020, worldwide mobile subscriptions are close to an average of one per capita. The analogue technology used in 1G mobile networks was introduced in 1978 and superseded by the digital technology of 2G in 1991. Subsequently 3G technology, bringing 'smart' phones with mobile internet and multimedia messaging, was introduced in 2000. 4G was introduced in 2009 facilitating more data-intensive use of social media and downloading of pictures and videos. These dates indicate the first international introduction of the technology, however the timings of the introduction of the technology in different countries vary widely. The introduction of a new generation of mobile phone telephony in a country is the culmination of a decision-making process resulting in a major investment in infrastructure and marketing made in the

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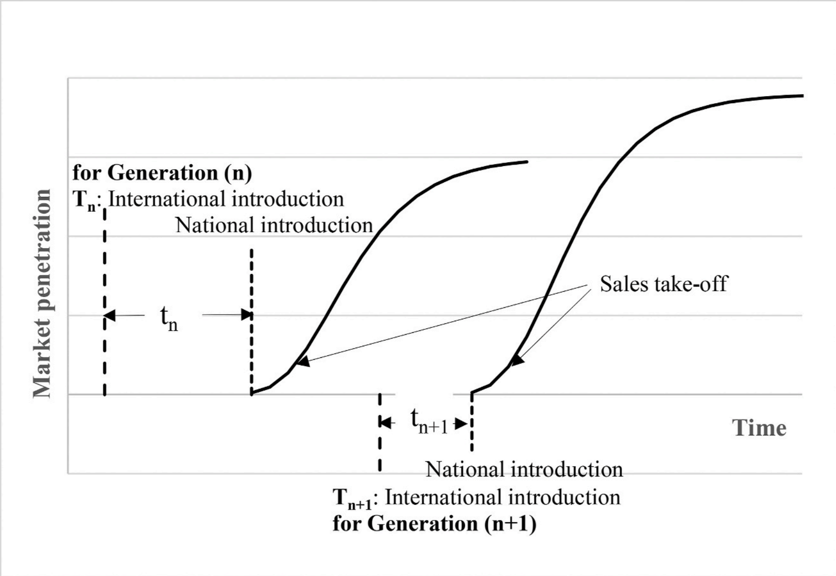

Fig. 1. The timing of the international introduction, the national introduction and subsequent adoption of generation *(n)* of mobile telephony, followed by the same process for generation *(n+1)*.

expectation of a rewarding return. There are numerous agents who would benefit from accurate predictions of introduction times. These include: suppliers of network equipment for production planning; suppliers of mobile phones who need to have inventories of appropriately configured handsets; international network planners who need to provide sufficient bandwidth for communications between different countries; network operators and regulatory authorities. For network operators/providers having good predictions of the timing of the introduction of successive generations of mobile generation in countries that they are targeting is of high importance. They are constantly exploring investment opportunities in countries outside their current portfolio and need to assess the likely return on investment. Similarly, having good predictions of the timing of the introduction of successive generations of mobile generation in a country can help regulatory authorities design and drive the national policy for both the existing operators and new entrants.

Our objective is to develop the means to predict the time interval between the international introduction of a generation of mobile telephony and its introduction into a specific country and to evaluate the accuracy of predictions over time and between countries. Our study uses data describing the introduction of four successive generations of mobile telephony. Using economic, social, political and geographical variables suggested in the innovation literature, we discover how well the variation in international introduction times can be explained and forecast by a country's observable characteristics.

In our analyses of the introduction of four generations of mobile telephones from 1978 to 2016 in 172 countries, we consider modelling and forecasting introduction times at two levels of granularity. At a fine level, we use Cox's proportional hazards model for the time elapsed until introduction occurs. At a coarser level, we divide countries into segments based on introduction time and model segment membership using multinomial logistic regression. Classifying adopters of a technology along a time axis was pioneered by Rogers (1962), who categorized adopters into five groups as innovators, early adopters, early majority, late majority and laggards.

Our analyses reveal that the decision processes determining national introduction times underwent substantial changes between generations, evidenced by the changing significance of covariates. A country by country investigation of the accuracy of model-based estimates of introduction times identified a set of 36 (out of 172) countries whose introduction times were consistently poorly estimated. Examination of particular cases suggests that the estimation errors are likely to be caused by idiosyncratic national factors rather than the omission of one or more covariates. A flowchart explaining the objectives and contributions of this study is given in Figure A1 in the Appendix.

The structure of the paper is as follows. In Section 2, we review the literature on modelling the time to introduction of a technology and on the potential drivers of innovation. In Section 3, we identify the methodologies we will use for model estimation at both fine and coarse levels of granularity. The data describing the introduction of successive generations of mobile telephony and the explanatory covariates used are detailed in Section 4. The estimation procedures for the national introduction times at both fine and coarse levels of granularity are discussed in Section 5. The models resulting from these analyses are used to forecast introduction times for the successive generations of mobile telephony in Section 6. We examine what variation the models capture and what is left unexplained in Section 7. We draw our conclusions in Section 8.

2. Literature review

In the development of a technology within a country, the initial event is the international introduction of a technology, the first time

Table 1
Covariates identified in the literature as influencing innovation diffusion.

Covariate	Source
GDP/capita	Dekimpe et al. (2000); Stremersch and Tellis (2004); Perkins and Neumayer (2005); van Everdingen et al. (2005); Chandrashekaran and Tellis (2008)
Total GDP	Gaston-Breton and Martin Martin (2011)
Openness	Dreher (2006)
Economic Globalisation	Dreher (2006); Leary and Thorton (1989)
Social Globalisation	Dreher (2006); Islam and Meade (2015)
Political Globalisation	Dreher (2006)
Ethnic Fractionalisation	Takada and Jain (1991); Talukdar et al. (2002)
Cultural Fractionalisation	Fearon (2003)
Human Development Index	Dekimpe et al. (2000), Comin and Hobijn (2004)
Urbanisation	Day et al. (1988)
Civil Liberties	Baliamoune-Lutz (2003); Doh and Acs (2010)
Population Density	Boserup (1981); Frederiksen (1981); Klasen and Nestmann (2006)
Population Size	Gaston-Breton and Martin Martin (2011)
Fixed line penetration	Jarvis et al. (2003)
Market Concentration	Hirschman (1964)

the technology is used in any country, also called the year of commercialisation, the year of first adoption or the launch year in different studies. This event is followed by the local introduction of the technology after which, the technology diffuses into the population. Sales take-off, the beginning of the growth period in the technology's life cycle, occurs when the sales growth rate significantly accelerates, see Tellis et al. (2003). Fig. 1 shows an example of the development of two successive generations of mobile telephony moving from international introduction to national introduction and subsequent adoption. Our concern is which factors determine the interval between the first two of these events, the international introduction and the national introduction of generation *(n)*, denoted as t_n.

Our reference to the generations as 1G, 2G etc is consistent with common usage and the usage of the International Telecommunications Union. However, Tadayoni et al. (2018) note that the measurement of the evolution of the technology of mobile telephony in terms of generations does not meet with universal approval as the transition of 3G to 4G, say, does not always coincide with the changes of the underlying technologies. For more details of the technologies underlying 1G, 2G and 3G, see Kim et al. (2010).

The timing of the introduction of a new technology has been studied by several authors. The idea of using the timing of the national introduction of a technology to predict the timing of the introduction of a related technology in the same country was used by Meade and Islam (2003). They used environmental variables in conjunction with a copula, a way of modelling a joint distribution, to link the introduction of mobile telephony to the previous introduction of facsimile transmission. More generally, in a study of 45 technologies (not including mobile telephony), Pae and Lehmann (2003) find that the rate of adoption of a new generation of technology is positively related to the interval between generations, i.e. the longer the interval, the slower the adoption of the incoming technology. They suggest that for longer intergeneration times, the optimal policy is to launch the new technology immediately. For shorter intergeneration times, there is a balance to be found between the benefits of immediate launch of the newer technology and losses due to cannibalisation of adoptions of the older technology. In some cases, the introduction of the later generation brings dramatic benefits, Gupta and Jain (2016) note that the introduction of 2G in India led to a rise in teledensity from 1% in 1985 to 77% in 2011.

