Network effects, network structure and consumer interaction in mobile telecommunications in Europe and Asia

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PII: S0167-2681(10)00106-X
DOI: doi:10.1016/j.jebo.2010.06.005
Reference: JEBO 2553

To appear in: *Journal of Economic Behavior & Organization*

Received date: 21-6-2008
Revised date: 19-6-2010
Accepted date: 21-6-2010

Please cite this article as: Birke, D., Network effects, network structure and consumer interaction in mobile telecommunications in Europe and Asia[1], *Journal of Economic Behavior and Organization* (2010), doi:10.1016/j.jebo.2010.06.005

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Abstract

This paper estimates the importance of (tariff-mediated) network effects and the impact of a consumer's social network on her choice of mobile phone provider. The study uses network data obtained from surveys of students in several European and Asian countries. We use the Quadratic Assignment Procedure, a non-parametric permutation test, to adjust for the particular error structure of network data. We find that respondents strongly coordinate their choice of mobile phone providers, but only if their provider induces network effects. This suggests that this coordination depends on network effects rather than on information contagion or pressure to conform to the social environment.

Keywords: network effects, social networks, mobile telecommunications, QAP
JEL classification: C14, D12, L14, L96

[1] We are very grateful to Koen Frenken, Yoong Hon Lee and Francesco Lissoni for making the data collection at the different universities possible. We are grateful to the editor and two referees of this journal for their helpful comments on an earlier version of this paper. We would also like to thank Paul David, Nicolas Economides, Koen Frenken, Sourafel Girma, Francesco Lissoni, David Paton, Roy Radner, Arun Sundararajan, Reinhilde Veugelers, participants at the RES 2007 conference, and participants at various conferences and seminars for helpful comments. Daniel Birke would also like to acknowledge financial support by the ERSC. All remaining errors are ours alone.

1 Introduction

How do consumers choose between rival products in a market with network effects? A standard assumption of the network effects literature is that it is the overall size of the network that matters to the consumer. However, this assumption may only hold as a first approximation. For technologies that require direct interaction between consumers (such as telecommunications), we shall argue that the precise social network of a particular consumer is the relevant measure of the network as far as that consumer is concerned.

After the seminal articles of Rohlfs (1974), Katz and Shapiro (1985) and Farrell and Saloner (1985), there has been a plethora of theoretical studies into the nature of network effects and by now network effects theory has reached a rather mature state. However, empirical work in this area has been slow to keep track with the advances in theory, and it is only comparatively recently that such studies have appeared in any numbers. Recent empirical studies include Goolsbee and Klenow (2002) on home computers, Berndt et al. (2003) on anti-ulcer drugs, Rysman (2004) on yellow pages and Gowrisankaran and Stavins (2004) on electronic payment.

The literature on network effects usually distinguishes between two types of network effects: direct network effects and indirect effects. Direct network effects refer to the case where users benefit directly from the fact that there are large numbers of other users of the same network. In mobile communications, a direct network effect arises when the user can call a larger set of other users. Indirect network effects, on the other hand, arise because bigger networks support a larger range of complementary products and services. In second generation mobile networks, indirect network effects are only of second-order significance, but it seems probable that they play an increasing role with the introduction of third generation networks, where usage is more influenced by the availability of data services.

While it is widely acknowledged that network effects are a key feature of telecommunications industries, and indeed that telecommunications networks provide perhaps the leading example of network effects, relatively few studies, like e.g. Kim and Kwon (2003), have analyzed the empirical importance and extent of network effects in the telecommunications market.

Almost all these studies use market-level data and when individual-level data is used (as in Goolsbee and Klenow, 2002), interactions between consumers are not modeled. In general, there are few studies in economics (and in management studies) that take this consumer interaction directly into account. The only exceptions in the economics of networks literature are a game theoretic model of Sundararajan (2005) and an empirical analysis of interactive network effects in the diffusion of a company video messaging system in a large investment bank (Tucker, 2006).

For some networks, like the network of ATM machines (see Saloner and Shepard, 1995), the assumption that overall network size matters seems plausible. However, especially in markets with direct interaction between consumers, like mobile telecommunications, it is rather an individual's social network that determines an adoption decision. Mobile networks are highly compatible with each other and the network effects that exist in the market are mainly induced by network providers in many countries through higher prices for calls to other networks (off-net calls) than for calls to the same network (on-net calls). These have been described as tariff-mediated network effects by Laffont et al. (1998), but they make the assumption that every subscriber to a network is of the same importance to the consumer. In a previous paper (Birke and Swann, 2006), we have shown that choice of mobile phone provider is strongly coordinated within households and that this effect is far stronger than the effect of overall network size.

In the current paper, we directly examine provider choice in a social network and test whether provider choice in a social network is correlated. The approach is therefore similar to the one taken in Bandiera and Rasul (2006) who study the correlation of adoption decisions of a new crop in social networks in Northern Mozambique. To gather data on social networks of mobile phone users, we conducted surveys of classes of students at Nottingham University Business School, the University of Nottingham's campus in Malaysia, the University of Utrecht (the Netherlands) and the University of Brescia in Italy. In running the survey in different countries, we took an approach similar to (quantitative) case study research in that the countries were chosen because of the different pricing structures in the respective markets.

As Manski (1993) points out, contextual effects and unobserved heterogeneity can lead to correlation of choice decisions of network members without network effects being present. Indeed, Bandiera and Rasul (2006) argue that correlation in their social networks is due to social learning. Likewise, different brands might be attractive to different consumers and brand affinity might be clustered among friends who share similar characteristics. Different underlying causes may have very different policy implications and for that reason, identification of causal relationships has been one of the main concerns of the recent empirical literature on network effects in economics and marketing (Hartmann et al., 2008).

To be able to test whether consumers coordinate choice of mobile phone provider because of induced network effects rather than because of word of mouth effects, it is necessary to have respondents who face different charges for on- and off-net calls. Due to a large number of different tariff plans, this data is very difficult to obtain for each individual and it would also have the drawback that price information reflect current prices which might be different from the prices that the consumer faced at the time of choosing the provider.[2]

There are two alternatives to the use of individual level data. First, choice behavior can be contrasted for networks that charge higher prices for off-net calls and networks that do not. We have this opportunity in the UK, where the provider *Three* does not charge different prices for on- and off-net calls. The second alternative is to contrast choice behavior between countries with tariff-mediated network effects (most countries, including the UK, Italy and Malaysia) and countries where companies do not induce network effects (like the Netherlands).

This paper is organized as follows. Section 2 gives a brief introduction to the mobile telecommunications market in the UK, Malaysia, the Netherlands and Italy. Section 3 outlines the different surveys and discusses the econometric approach used in this paper. We also discuss some of the issues that may arise in this approach: first, some potential issues of endogeneity, and second, some alternative interpretations of our findings in terms of conformism or information sharing rather than network effects as such. Section 4 provides a graphical and statistical analysis for each of the surveys, and compares the results. We show

[2] This is obviously only important if there are switching costs in the market, which is a reasonable assumption for the mobile telecommunications market.

that students coordinate provider choice within their social network, but only if network effects are induced by mobile phone providers. Section 5 discusses the results and comments on their broader policy relevance. The findings are highly relevant to some recent policy debates about the potentially anticompetitive effects of price discrimination between on-net and off-net mobile calls.

2 The telecommunications market in the studied countries

This study of how consumers coordinate their provider choice spans four different countries: two surveys are from the UK and one each from the Netherlands, Malaysia and Italy. We are treating these surveys as five different (quantitative) case studies. In this section, we briefly describe some characteristics of the respective mobile telecommunications markets that are relevant to our research.

In all markets except Malaysia, mobile number portability is implemented. However, even when it is possible to keep the mobile phone number when switching, there are considerable switching costs due to contractual minimum subscriptions to a service, handset lock-ins etc. It can therefore be expected that there is considerable inertia in the coordination process and that more customers would coordinate operator choice without these switching costs. Importantly, these switching costs are similar across operators and should therefore not materially affect the econometric results.

The original survey was conducted at Nottingham University Business School in spring 2005 and was repeated a year later. The UK market is highly competitive with five companies fiercely competing for customers. The four original GSM-providers (O_2, Vodafone, T-Mobile, and Orange) have roughly equal market shares, which is in contrast to most other countries, where there typically are one or two dominant providers. In 2003, *Three* entered the market and introduced the first third generation network in the UK. After a slow start, the company had over 3 million users in 2006, but still trails well behind the other companies that have between 14 and 15 million users. Tariff-mediated network effects are important in the UK. According to the telecommunications regulator OFCOM, at their peak (Q2 2001), prices for off-net calls were about five times more expensive than prices for

on-net calls. By the beginning of 2004 this price ratio had come down to three times and has further fallen since. In 2006, packages with large 'included minutes' allowances have become increasingly popular and these packages normally don't differentiate between on- and off-net calls. However, there still exists a marked difference between the prices for on- and off-net calls and a high inertia in choosing a mobile phone provider can be expected.[3]

In contrast to the UK, the Malaysian market was still expanding in 2005. It is served by three main companies: Maxis is the current market leader with about 7 million subscribers (40 % market share), Celcom has about 6.3 million customers (36 %) and DiGi 4.2 million (24 %).[4] In general, there is a smaller number of price plans than in the UK and also fewer special offers and deals that include a mobile phone handset. On-net calls are slightly cheaper than off-net calls, but the biggest difference is for text messages: prices are only half or a quarter if SMS are sent to the same network. Apart from these tariff-mediated network effects, companies also offer special Friend & Family deals (most prominently DiGi) and offer some services, such as sharing of call credits, exclusively to two subscribers to the same network.