As Pae and Lehmann (2003) point out, after the technology is introduced to a country it is some time before that market takes off. Islam and Meade (2018), in a counterfactual approach, used a non-linear hazard model for the time to market take-off following the introduction of four generations of mobile telephony. They found a significant indirect effect of economic region on sales take-off time, via introduction time which acted as a mediating variable. Market concentration was found to delay both introduction and take-off, although the impact is weaker for later generations. A factor behind changes in market concentration is identified by Fuentelsaz et al. (2008), who note the transformation from pre-eminently local markets for 2G to a clearly global industry in 3G with a number of large companies each operating in several countries.

The timing of the international launch of a new generation of mobile telephony is modelled and forecast by Kim et al. (2010). They use regression with the commercialisation date as the dependent variable; the independent variables are four technical variables describing the technology, chosen with the help of an expert panel. These variables are: channel bandwidth in kHz; number of channels; channel bit rate in kbps; and data capacity in kbps. Starting in 1975, they show that the interval between generations is close to 11 years; depending on assumptions about data capacity, their model predicted that 4G would appear between 2012 and 2015. The actual first commercialisation occurred below their lower limit, with 4G networks being available in Norway and Sweden in late 2009. A case study of forecasting the introduction of 5G in Turkey using local technical variables is given by Kalem et al. (2020).

The literature has identified many potential drivers of the innovation process, a discussion of this literature can be found in Islam and Meade (2018). The drivers relevant to mobile telephony for which there is data available for many countries are listed in Table 1. Investment in telecommunications infrastructure is a recognised driver of economic growth, Hofman et al. (2016) attribute the relative lack of growth in the economies of Latin America countries relative to the US economy to a persistent lack of investment in ICT. Yang and Olfman (2006) note that even with investment in telecommunications, countries need to improve their 'fundamental knowledge components', namely the number of scientists and engineers, the level of literacy and the adoption of coherent education policies.

Forge and Vu (2020) identify critical characteristics to be considered by industry policy makers in low and medium income countries: weaker institutions, sparser technological infrastructure, lower skilled work force, rapid population growth and hurried urbanisation, weak service sector and a significant informal economy. Unfortunately, international data quantifying these possible drivers or potential inhibitors of innovation are not widely available.

The behaviour of the decision makers driving the diffusion of a new technology and the take-off of sales, predominantly individual consumers or households, has been widely studied. The diffusion of mobile telephony has been modelled and forecast for many countries, for reviews of these studies see Gupta and Jain (2012, 2020), Meade and Islam (2015) and Kalem et al. (2020). However, the factors influencing the decision makers behind the national introduction of a new generation of mobile telephony, government bodies, regulators, and operators, has received less attention. Thus, the focus of our study is to identify and better understand the factors underlying the decision to introduce a new generation of mobile telephony.

3. Methodology

The national introduction time of each generation of mobile telephony is considered at two levels of granularity. Firstly, at a fine level of granularity, the interval between the international introduction and national introduction of generation *(n)*, t_n, is treated as a continuous survival time using Cox's Proportional Hazard model. Secondly, at a coarser granularity the interval, t_n, is allocated to a segment representing early introducers, later introducers and late or non-introducers. Membership of these segments is modelled using multinomial logistic regression.

3.1. Explaining t_n at a fine level of granularity

We use Cox's proportional hazard (CPH) model to explain the variation in time to the national introduction of generation *(n)* following its international introduction. Not all countries introduced all four generations of mobile telephony, a non-introduction is a censored observation, CPH has the additional benefit that censored observations are explicitly included in the analysis. The model represents the hazard rate, $\lambda(t_n|X_j)$, this is the risk (relative probability of introduction at time t_n) of generation (*n*) being introduced to country *j*

$$\lambda(t_n|\mathbf{X}_j) = \lambda_0(t_n)\ exp\left(\sum_{i=1}^{M}\beta_i X_{ij}\right)$$

where $\mathbf{X}_j$ is a vector of *M* covariates $(X_{1j}, X_{2j}, .., X_{Mj})$ describing country j and β_i is the estimated coefficient describing the effect of covariate *i*. The covariates are a subset of those identified in Section 2, depending on the availability of a full dataset over time and for all countries. In addition to these socio-economic and political covariates, we include binary variables indicating membership of a geographic region. If a covariate has a positive coefficient then an increase in this covariate will increase the risk of introduction. Conversely, a negative coefficient for a covariate means an increase in the covariate will lengthen the time to introduction.

Our modelling has three stages for each generation. We fit the model using the socio-economic and political covariates and the regional dummies, denoted *All Variables*. This model will explain the maximum proportion of variation in introduction times. We use the two subsets of variables separately, *Covariates only* and *Regional dummies only*. The *Covariates only* model allows us to interpret the relative importance of the different covariates. The *Regional dummies only* model indicates the influence of geographical location on introduction times.

3.2. Explaining t_n at a coarser level of granularity

The coarser granularity is achieved by converting the continuous variable, t_n, to a categorical variable. The underlying intuition for this methodology is that it may be easier to identify and model the introduction times for a segment of countries rather than a specific time for each country. There are many approaches to international market segmentation, see Budeva and Mullen (2014, Table 1) for a list of references. An *a priori* approach groups similar countries into segments, where similarity is defined using economic, social, or political covariates. Examples include Hofstede (2001) and Lee (1990). An *a posteriori* analysis considers segments based on realized market behaviour, for example see Sood et al. (2009). Some studies investigate changing segment membership over time, see Cannon and Yaprak (2011).

Taking an *a posteriori* approach to segmentation, we allocate countries to segments according to the length of the interval to national introduction of generation *(n)*, t_n. The countries are allocated to these segments using cluster analysis. There are two main types of cluster analysis, partitioning and hierarchical clustering. We use a partitioning algorithm, K-means cluster analysis, to identify the segments of early introducers, later and late introducers. This form of cluster analysis is far less subjective than hierarchical cluster analysis and thus allows us to ensure that segment membership in successive generations is determined using identical criteria. The interval between the international introduction of generation *(n)* and its introduction in country *j*, $t_{n,j}$, is used as a clustering variable to identify the segments. The criterion for the choice of the number of clusters depends on the proportion of variation explained by cluster membership. Using SS (sum of squares) as the measure of variation, the number of segments, K, is chosen by identifying the 'elbow' point where the rate of increase of the ratio (between cluster SS/total SS) is highest. We label the segments, A, B, C … in order of increasing time to introduction and we denote Segment A of the first generation as 1G(A) etc.

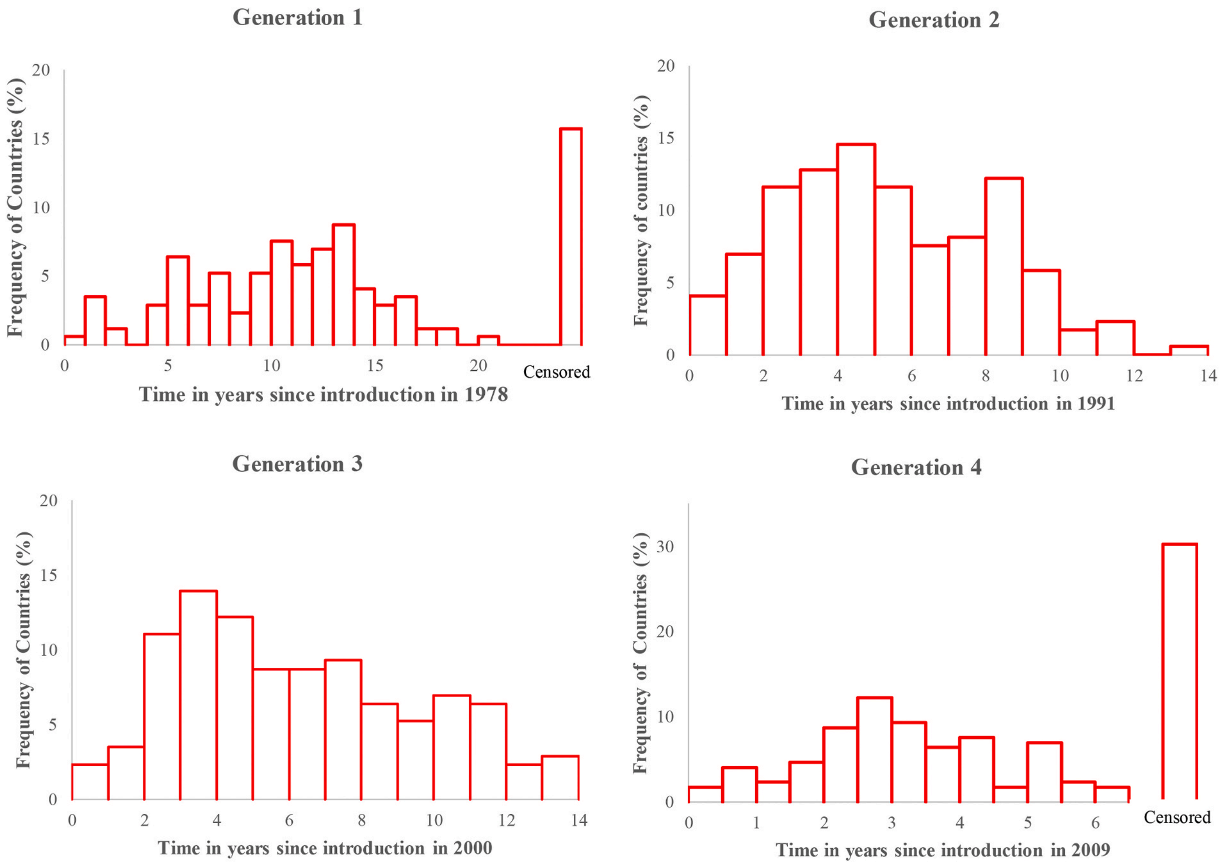

Fig. 2. Histograms of the times to introduction of the four generations of mobile phones in 172 countries.

The next step is to explain the membership of the segments for each generation. We use multinomial logistic regression to explain segment membership using the same sets of covariates as in 3.1. The estimates in the model are of the coefficients in this equation.

$$\Pr(country\ j \in Segment\ A) = \frac{\exp\left(\gamma_{A,0} + \sum_{i=1}^{M} \gamma_{A,i} X_{i,j}\right)}{1 + \sum_{k=A,Cor\ D} \exp\left(\gamma_{k,0} + \sum_{i=1}^{M} \gamma_{k,i} X_{i,j}\right)}$$

where there are M covariates and segment B is the reference segment, i.e. $\Pr(country\ c \in Segment\ B) = 1 - \sum_{k=A,CorD} \Pr(country\ c \in Segment\ k)$. Thus, if $\gamma_{k,i}$ is positive, then an increase in covariate i increases the probability of membership of Segment k.

As in 3.1, for each generation we construct three models: *All variables*, *Covariates only*, *Regional dummies only*.

4. Description of data, the covariates used and their sources

4.1. Description of the times to introduction of the four generations of mobile phones

Introduced in 1978, the analogue technology of 1G mobile networks was superseded by the digital technology of 2G in 1991. The 'smart' phone with mobile internet and multimedia messaging of 3G technology was introduced in 2000, followed by the more data-intensive capabilities of 4G in 2009. (Using the notation from Fig. 1, $T_1 = 1978$, $T_2 = 1991$, $T_3 = 2000$, $T_4 = 2009$). Our main data sources are the International Telecommunications Union (2011) and Groupe Speciale Mobile Association (2016). Our analysis uses the time interval between the international introduction and the time that each of the four generations of mobile telephony was introduced to each of 172 countries. These countries are listed in Table A1 of the Appendix, grouped by geographic region. Histograms of the introduction times for each generation are shown in . The median time to introduction drops from 10.8 years for the analogue 1G (27% of countries never introduce this generation, these are considered censored observations of the time to introduction), to 5.0 years for 2G, to 5.9 years for 3G and then drops to 4.0 years for 4G (assuming all 172 countries eventually adopt 4G, those countries yet to adopt

Table 2
Cox's proportional hazard model of the time to introduction of each generation (Covariate details relate to the *Covariates only* model), p values less than 10% are shaded.

Covariate/Regional Dummy	1G		2G		3G		4G	
	coeff.	*p val.*	coeff.	*p val.*	coeff.	*p val.*	coeff.	*p val.*
GDP/capita	0.040	*0.005*	0.059	*0.001*	0.041	*0.002*	0.015	*0.098*
ln (total GDP)	0.080	*0.770*	−0.530	*0.050*	−0.586	*0.012*	−0.380	*0.234*
Openness	−0.064	*0.819*	−0.222	*0.327*	−0.006	*0.978*	0.186	*0.418*
Economic Globalisation	3.925	*0.000*	0.648	*0.427*	2.357	*0.013*	0.154	*0.879*
Political Globalisation	1.137	*0.092*	0.270	*0.709*	−1.795	*0.006*	−1.637	*0.076*
Social Globalisation	−1.547	*0.090*	1.032	*0.275*	1.899	*0.089*	1.307	*0.265*
Ethnic Fractionalisation	−1.419	*0.056*	−0.614	*0.321*	−0.273	*0.641*	−0.247	*0.749*
Cultural Fractionalisation	0.754	*0.357*	0.435	*0.536*	0.135	*0.847*	1.820	*0.036*
Human Development Index	1.648	*0.375*	4.129	*0.009*	3.981	*0.017*	7.784	*0.002*
Urbanisation	0.021	*0.007*	0.003	*0.614*	0.003	*0.665*	−0.003	*0.667*
Civil Liberties	−0.821	*0.069*	0.866	*0.062*	−1.509	*0.004*	−0.798	*0.161*
HHI							−0.026	*0.753*
ln (Population Density)	0.063	*0.359*	0.127	*0.038*	0.001	*0.988*	−0.093	*0.232*
ln (Population Size)	0.195	*0.474*	0.690	*0.015*	1.118	*0.000*	0.679	*0.043*
ln (Fixed line penetration)	−0.284	*0.087*						
Mobile penetration by previous generation			0.189	*0.092*	−0.008	*0.227*	−0.001	*0.750*
Concordance *R squared*								
All Variables	0.839	*0.673*	0.811	*0.698*	0.799	*0.647*	0.793	*0.534*
Covariates Only	0.825	*0.587*	0.751	*0.507*	0.780	*0.560*	0.767	*0.438*
Regional Dummies only	0.753	*0.440*	0.757	*0.546*	0.727	*0.462*	0.734	*0.390*

are also considered as censored observations).