The Netherlands is different from both countries in that providers do not charge a price difference between on- and off-net calls. If our hypothesis about the importance of network effects in mobile telecommunications is right, we would therefore expect that this different pricing strategy by Dutch mobile phone providers is reflected in the choice behavior of Dutch consumers and that Dutch consumers do not strongly coordinate their provider choice with their peers. Five providers with their own network and a number of other service providers compete in the Dutch market. The incumbent, KPN Mobile, is still by far the largest provider with a market share of roughly 40%, followed by Vodafone (24%), T-Mobile (15%), Telfort (12%), and Orange (10%). However, the Netherlands has a relatively high number of

[3] OFCOM unfortunately does not identify the price difference by operator. However, based on discussions with industry experts, we conclude that the price differences between on- and off-net calls are roughly similar for the four main UK operators. As each operator probably has in excess of 1000 different tariffs, the inclusion of a price variable is beyond the scope of this paper. However, Three is the major exception and has pursued a pricing strategy based on equal prices for on- and off-net calls.

[4] All these figures refer to the third quarter 2005. Celcom is a subsidiary of the incumbent Telecom Malaysia. Telenor has a majority share (61 %) in DiGi.

providers (5) and the smaller providers have been able to catch up in recent years (especially T-Mobile).

Finally, the Italian market is characterized by strong network effects. About half of the price plans offered by Italian mobile phone companies (and almost all subscribed to by respondents in our study) discriminate between calls to the same network and calls to other networks. Furthermore, "family-and-friends"-type tariffs are offered by mobile phone companies to keep strong social contacts on the same network. The Italian market is dominated by the incumbent TIM (40% market share) and Vodafone (34%), while Wind and H3G command over 19% and 7% of the market respectively.

3 Methodology

3.1 The surveys

The study consists of quantitative case studies of five different classes of students in the UK (two different surveys), Malaysia, the Netherlands and Italy. Apart from the first UK survey, which was conducted in 2005, all other surveys were conducted in the first half of 2006. In social network studies, it is generally not possible to sample randomly from the population, because most methods have been developed for analyzing complete networks. It is therefore necessary to either analyze the complete population or somehow bound the network in another way. In our case, this is done by looking at classes of students in the Second or Third year of their undergraduate studies. These students typically started out at the university together and we can reasonably assume a relatively high interaction between students and other members of the same class.

The questionnaire on which the survey is based consists of two parts. The first part collects demographic information and asks students about their attitudes to and use of mobile phones. In the second part, students were handed out a roster of course participants and were asked to identify themselves and the people they communicate with. The exact wording of the question was "Please tick the people that you call with your mobile". Both parts took about ten minutes to fill in and were distributed and collected during lectures to ensure a high response rate.

Table 1 shows sample sizes and response rates for the different countries. The samples from the UK are by far the biggest and response rates are above 50% in all countries. The lower response rate for the UK 2006 sample is mainly due to a higher number of students that decided only to fill in the questionnaire part, but not the roster part.

	UK 2005	UK 2006	Malaysia	The Netherlands	Italy
No. of students	236	268	48	71	111
No. of respondents	159	148	24	54	91
Response rate	67%	55%	50%	76%	82%

Table 1 Sample size and response rates

The original data on communication patterns was summarized in symmetric square matrices of N rows and columns, with N being the number of respondents. A "1" in a particular cell of the matrix indicates a communication relationship and a "0" indicates the absence of a communication relationship. As usual for the treatment of network data, diagonal elements are set to zero. In general, relationships do not have to be reciprocal. Thus, if A says that she communicates with B, that does not necessarily mean that B also nominates A. However, most relationships are reciprocal and we conducted two sensitivity tests by making all relationships symmetric and by dropping non-reciprocal links. This did not change the results. A few students participated in the lecture, but were not included on the roster and could therefore not be nominated by other respondents. For those students, we assumed that all relationships are reciprocal.

3.2 Estimation procedure

For a regression analysis the original matrices were transformed into dyadic relationships (relationships between two nodes). Ignoring the diagonal 0´s, we therefore get a vector of length N(N-1) with one value for each dyad:

$$y = \begin{pmatrix} y_{1,2} \\ y_{1,3} \\ \vdots \\ y_{2,1} \\ \vdots \\ y_{N,N-1} \end{pmatrix}$$