Using data from International Telecommunication Union (ITU) and GSMA Intelligence, we see that the number of the decision makers involved in the decision to introduce a new generation of mobile telephony increases with later generations. For 1G, 77% of countries had a single operator, typically the incumbent national telephone operator, i.e. the modal number of operators was 1 per country. With the introduction of 2G, the modal number of operators increased to 2 per country. For 3G and 4G, nearly all countries had more than one operator, about 30% of countries had 3 operators and a further 30% had 4 operators. For 3G and 4G we have data about the nationality of the operators in each country. For 15% of countries, the 3G operators were all domestic, of the 85% of countries with at least one foreign operator, 23% were all foreign operators. For 4G, the corresponding proportions are 23% wholly domestic and 22% wholly foreign operators.

4.2. Covariates used to explain the time to introduction of a technology and their sources

The constraints on our choice of covariates identified in Section 3 as drivers of innovation are their availability over time, from 1978, and over the 172 countries in our dataset. Following the discussion in our literature review, the drivers used are chosen to represent different components found in the literature: globalization, market size, human development, cultural heterogeneity, competition and demography.

We list the covariates used in our study in Table 1, one or more references for each covariate is given. To measure realized market development (see Jarvis et al., 2003) we use fixed line penetration at the time of international introduction of 1G, analogously for subsequent generations we use the penetration of mobile telephony, (for those countries which did not introduce 1G, this is taken as zero). With 15 covariates describing national characteristics, there is bound to be multicollinearity present which may affect interpretation of estimated coefficients. In some analyses, factor analysis may be helpful, see Tellis et al. (2003) and Chandrashekaran and Tellis (2008). However, in our analyses we use the actual covariates. Using factor scores would require a factor analysis for each generation and thus the resulting factors and factor scores would not be comparable between generations.

In addition to these covariates, we use zero-one dummy variables to indicate a country's geographic region. This is in line with Myers's (1996) suggestion of geographical segmentation for business to business marketing.

5. Time to introduction - model estimation

Here we determine how much of the heterogeneity in the times to introduction of the successive generations of mobile telephony can be explained by economic, social, and political covariates and by the country's location. As indicated in Section 3, Methodology, the analysis considers two levels of granularity.

5.1. Fine granularity: estimation using Cox's proportional hazard model

In Table 2, we show the estimated coefficients of the *Covariates only* model and the goodness of fit of all three models is summarised by the coefficients of concordance and R squared. The explanatory power of the *All Variables* model, measured by concordance, decreases slightly as the generations progress, from 0.84 for 1G to 0.79 for 4G. We see that the coefficients of concordance of the

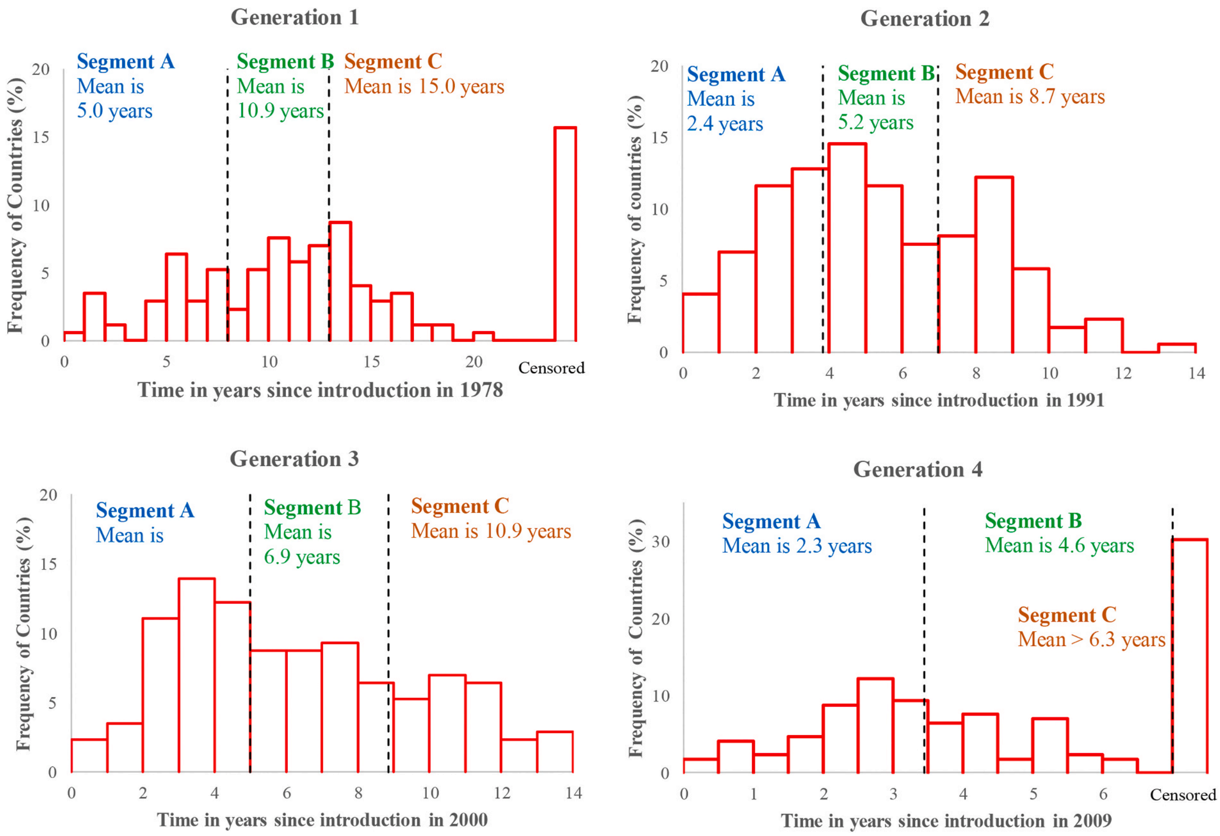

Fig. 3. Histograms of the times to introduction of the four generations of mobile phones showing the division into segments and the mean introduction time within each segment.

Covariates only model and the *Regional dummies only* model are similar, the largest difference (0.07) is for 1G. 2G is the only generation where the *Regional dummies only* model has a higher concordance than the *Covariates only* model. These comparisons show that the explanatory powers of the two sets of variables, the socio-economic and political covariates and the regional dummies, are very similar. The average extra explanatory power gained by using both sets of variables in the *All Variables* model is an increase of 0.03 (3.7%) over the *Covariates only* and 0.07 (6.7%) over the *Regional dummies only*.

We consider the estimated coefficients of the *Covariates only* model to assess the relative importance of these variables as drivers of the local introduction of each generation of mobile telephony. The following covariates have a positive effect in hastening the introduction of successive generations: development measured by GDP/capita; economic globalisation; human development index; population size. For Civil Liberties, a low score is good, a high score is bad, thus we see that the lack of civil liberties significantly impedes the introduction of three generations. Similarly, ethnic fractionalisation tends to lengthen the time to introduction, although this is mitigated by cultural fractionalisation appearing to have a positive effect. A higher penetration of fixed line telephones has a significant effect in extending the time to introduction of 1G mobiles. In contrast, the penetration of 1G tends to advance the introduction of 2G. Due to collinearity with other covariates, some covariates appear with non-intuitive signs in some or all generations, such as total GDP.

5.2. *Coarse granularity: estimation using multinomial logistic regression*

Firstly, we discuss the allocation of each of the 172 countries to a segment for each generation, where the countries belonging to each segment are relatively homogeneous. Secondly, once the segments have been identified, multinomial regression is used to model segment membership in a similar manner to that used in Section 4.1.

5.2.1. *Identifying the segments*

The introduction time of the first generation of (analogue) mobile phones varies widely as shown by the histogram in Fig. 2. Of the 172 countries considered, 47 never introduced the first generation of mobile telephony, for the 125 countries which introduced the analogue generation, the median time of introduction is 10.8 years and the upper quartile is 13.3 years. These countries where the first generation was introduced are allocated to K = 2, 3, 4. 5 clusters and the ratio (between SS/total SS) takes the following values respectively: 70.0%, 84.5%, 90.2%, 94.7%, thus the elbow point occurs at K = 3 clusters. We consider these clusters as Segments 1G

Table 3
Transition tables showing the movements between segment membership in 2G from 1G; to 3G from 2G; to 4G segment membership from 3G.