Where the element y_{ij} indicates whether i nominates j (y_{ij} =1) or not (y_{ij} =0). We can then estimate the general latent variable model for binary response models:

$$y_{ij}^{*} = \mathbf{x}\boldsymbol{\beta} + \varepsilon_{ij},$$

y_{ij}=1 if y_{ij}*>0

y_{ij}=0 if y_{ij}*≤0

However, error terms are not independent, identically distributed. The correlation between the error terms for dyad i,j ($\varepsilon_{i,j}$) and dyad k,*l* ($\varepsilon_{k,l}$) is $\rho_{ij,kl}$ and the general autocorrelation structure for this model is given as[5]:

$$\Omega_{i,j;k,l} = \sigma^2 \begin{array}{c} \\ \varepsilon_{1,2} \\ \varepsilon_{1,3} \\ \vdots \\ \varepsilon_{N,N-1} \end{array} \begin{array}{c} \begin{array}{cccc} \varepsilon_{1,2} & \varepsilon_{1,3} & \cdots & \varepsilon_{N,N-1} \end{array} \\ \begin{pmatrix} 1 & \rho_{1,2;1,3} & \cdots & \rho_{1,2;N,N-1} \\ \rho_{1,3;1,2} & 1 & \cdots & \rho_{1,3;N,N-1} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{N,N-1;1,2} & \rho_{N,N-1;1,3} & \cdots & 1 \end{pmatrix} \end{array}$$

When using network data, it is not valid to assume that observations are independent, as is assumed in OLS and logit models. Observations are clearly not independent as there are at least 2(N-1) dyads involving every individual. This correlation between observations involving the same nodes stems, for example, from the fact that consumers are far more likely to have the same provider as their friends if they use a provider with a high market share in the network. This would result in a positive correlation between observations from the same

[5] In undirected networks (such as the symmetric tie version used in this paper), $\varepsilon_{1,2}$= $\varepsilon_{2,1}$. The QAP permutation test used to adjust p-values ensures this.

row or column:

$$\rho_{i,j;k,l} = \begin{cases} 1 & \text{if i=k and j=}l\text{;} \quad \text{(diagonals of } \Omega\text{)} \\ \rho_{i;j,l} & \text{if i=k and j}\neq l\text{;} \quad \text{(row autocorrelation parameters)} \\ \rho_{j;i,k} & \text{if i}\neq\text{k and j=}l\text{;} \quad \text{(column autocorrelation parameters)} \\ 0 & \text{otherwise.} \end{cases}$$

While parameter estimates are still unbiased, this autocorrelation causes p-values to overestimate the significance level of the hypothesis test. Although it is possible to account for a lot of the correlation due to observed characteristics (like e.g. market shares of providers), there are also unobserved characteristics like price sensitivity that lead to a correlation of error terms.

One possible way to adjust for incorrect standard errors is the Quadratic Assignment Procedure (QAP) - see Krackhardt (1988). The idea of QAP is to permute rows and columns of the original data matrix for the dependent variable and then to reestimate the original regression model. This procedure can be understood as a test of how often the observed network structure could have evolved purely by chance. Table 2 shows the permutation procedure: The original matrix on the left is taken and rows and columns are permuted in the same way. For example, row 2 takes the place of row 1 and column 2 takes the place of column 1. Likewise, row 4 takes the place of row 2 and so on. The right part of Table 2 shows the resulting matrix. By this permutation procedure, it is ensured that the values that belong together in a row (or column) stay together. Diagonal elements are still on the diagonal.

a)

	1	**2**	**3**	**4**
1	$X_{1,1}$	$X_{1,2}$	$X_{1,3}$	$X_{1,4}$
2	$X_{2,1}$	$X_{2,2}$	$X_{2,3}$	$X_{2,4}$
3	$X_{3,1}$	$X_{3,2}$	$X_{3,3}$	$X_{3,4}$
4	$X_{4,1}$	$X_{4,2}$	$X_{4,3}$	$X_{4,4}$

b) 2 => 1, 4 => 2, 3 => 4, 1 => 3

	1	**2**	**3**	**4**
1	$X_{2,2}$	$X_{2,4}$	$X_{2,1}$	$X_{2,3}$
2	$X_{4,2}$	$X_{4,4}$	$X_{4,1}$	$X_{4,3}$
3	$X_{1,2}$	$X_{1,4}$	$X_{1,1}$	$X_{1,3}$
4	$X_{3,2}$	$X_{3,4}$	$X_{3,1}$	$X_{3,3}$

Table 2 Permutation of rows and columns (QAP)

Permutation tests like the QAP are similar to the bootstrap. Unlike the bootstrap, the empirical confidence interval is around the null, not around the sample value, which makes the QAP correspond to the situation in classical hypothesis testing. Whereas in bootstrap tests samples are drawn randomly with replacement, permutation tests like QAP sample without replacement.

This permutation and re-estimation is reiterated to get an empirical sampling distribution. Finally, the results from the original regression model are compared to the simulated distribution based on QAP and the percentage of cases in which the original or higher values occurred is calculated. For our analysis, 1000 iterations were used.