		Generation 2 Segments			
		2G(A)	2G(B)	2G(C)	Total
Generation 1 Segments	1G(A)	31	8	0	39
	1G(B)	18	17	13	48
	1G(C)	2	10	26	38
	1G(D)	9	24	14	47
	Total	60	59	53	172

		Generation 3 Segments			
		3G(A)	3G(B)	3G(C)	Total
Generation 2 Segments	2G(A)	41	13	6	60
	2G(B)	22	25	12	59
	2G(C)	11	17	25	53
	Total	74	55	43	172

		Generation 4 Segments			
		4G(A)	4G(B)	4G(C)	Total
Generation 3 Segments	3G(A)	51	16	7	74
	3G(B)	18	18	19	55
	3G(C)	4	13	26	43
	Total	73	47	52	172

(A), 1G(B) and 1G(C), the divisions between the segments are shown in Fig. 3. 1G(A) contains the first wave of countries where the 1G is introduced. After 8 years, the second wave of countries, 1G(B), sees the technology introduced. The third wave of introductions, 1G (C), begins 13 years after the introduction of the analogue generation in 1991, coinciding with the introduction of the first digital generation, 2G. The 47 countries which did not introduce the first generation are considered separately as 1G(D).

All the 172 countries introduce the second (digital) generation, 2G, with a median introduction time of 5 years, a choice of 3 segments is found appropriate, the mean introduction times for the segments are given in Fig. 3. The transitions from 1G segments to 2G segments is shown in Table 3, where we see a noticeable interchange between segments. For example, segment 2G(A) acquires 37% (18 out of 48) of 1G(B), 5% (2 out of 28) of 1G(C) and 19% (9 out of 47) of 1G(D).

The generations following 2G, 3G and 4G, are enhancements of the digital technology and thus the incremental advantages of the newer technology are less dramatic than in the introductions of 1G and 2G. All the 172 countries which introduced 2G also introduced 3G with a median introduction time of 5.9 years. The mean introduction times for the three 3G segments are shown in Fig. 3. Note that 3G(C) starts after 9 years, which coincides with the international introduction of 4G. The transitions from 2G segments to 3G segments are shown in Table 3. Again, we see noticeable interchange between segments, 47% of countries move to different segments.

When our data were collected in 2016, 120 of the 172 countries had introduced 4G. In this case we decided that we would continue to use three segments, thus we use cluster analysis to partition the 120 countries into segments 4G(A) and 4G(B), while 4G(C) contains the 52 countries yet to introduce 4G. Note that this segmentation of censored data differs from 1G, where segment 1G(D) contains countries known never to have adopted 1G. The transitions from 3G to 4G are also shown in Table 3. The interchange between segments continues, the summary statistics are very similar to the 2G to 3G transition: 45% of countries move to different segments; 69% of 3G(A) remain in 4G(A).

5.2.2. *Using multinomial logistic regression to model segment membership*

As in Section 4.1, we consider three sets of covariates for the multinomial logistic regression model, *All Variables*, *Covariates only* and *Regional dummies only*. The socio-economic covariates openness, political and social globalisation were found to be non-significant at an early stage in this part of the analysis and were dropped to reduce the effects of collinearity. For all generations, segment B is used as the reference segment, members of this segment were neither very early or very late to introduce, this allows us to highlight the contrasts between those countries early to introduce in Segment A with those later to introduce in Segment C, or for 1G not to introduce in Segment D. We discuss the *Covariates only* model of segment membership for 1G in detail and then summarise the modelling for 2G, 3G and 4G. For 1G, the estimated coefficients and their p values are given in Table 4. For variables favouring early introduction of 1G, we see that countries with high economic globalisation, high urbanisation and good civil liberties are likely to be allocated to Segment 1G(A). For variables deterring early introduction of 1G, we see that countries with low population densities are significantly more

Table 4
Estimated coefficients of a multinomial logistic regression using the *Covariates only* model to predict segment membership for 1G.

Covariates only model	Segment A		Segment C		Segment D	
	Coeff.	*p val.*	Coeff.	*p val.*	Coeff.	p val.
Intercept	−4.170	*0.320*	7.877	*0.014*	7.887	0.013
GDP/capita	0.051	*0.205*	−0.279	*0.161*	0.010	0.859
Total GDP	−0.736	*0.454*	−0.613	*0.516*	−1.296	0.077
Economic Globalisation	3.019	*0.210*	−7.724	*0.007*	−10.412	0.000
Ethnic Fractionalisation	−8.851	*0.007*	−0.051	*0.978*	1.886	0.303
Cultural Fractionalisation	10.184	*0.004*	2.123	*0.314*	0.821	0.688
Human Development Index	6.571	*0.351*	−2.825	*0.540*	−0.053	0.991
Urbanisation	0.053	*0.073*	−0.024	*0.354*	−0.051	0.040
Civil Liberties	−4.742	*0.005*	0.800	*0.528*	1.065	0.375
ln (Population Density)	−0.369	*0.102*	−0.397	*0.086*	−0.486	0.027
ln (Population Size)	1.289	*0.185*	0.194	*0.835*	0.708	0.324
ln (Fixed line penetration)	−0.676	*0.326*	1.226	*0.012*	1.302	0.008

Table 5
The minimum *p-values* of covariates from the *Covariates only* multinomial logistic model to explain segment allocation for four generations; followed by a summary of the accuracy of the *All variables* model, the *Covariates only* model and the *Regional dummies only* model. (p values less than 10% are shaded.)

Covariates only model	1G	2G	3G	4G
GDP/capita	0.161	0.073	0.186	0.509
Total GDP	0.077	0.014	0.017	0.436
Economic Globalisation	0.000	0.710	0.003	0.060
Ethnic Fractionalisation	0.007	0.512	0.007	0.341
Cultural Fractionalisation	0.004	0.659	0.025	0.018
Human Development Index	0.351	0.030	0.000	0.037
Urbanisation	0.040	0.134	0.185	0.238
Civil Liberties	0.005	0.775	0.711	0.372
HHI	na	na	na	0.015
ln (Population Density)	0.027	0.225	0.465	0.406
ln (Population Size)	0.185	0.007	0.013	0.259
ln (Fixed line penetration)	0.008	na	na	na
Mobile penetration by previous generation	na	0.316	0.595	0.544
AIC				
All variables	335.7	289.2	313.2	339.2
Covariates only	376.6	314.0	283.0	307.6
Regional dummies only	397.9	322.6	321.7	347.5
Overall Accuracy				
All variables	73.3	75.0	75.6	69.2
Covariates only	59.9	61.0	68.6	65.1
Regional dummies only	57.6	61.0	66.3	61.0
Segment Accuracy (*All variables*)				
A	92.3	80.0	86.5	83.6
B	72.9	64.4	56.4	44.7
C	55.3	81.1	81.4	71.2
D	72.3			

likely to not adopt 1G. Countries with high ethnic fractionalisation are likely not to introduce 1G and be allocated to Segment 1G(D), although as in Section 4.1, cultural fractionalisation counterbalances this effect. A high level of fixed line penetration is significant for Segments 1G(C) and 1G(D), implying that countries relatively well supplied with landlines are likely to be late introducers or non-introducers of 1G.