3.3 Discussion of the Econometric Approach

In this section, we shall highlight some of the issues posed by this econometric approach. There are some potential problems with this approach and the interpretation of the results from it and these are worthy of discussion. The issues fall into two groups. First, the issue of endogeneity and the direction of causal links at work here. Second, the issue of whether coordination of provider choice might alternatively be explained by conformism or information sharing amongst groups of students, rather than tariff-mediated network effects as such.

At its simplest, the approach described above assumes that the student's choice of provider depends on his/her social network and the extent of tariff-mediated network effects.

If tariff-mediated network effects are important then the student economizes on communication costs by coordinating choice of provider with the choices of his/her peers. The composition of a student's network is treated as weakly exogenous. But in principle, at least, there are two reasons why the measured social network could be endogenous.

It could be that students' choices of provider are determined by quite different factors from network or tariff-mediated network effects, and the social network described by mobile phone calls is the *consequence* of the students' prior choice of provider and any tariff-mediated network effects. Is this alternative really plausible? True, if a student decides to join a particular student society, then it seems highly likely that their social network will evolve to reflect this choice. But we find it implausible that such an argument should apply to the group who use a particular provider. For one thing, choice of mobile provider is hardly a visible sign. The very small number of people who carry around a detailed mapping from mobile numbers to provider can recognize provider choice from a contact's mobile number, but the rest of us would need to ask explicitly.[6] Second, while members of a student society might expect to have some interests in common, it is far from clear as to why two users of the same mobile phone provider should assume from that fact alone that they use the same provider that they have much in common. The individual who chooses his/her social network on the basis of the relative cost of making mobile phone calls would seem to be suffering from considerable poverty in his/her social relations.

An alternative possibility is that individuals choose their provider for independent reasons and then choose their mode of communication according to whether their friends use the same mobile provider or not. So, if one friend uses the same mobile provider, communication by mobile calls is common while if the friend uses another provider, communication by other means (e.g. by SMS text or by email) may be more common. In this case, it is not so much choice of *provider* that depends on social networks and tariff-mediated network effects, but choice of *communication mode*. This is a more plausible possibility and in what follows we shall explore whether an endogeneity bias arises by comparing our results with those based on

[6] In the UK, in contrast to some other countries, there are several hundred prefixes associated with the different networks making it all but impossible to identify the network provider by its prefixes.

an alternative measure of friendship strength, derived from frequency of communication by instant messaging.

The second group of issues relates to whether the apparent coordination observed in our results should, following the methodology of the previous section, be interpreted as evidence of the importance of tariff-mediated network effects in provider choice or as a form of coordination mediated by a desire to save on information costs or a desire to confirm to group norms.

It is possible, for example, that the reason why a newcomer to mobile phones may choose the same mobile provider as a friend may be that the newcomer faces a learning curve and believes that learning curve will be negotiated quickest if he/she chooses the same provider (and handset) as a friend. This argument would be highly relevant, for example, in the case of an elderly relative choosing the same provider and handset as one of their children. However, given all the evidence, anecdotal and otherwise, about the technological proficiency of university students, this does not seem to be a very important argument in the context of the surveys used for this research.

Alternatively, it could be that choice is mediated by a strong desire to conform to group norms. The anthropologist Mary Douglas wrote that, "the real moment of choosing is ... choice of comrades and their way of life" (here quoted from Becker, 1996, p.13). Once that choice is made, choices over lesser matters are largely determined by group norms. Certainly, peer group pressures to confirm are strong amongst university students. But while choice of handset would be quite visible, choice of mobile *provider* is not a very visible sign. In short, it seems unlikely that students experience a strong peer-group pressure to confirm to a choice of provider, unless that pressure stems from the desire of the group to economize on communication costs arising from tariff-mediated network effects.

4 Network structure and provider choice

4.1 UK 2005

Social networks can very usefully be analyzed by graphical representations of these networks, in particular in the case of medium-sized networks with a couple of hundred nodes. Figure 1

depicts the social network within the UK 2005 class of students, based on their stated communication patterns.[7]

It is a directed graph and arrows depict the direction of the nominations from the roster. The graph was created using a spring embedded algorithm from UCI-NET (Borgatti et al., 2002), which is based on the idea of representing the social network graph as a system of mass particles. Nodes are the mass particles that repel each other and the edges are springs that exert an attractive force between nodes. Connected respondents will therefore be grouped together, whereas unconnected respondents will be separated.

Some form of clustering immediately becomes obvious. First, shapes of the objects, depicting nationalities, are highly clustered. Chinese students for example (up triangles) communicate almost exclusively with other Chinese students. At the bottom right of the graph, there is a group of Asian students who even form a distinct component and only have communication links within the group. Two Spanish students also communicate only between each other and can be found at the bottom right of the graph as well. Finally, there are two isolates at the upper left.