The results from estimating the three models for the four generations is shown in Table 5, Panel 1. The results of the *Covariates only* models are summarised by identifying the minimum p value of each covariate for each generation. GDP covariates and population covariates cease to be significant in 4G. The human development index is significant for 2G onwards. Urbanisation and civil liberties are only significant for 1G. Data on market concentration, measured by HHI, indicate that countries with larger numbers of 3G suppliers are more likely to be in the first wave of 4G introductions. The covariates describing economic globalisation and fractionalisation of society are significant for all generations apart from 2G. No single covariate is a significant (at 10%, shown by a shaded cell in the table) driver of segmentation across the four generations. If we take the significance of these covariates as evidence of their importance to decision makers choosing when to introduce the next generation of mobile telephony, it is clear that the weightings placed on covariates changes between generations. In Panel 2, we give summary statistics of AIC as a summary measure of model fit for all three models for each generation. For 1G and 2G the *All variables* model has the lowest AIC, for 3G and 4G the *Covariates only* model has the lowest AIC. This change indicates that geographical location, represented by the regional dummies, becomes less important as

Table 6
Spearman's Rank Correlation coefficient as a measure of forecast accuracy using uncensored observations only (count shown in brackets). It is also shown as a measure of goodness of fit (bold). Forecasts under H_1, H_2 and H_3 are given. CPH(*A*G,*B*G) means hazard rates computed using generation *A*'s model with generation *B*'s covariates.

	Estimate/Predict the introduction of:			
Using:	1G	2G	3G	4G
H_1: CPH(1G.1G)	**0.80**	0.53		
	125	*172*		
H_2: CPH(1G.2G)		0.52		
		172		
H_3: Actual 1G		0.73		
		125		
H_1: CPH(2G,2G)		**0.79**	0.53	
		172	*172*	
H_2: CPH(2G,3G)			0.55	
			172	
H_3: Actual 2G			0.38	
			172	
H_1: CPH(3G,3G)			**0.78**	0.49
			172	*120*
H_2: CPH(3G,4G)				0.47
				120
H_3: Actual 3G				0.41
				120

the digital generations progress.

Using the estimated coefficients of the multinomial logistic model, the probability that a country belongs to each segment can be calculated. We use the segment with the highest probability to predict segment membership. The overall accuracy, measured by the percentage of countries allocated to the correct segment, is shown in Panel 3 for the three models for each generation. For each generation, the *All variables* model is the most accurate, followed by the *Covariates only* model. The details of the accuracy of the *All variables* model by segment are given in Panel 4. The membership of the early introducing segment A is relatively accurately predicted with 80% or more, similarly for the later introducing segments, for 2G onwards, with an accuracy of 70% or more. The membership of the middle segment, B, (B and C in 1G), is the most difficult to predict, with an accuracy around 50%.

Overall, the greater success of the *All variables* model's prediction accuracy of segment membership implies that both the covariates and the regional dummies together capture more information than is suggested by a minimum AIC model.

6. Time to introduction - forecasting

Here we consider forecasting the time to national introduction of the next generation of mobile telephony. We use the *All variables* models derived from the analyses at both levels of granularity to forecast the national introduction times for 2G, 3G and 4G. The estimation of the CPH and multinomial logistic regression models in Section 5 is a retrospective procedure fitting known data. For forecasting, at the time of the international introduction of generation *(n+1)*, T_{n+1} (as shown in Fig. 1), we have access to the models of the introduction times of generation *(n)*, the actual introduction times for generation *(n)* and the values of the covariates used in the models known at time T_{n+1}. To use this data for forecasting, we consider three possible hypotheses:

H_1: the system governing national introduction times is stable and the estimated (hazard rate or segment membership) for the previous generation will predict that for the next generation.

H_2: the system is stable to the extent that the models for the previous generation remain valid, but the values of the covariates should be contemporary.

H_3: the actual introduction of the previous generation best encapsulates the available information and should be used as a forecast.

6.1. Fine granularity: forecasting using the CPH models

Here we use Spearman's rank correlation coefficient as a measure of both goodness of fit and forecasting accuracy. As the time scales of the different generations of mobile telephony tend to decrease, this is a convenient metric for comparison between introduction times in successive generations and the estimated hazard rates from the CPH model. The rank correlation coefficients for forecasts using the three hypotheses with the CPH model are shown in Table 6.

There is a contrast between the goodness of fit of the models (values around 0.80) with their forecasting accuracy (values around 0.50). There is little appreciable difference between the model-based forecasts under H_1 or H_2, using more up to date covariate values does not increase forecasting accuracy. For H_3, we see that using the ranking of the introduction time in the previous generation to predict the ranking in the next generation is no more rewarding. Although for H_3, the Spearman's coefficient is relatively high, 0.73, between 1G and 2G, it falls to around 0.40 for 2G to 3G and for 3G to 4G. H_1 is most accurate overall (using average ranking), but forecasting accuracy is poor for all hypotheses. To illustrate using H_1 (CPH(2G, 2G)) to predict 3G, comparing the predicted and actual

Table 7
The measure of forecast accuracy is per cent of countries correctly allocated. It is also used as a measure of goodness of fit (bold). Forecasts under H_1, H_2 and H_3 are given, the number of countries considered in each case is given in italics. ML (*A*G,*B*G) means segment membership is computed using generation *A*'s model with generation *B*'s covariates.

Using	Estimate/Predict the introduction of:			
	1G	2G	3G	4G
H_1: ML (1G,1G)	**73.3**	56.9		
	172	*123*		
H_2: ML (1G,2G)		54.4		
		136		
H_3: Actual 1G		59.2		
		125		
H_1: ML (2G,2G)		**75.0**	51.2	
		172	*172*	
H_2: ML (2G,3G)			41.3	
			172	
H_3: Actual 2G			52.9	
			172	
H_1: ML (3G,3G)			**75.6**	57.6
			172	*172*
H_2: ML (3G,4G)				54.1
				172
H_3: Actual 3G				55.2
				172

rankings, the correlation coefficient is 0.53 and the median absolute difference between rankings is 28.5. Within this example, we can compare two neighbouring Caribbean countries, Haiti is forecast reasonably well with a predicted rank of 168 and an actual 3G rank is 151, in contrast the Dominican Republic has a predicted rank of 142 and actual 3G rank of 15.

It should be noted that the analysis uses more information than would be available at the international introduction of the next generation. The later introductions of the previous generation occur after the international introduction of the next generation. Thus, although the forecasting performance discussed is poor it may be worse if done in real time.

6.2. *Coarse granularity: forecasting segment membership using multinomial logistic models*

Here we generate forecasts of segment membership using the three hypotheses. The proportion of countries whose segment membership is correctly predicted is the measure of forecasting accuracy. The results are given in Table 7.

As in Section 6.1, there is a contrast between the goodness of fit of the multinomial logistic model (at around 75% of countries correctly allocated) with model-based forecasting accuracy, H_1 and H_2, (at between 40 and 60%). Despite the relatively high level of changes in segment membership identified in Section 4.2.1, using the actual membership from the previous generation, H_3, as a predictor of segment membership produces slightly better forecasting accuracy for 2G and 3G. Using average ranking to compare the hypotheses, H_3 is more accurate than H_1 and H_2 is the least accurate. However, forecasting accuracy overall is poor. As in Section 6.1, the evidence in support of any of the hypotheses is weak.

7. Examination of what the models capture and what they miss

From the previous two sections, there are two broad conclusions concerning model fit and forecasting accuracy. Firstly, the socio-economic covariates and regional dummies explain roughly 60%–70% of the variation in introduction times. Secondly, using any of the three forecasting hypotheses results in poor forecasting accuracy. The poor forecasting accuracy suggests that the system underlying the determination of introduction times is changing over time. Part of this dynamic is explained by the changing coefficient values and significance of the explanatory socio-economic covariates between successive generations, see tbl2Tables 2 and 5tbl5.