Second, the graph shows a clustering of shadings, which depict the main provider chosen. This clustering of shadings clearly occurs along nationality lines. The majority of Chinese students use Vodafone and similar patterns can be observed for other nationalities as well. However, there also seems to be a coordination of providers within nationalities. Within each national group, students that call each other tend to use the same mobile phone provider.

One of the most important advantages of a graphical analysis is to develop our intuitive understanding. Furthermore, visual representations of networks enable an easy communication of results with an audience and are more intuitive to most people. In addition we carried out a regression analysis to quantify the degree of coordination of provider choice found in the sample.

We estimate a logit model using *same_provider* as the dependent variable. This variable takes on the value 1 if two students use the same provider and 0 otherwise.[8] There are two

[7] A color version of the graph can be found in the appendix.

[8] Some of the respondents in the UK and in particular in Italy had multiple providers and same_provider takes any combination of these providers into account. This might potentially bias the estimate downwards. To

different types of independent variables. First, there are dyadic variables that indicate whether the two nodes that form a dyad have certain properties. The variables are *same_nationality* (respondents of the dyad have the same nationality/ come from the same group of nations as defined above), *same_course* (students study for the same degree course)[9], *friend* (respondents call each other on their mobile phone), *same_sex* (nodes have the same gender) and *same_payment* (respondents use the same type of payment: contract vs. pre-paid). Second, we include a set of provider dummies with *Three* being the base case. This is necessary as providers have different market shares and it is therefore more likely that two respondents have the same provider if they both use a provider with a high market share. Table 6 (Model 1) shows the results from a logit estimation of the model with QAP p-values. P-values rather than standard errors are displayed as the QAP permutation test gives probabilities rather than standard errors.

Dep. Var.: same_provider	Model 1: QAP regression	Model 2: Fixed effects
Same_nationality	0.889 (0.000)***	1.304 (0.000)***
Friend	0.600 (0.000)***	0.419 (0.000)***
Same_course	-0.058 (0.715)	-0.144 (0.002)***
Same_sex	0.107 (0.031)**	0.065 (0.047)**
Same_payment	0.051 (0.427)	0.080 (0.072)*
Provider dummies	Not reported due to space constraints	---
Individual dummies	---	Not reported due to space constraints
Constant	-3.142 (0.000)***	-0.735 (0.000)***

understand why, take a (fictional) respondent who uses all available providers in a market to be on the same network as all other calling partners. Such a respondent would show up as not coordinating with his friends although he reacts to the induced network effects in the strongest possible way. In the UK, although some of the respondents have up to three mobile providers, results are very similar whether we only take the main provider into account or whether we allow for multiple providers. As discussed below in the section discussing the Italian results, estimates measuring the coordination of provider choice are higher in the Italian case when we take multiple providers into account.

[9] The courses that students have to take in the first two years are relatively similar regardless of the degree studied and we therefore expect no big impact from this variable.

No of observations	24335	24335
Pseudo R^2	0.133	0.150
Log likelihood	-11947.8	-11721.6

Figures in brackets are p-values for the hypothesis that the coefficient is equal to zero.

* Significant at 10%-level; ** Significant at 5%-level; *** Significant at 1%-level

Table 3 Determinants of choosing the same provider (UK 2005)

The variables *same_nationality*, *friend* and *same_sex* are highly significant and show the expected sign, confirming the graphical analysis from Figure 1. Two respondents of the same nationality, who are friends and of the same sex are significantly more likely to use the same provider. *Same_nationality* and *friend* have a particularly high significance level and in fact no permutation resulted in a parameter estimate higher than the observed values from the original regression. *Same_sex* is still significant at the 5%-level, but the coefficient is far lower than the other two.

[Insert Figure 1 Interaction network of students (UK 2005) about here]

Most of the provider dummies are significant as well, which confirms that it is necessary to control for market share. A negative parameter estimate for T-Mobile, for example, reflects the relatively low number of T-Mobile users in the sample and the resulting lower probability that two students both use T-Mobile.

$$y_{ij}^{*} = \mathbf{x}\boldsymbol{\beta} + a_i + a_j + \varepsilon_{ij},$$

$y_{ij}=1$ if $y_{ij}^{*}>0$

$y_{ij}=0$ if $y_{ij}^{*}\leq 0$

To check the robustness of the model, we estimate the following fixed effects model as an alternative:

where a_i and a_j are the respective fixed effects of the two respondents i and j involved in a dyad. For each respondent, Model 2 from Table 3 includes dummy variables for all dyads to which the respondent belongs. Consequently, we have to include N-1 dummies, altogether, and these dummies cover all systematic individual level effects that might have lead to a coordination of provider choice. The only variables left in the model then are the dyadic variables. The estimates for the main coefficients are similar and confirm the results of the original model.

If we run the regression separately for different providers, we find a positive coefficient for the *friend* parameter for all providers but *Three*. To summarize the effect of a communication relationship on provider coordination and to directly compare the degree of coordination between different providers, we can calculate the odds-ratio of a same_provider x friendship cross-tabulation (see Moody, 2001). The odds-ratio alpha can be calculated as AD/BC (see Table 4) and is independent of the distribution of provider market shares. Alpha can take on values between 0 and $+\infty$ and will be 1 when the odds of using the same provider dyad are the same whether two respondents are friends or not.

	Same_provider dyad	Not same_provider dyad
Friend	A	B
No friend	C	D

Table 4 Calculation of provider coordination measure

The degree of coordination for the main providers can then be seen in Table 5. Alpha is lower than one only for Three users, whereas the odds of Vodafone users having the same provider are 4.14 times higher for two friends than for two non friends. The significance can be tested with the help of a χ^2-test, and the significance is shown in Table 6 using the standard 'star' convention.

	Three	O_2	Orange	T-Mobile	Vodafone
Degree of coordination (α)	0.43**	2.14***	1.59	6.99***	4.14***

Table 5 Degree of coordination (UK 2005) by provider

This is further support for our hypothesis that network effects are the reason for consumers coordinating their provider choice. In 2005, *Three* was the only UK provider that did not charge higher prices for off-net calls, but rather offered packages of calling time regardless of the network to which calls are made. Consequently, there is no pecuniary incentive for *Three* users to coordinate with their peers. This can also well be seen in Figure 1, where *Three* users are evenly distributed over the graph. The results are also contrary to the argument that learning, group conformism or word-of-mouth effects are the prime cause of this coordination. *Three*'s third generation network and handsets are arguably more difficult to master than other mobile phones and we would expect a coordination of provider choice for *Three* if these effects were strong.

The correlation of provider choice within nationalities is especially interesting and there may be several reasons for this. All UK providers also operate networks in a number of other countries; sometimes under the same brand, sometimes under different brands. Non-UK students might have simply continued to use the same provider they already used in their home country. However, concentration of providers worldwide is far lower than in the market for mobile phone handsets. Furthermore, most students come from countries where these providers do not have a network, as most providers have a rather European focus. Table 6 compares the degree of coordination among different nations using odds-ratios as above.

	British	Other Europeans	Chinese	Other Asians	Africans
Degree of coordination (α)	2.00***	1.47	4.17***	1.15	5.17***

Table 6 Degree of coordination (UK 2005) by nationality

This means that although British students also coordinate their provider choice, this tendency is even stronger for Chinese and African students.[10] The main reason for this might be that the social network of international students in this setting is more focused on other students from the same class. Coordination of providers within nationalities might also

[10] 50% of the respondents are British, 25% are Chinese and the rest are from other nationalities.

be due to common unobserved characteristics and attitudes of respondents with the same background or it could be a coordination mechanism. We therefore regress *friend* on *same_nationality* and *same_sex*.[11] The predicted probability of an interaction between two respondents is generally rather low, but for two respondents from the same nationality and the same sex this probability is ten times higher than for two respondents of different nationalities and different gender (see Table 7).

	not same nationality	same nationality
Not same sex	.006	.036
same sex	.012	.069

Table 7 Predicted probabilities of calling each other

The students for which coordination is strongest are Chinese students who in the large majority used Vodafone. To the best of our knowledge, at the time of the survey[12] there was no special tariff offered by Vodafone targeting Chinese students (such as cheap calls to China) and Vodafone does not have its own network in the PRC, which students might have used prior to their study in England.[13] Anecdotal evidence suggests that Chinese students told each other on arrival that all Chinese students use Vodafone and that new arrivals should use Vodafone as well, if they want other people to call them, which means that there is explicit peer group coordination at work. This has afterwards also been confirmed by students from other nationalities.[14] If nationality is a strong determinant of friendship, it is a good guess to choose the same network as other people with the same nationality in order to keep as many calls 'on-net' as possible. Furthermore, even when accounting for this effect, friends are still more likely to choose the same provider.

[11] Full estimation results can be obtained upon request.

[12] More recently, special international tariffs are offered by some providers. O_2 has taken the lead here and there is anecdotal evidence that some Chinese students are switching to O_2 to benefit from these discounts.

[13] Vodafone has a minor stake in China Mobile, but it is a rather small stake (approximately 3.27%) and is most likely not known to the average consumer.

[14] One of the comments, we received from international seminar and conference participants was that they encountered similar coordination mechanisms when they moved abroad.

4.2 UK 2006

In spring 2006, we repeated the UK survey with a new cohort of students at Nottingham University Business School. In the meantime, the mobile phone market changed in a couple of ways. There has been a general trend in the UK for companies to offer monthly packages of minutes. These 'minute packages' typically can be used for both on-net and off-net calls and there is no price discrimination between the two. Prices only vary once the free minutes are used up or for respondents who have not bought these minutes packages.