Here we examine how well each country's segment membership has been estimated by the multinomial logistic models over the three digital generations. This examination is equivalent to an analysis of the goodness of fit of the *All variables* model in Section 5.2. We restrict the analysis to 2G, 3G and 4G as all countries are involved in at least the first two of these generations and all three generations have been divided into three segments. Our notation summarising the accuracy of the predictions of a country's segment membership is (2G Actual| 2G Prediction, 3G Actual| 3G Prediction, 4G Actual| 4G Prediction), the countries are listed with their prediction summary in the Appendix, Table A1. We define a segment prediction error as: zero if the segment of a country is correctly predicted, as 1 if an adjacent segment is predicted, as 2 if a non-adjacent segment is predicted.

These errors over three generations are accumulated and shown in Table 8 grouped into geographical sub-regions. The segment membership of 68 countries is correctly predicted for each generation, the segment membership of a further 68 is predicted with only a single error. Since the segmentation derived from the cluster analysis places a precise border between the segments, whereas in reality the distinction between segments is likely to be fuzzy, thus there may be some mis-allocation of countries whose introduction times are near a segment border. Thus, we consider the segment membership of these 136 countries as being well predicted by the *All variables*

Table 8
Summary of segment membership prediction errors by geographic region.

	Errors	0	1	2	3	4	5	Total	% errors >1
Africa	Central	3	2			2		7	28.6
	East	3	10	1	1			15	13.3
	North	1	4	1				6	16.7
	South	2	3					5	0.0
	West	4	8	2	1			15	20.0
America	Carib.	3	2	2			1	8	37.5
	Central	3	2	2	1			8	37.5
	North	1	1					2	0.0
	South	1	5	4	2			12	50.0
Asia	Central	4	1					5	0.0
	East	4	2					6	0.0
	South	4	3	2				9	22.2
	South East	3	6	1				10	10.0
	West	5	4	5	2	1		17	47.1
Europe	East	4	2	2	1			9	33.3
	North	7	3					10	0.0
	South	5	6	1				12	8.3
	West	7	1					8	0.0
Oceania	Aus. & NZ	1	1					2	0.0
	Other	3	2	1				6	16.7
Total		68	68	24	8	3	1	172	20.9

model. For these countries, it is argued that the decision to allocate each of these countries to its particular segment in each generation is based on a consistent set of information, the values of the covariates considered.

For the remaining 36 countries with accumulated errors of 2 or more, the implication is that extra information, outside of this consistent information set, is being used to allocate these countries to segments. The larger concentrations of these 36 countries are in South and Central America, the Caribbean, West Asia, East Europe and Central Africa. As would be expected, investigations show that there is no information in the covariates that discriminate between the 136 "predictable" countries and the 36 "difficult to predict" countries. A partial explanation may lie in the stability of a country's segment membership: of the 60 countries which belonged to the same segment for three generations, 90% were "predictable" countries; of the 95 countries that belonged to two different segments, 75% were predictable; of the 17 countries that belonged to three different segments 65% were "predictable". Some explanations for incorrect segment membership predictions lie at a local level. For example, considering the two countries that share the island of Hispaniola in the Caribbean, the predictions for Haiti are accurate (C|C, C|C, C|C), the predictions for the Dominican Republic (B|C, A|C, A|C) are the worst in the whole analysis. Since segment C was predicted in each digital generation for both countries, the description of these countries in terms of the covariates used is similar, the difference in the decisions to introduce each generation must be due to differences in political or business environments not captured by the covariates or the implementation of different policies. As mentioned in Section 2, international data quantifying the range of factors characterising the disadvantages suffered by medium and low income countries identified by Yang and Olfman (2006) and Forge and Vu (2020) are not widely available.

8. Conclusions

The decision to introduce the next generation of mobile telephony into a country is the conclusion of a process leading to serious investments in infrastructure and marketing. Looking at the introduction time of four generations in 172 countries, we examine how well the literature-based socio-economic covariates explain the heterogeneity in these introduction times. We consider the explanatory covariates in three subsets, an *All variables* model, a socio-economic *Covariates only* model and a *Regional dummies only* model. The analysis is performed at two levels of granularity. Firstly, at a fine level of granularity, we use a proportional hazards model with the actual introduction times, this allows us to estimate the order in which countries introduce the technology, The goodness of fit for these models decreases for 3G and 4G. Secondly, at a coarser level of granularity, we partition countries into segments based on introduction time, multinomial logistic regression is then used to explain segment membership. The accuracy of the logistic regression is lowest for 4G. The *Covariates only* models reveal a changing pattern in the relevance of socio-economic covariates between successive generations. For both sets of analysis, we consider three hypotheses for predicting the introduction time of the next generation of mobile telephony using the information available at the time of the international launch of the new generation of mobile telephony. These use: the estimated model of generation (*n*) with the set of covariates from generation *(n)*; the estimated model of generation (*n*) with the values of covariates observed at the international introduction of generation *(n+1)*; the actual results from generation (*n)* to predict the introduction times for generation (*n+1)*. Considering the first hypothesis: at a fine level of granularity, measured by Spearman's rank correlation, the forecast accuracy is around 0.5 for 2G, 3G and 4G; at a coarser level of granularity, measured by percent of countries correctly allocated, the forecast accuracy ranges from 51 to 58%.

Over the four decades of data, the values of the socio-economic covariates change for each country, further the *Covariates only* model reveals the changing significance of the covariates. Taken together, the changing socio-economic dynamics alongside the changing models make estimating the introduction times of the next generation of mobile telephony challenging and forecasting the introduction times for the next generation problematic. Our analysis of errors in estimated segment membership revealed that, insample, 40% of countries were allocated correctly to their segment, another 40% were allocated with only one error (allocated to an adjacent segment) over three generations. The decision process to introduce the new generations of mobile telephony to the remaining 20% of countries were poorly explained by the information used by the models. It is unlikely that one or more missing variables are responsible for the lack of explanation, more likely that individual idiosyncrasies are affecting the decision process. An in-depth study of the investment decisions underlying the introduction of these generations of mobile telephony is material for further research.

Acknowledgement

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Appendix

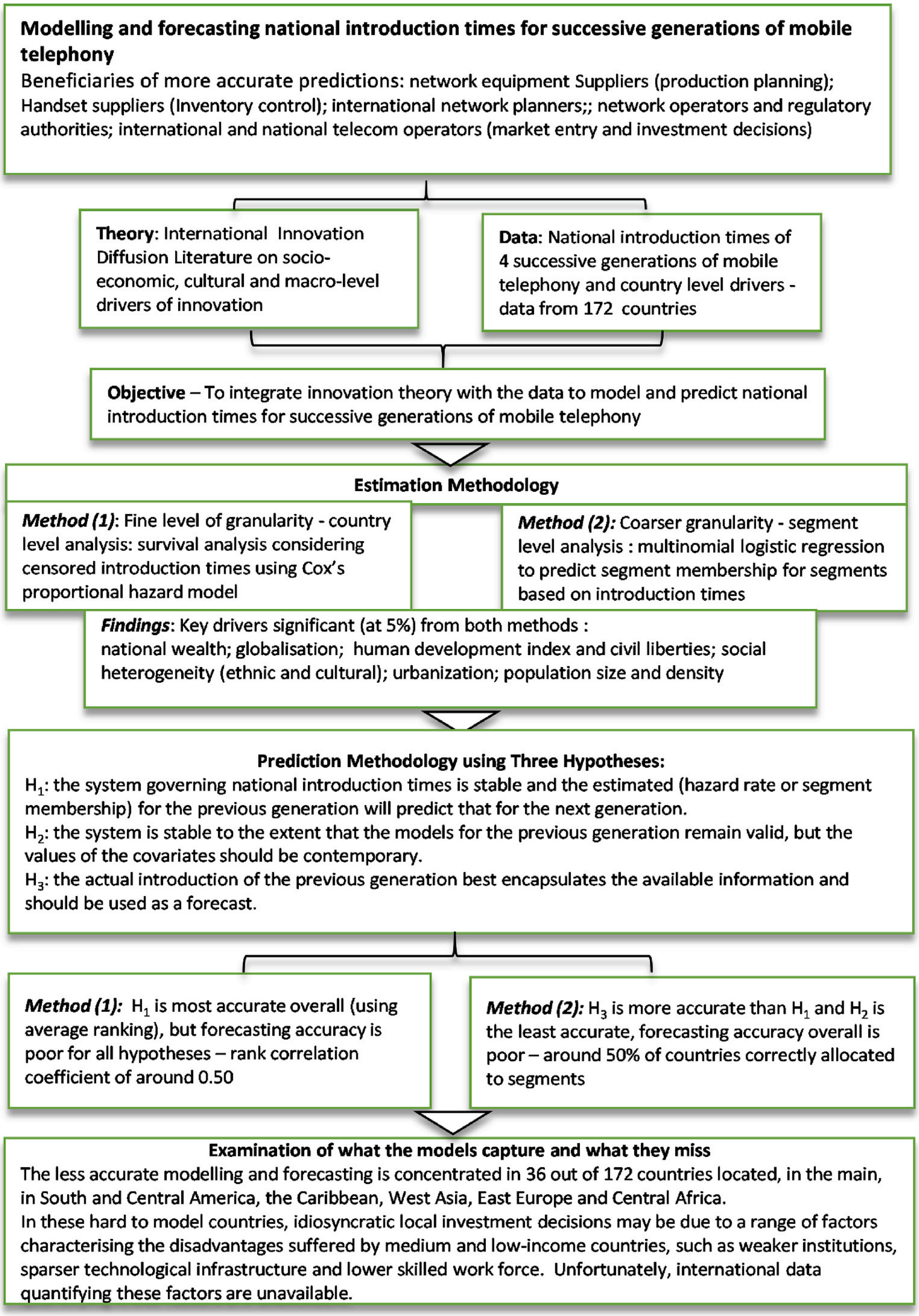

Fig. A1. A flowchart clarifying the objectives and contributions of this study.

Table A1
A list of the 172 countries in the study, showing the actual and predicted segment membership for the three digital generations. Those countries with cumulated errors of 2 or more are shown in *italics*.

Africa, Central		Honduras	C|C, B|B, B|B	Yemen	C|C, A|B, C|C
Cent. African Rep.	C|C, C|C, C|C	Panama	C|C, A|A, B|B	Qatar	A|A, B|A, A|A
Congo, Dem. Rep.	C|C, B|B, C|C	Mexico	B|B, A|A, A|B	Saudi Arabia	B|A, B|B, A|A
Gabon	A|A, C|C, B|B	Nicaragua	B|C, A|A, B|B	*Armenia*	*B|B, B|B, A|C*

(*continued on next page*)

Table A1 (*continued*)

<table>
<tr><th>Africa, Central</th><th></th><th>Honduras</th><th>C|C, B|B, B|B</th><th>Yemen</th><th>C|C, A|B, C|C</th></tr>
<tr><td>Cameroon</td><td>C|C, B|C, B|B</td><td>Costa Rica</td><td>C|C, C|A, B|B</td><td>Bahrain</td><td>A|B, A|B, A|A</td></tr>
<tr><td>Chad</td><td>C|C, C|C, B|C</td><td>El Salvador</td><td>C|C, B|A, C|B</td><td>Iraq</td><td>C|B, B|B, B|C</td></tr>
<tr><td>Angola</td><td>C|C, A|C, A|C</td><td>Belize</td><td>C|C, A|C, C|B</td><td>Israel</td><td>B|A, A|A, B|A</td></tr>
<tr><td>Congo</td><td>B|C, C|A, C|B</td><td>America, North</td><td></td><td>Turkey</td><td>A|A, B|B, C|A</td></tr>
<tr><td>Africa, East</td><td></td><td>USA</td><td>A|A, A|A, A|A</td><td>Cyprus</td><td>A|B, A|B, B|A</td></tr>
<tr><td>Burundi</td><td>C|C, C|C, C|C</td><td>Canada</td><td>B|A, A|A, A|A</td><td>Lebanon</td><td>A|A, C|A, A|B</td></tr>
<tr><td>Ethiopia</td><td>C|C, B|B, B|B</td><td>America, South</td><td></td><td>Jordan</td><td>A|B, C|B, C|A</td></tr>
<tr><td>Somalia</td><td>C|C, C|C, C|C</td><td>Ecuador</td><td>B|B, A|A, B|B</td><td>Europe, East</td><td></td></tr>
<tr><td>Kenya</td><td>B|C, B|B, B|B</td><td>Brazil</td><td>B|B, A|A, A|B</td><td>Moldova</td><td>B|B, A|A, A|A</td></tr>
<tr><td>Madagascar</td><td>A|B, C|C, B|B</td><td>Chile</td><td>B|B, A|A, B|A</td><td>Poland</td><td>B|B, A|A, A|A</td></tr>
<tr><td>Malawi</td><td>B|C, C|C, C|C</td><td>Colombia</td><td>C|B, A|A, B|B</td><td>Romania</td><td>B|B, A|A, A|A</td></tr>
<tr><td>Mauritius</td><td>B|B, A|B, A|A</td><td>Peru</td><td>B|B, A|A, B|A</td><td>Russian Federation</td><td>A|A, A|A, A|A</td></tr>
<tr><td>Rwanda</td><td>C|C, C|C, B|C</td><td>Venezuela</td><td>C|B, A|A, B|B</td><td>Hungary</td><td>A|B, A|A, A|A</td></tr>
<tr><td>Uganda</td><td>A|B, C|C, A|A</td><td>Bolivia</td><td>B|C, B|A, A|A</td><td>Slovakia</td><td>B|B, B|A, A|A</td></tr>
<tr><td>Zimbabwe</td><td>B|B, B|B, B|C</td><td>Suriname</td><td>B|C, C|C, C|B</td><td>Belarus</td><td>C|B, C|C, B|A</td></tr>
<tr><td>Djibouti</td><td>C|C, C|C, C|B</td><td>Uruguay</td><td>C|B, A|A, A|B</td><td>Ukraine</td><td>B|B, A|A, C|A</td></tr>
<tr><td>Seychelles</td><td>B|B, B|B, B|A</td><td>Argentina</td><td>B|B, A|A, C|A</td><td>Bulgaria</td><td>A|B, B|A, B|A</td></tr>
<tr><td>Zambia</td><td>C|B, C|C, B|B</td><td>Paraguay</td><td>C|C, B|A, A|C</td><td>Europe, North</td><td></td></tr>
<tr><td>Tanzania</td><td>C|B, B|B, A|B</td><td>Guyana</td><td>C|C, C|A, C|B</td><td>Denmark</td><td>A|A, A|A, A|A</td></tr>
<tr><td>Mozambique</td><td>B|C, B|C, C|B</td><td>Asia, Central</td><td></td><td>Estonia</td><td>A|A, A|A, A|A</td></tr>
<tr><td>Africa, North</td><td></td><td>Kazakhstan</td><td>C|C, A|A, A|A</td><td>Finland</td><td>A|A, A|A, A|A</td></tr>
<tr><td>Egypt</td><td>B|B, B|B, C|C</td><td>Kyrgyzstan</td><td>B|B, A|A, A|A</td><td>Latvia</td><td>A|A, A|A, A|A</td></tr>
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