Another important change that might potentially affect the outcome of the study is the introduction by O_2 of special offers for international calls. Especially for international students, it might therefore be beneficial to switch to O_2 and benefit from cheaper calls back home. Table 8 (Model 1) shows the results of the regression analysis as described for the UK 2005 study in Table 3.

Dep. Var.: same provider	Model 1: Base model	Model 2: QAP: Friendship strength	Model 3: QAP: Friendship strength (IM network)	Model 4: QAP Friendship strength (Combined Network	Model 5: Fixed effects: friendship strength
Same_nationality	.355 (0.000)***	.354 (0.000)***	.210 (0.000)***	.371 (0.000)***	0.649 (0.000)***
Friend	. 651 (0.000)***	---	---	---	---
Friend1 (< once a week)	---	.703 (0.000)***	.562 (0.025)**	.751 (0.002)***	.523 (0.002)***
Friend2 (once a week)	---	.581 (0.000)***	.592 (0.003)***	.406 (0.020)**	.536 (0.001)***
Friend3 (daily)	---	.700 (0.001)***	.842 (0.000)***	.890 (0.000)***	.639 (0.006)***
Same_course	-.025 (0.675)	-.025 (0.696)	-.022 (0.576)	-.023 (0.551)	-.090 (0.486)
Same_sex	-.028 (0.257)	-.028 (0.257)	-.038 (0.339)	-.039 (0.109)	-.036 (0.168)
Same_payment	-.004 (0.962)	-.004 (0.960)	.002 (0.968)	.001 (0.707)	.0169 (0.758)
Provider	Not reported	Not reported	Not reported	Not reported	---

dummies	due to space constraints	due to space constraints	due to space constraints	due to space constraints	
Individual dummies	---	---	---	---	Not reported due to space constraints
Constant	-3.360 (0.000)***	-3.360 (0.000)***	-3.460 (0.000)***	-3.396 (0.000)***	-4.108 (0.000)***
No. of observations	20306	20036	15004	21170	20306
Pseudo R^2	0.160	0.160	0.160	0.157	0.176
Log likelihood	-10271.6	-11271.4	-7473.9	-10718.3	-10083.3

Figures in brackets are p-values for the hypothesis that the coefficient is equal to zero

* Significant at 10%-level; ** Significant at 5%-level; *** Significant at 1%-level

Table 8 Determinants of choosing the same provider (UK 2006)

In the 2006 study, we asked students to indicate the frequency of interaction for their ties, as it is likely that the strong ties are more likely to affect the outcome (Suarez, 2005). We haven't used this information for the first regression of Table 8, where *friend* just takes the values 0 or 1, so that we can directly compare the UK 2005 and 2006 results. In general, the parameter estimates are roughly similar between the two studies. As in 2005, *same_nationality* and *friend* are strong predictors for *same_provider* in the 2006 data. In other words, we again find that respondents coordinate their choice of mobile phone provider. Maybe the most interesting difference between the results from the two studies is that the parameter estimate for *same_nationality* has more than halved. One reason for this trend is the introduction of special discounts for international calls on some networks, which has prompted some international students to change providers. Again, we do not observe coordination for *Three* users, with the exception of a single *Three* user who is connected to four other *Three* users.

Model 2 - 5 from Table 8 present the results when including dummy variables for different interaction frequencies. The coefficients for the three friendship parameters are nearly equal in size, which means that students coordinate with their friends regardless of the exact interaction frequency (daily, at least once a week, less than once a week). This means that in

the UK, friends do not coordinate with each other on an individual basis, but rather with their social network in general.

One potential drawback of our network measure is that it might be endogenous, i.e. people who are on different mobile phone networks might decide to use other communication means when interacting with each other to avoid expensive off-net calls. Although this would indeed be a very strong consequence of induced network effects, we can test whether this is the case by using a network measure that is orthogonal to provider choice. In the 2006 UK sample, we asked students with whom they communicated via instant messaging (IM). IM is one of the communication media that students are likely to use if they would want to avoid expensive off-net calls. However, most students used IM to chat online and only a minority (roughly 20%) used IM for voice communications.[15] 70% of all communication links occur both on IM and via mobile phones.

Model 3 in Table 8 reports the results for the friendship strength regression using the IM interaction network as the basis for the friendship variables. The number of observation is slightly lower as only 127 out of 148 students communicate via IM. Estimation results are very similar to Model 2 and we therefore conclude that our estimation results are not unduly affected by endogeneity. We further estimated a model combining mobile and IM links assuming that this is the best representation of the underlying friendship network. The results of this regression (Model 4) again are very similar to those obtained without including IM links, which reinforces our confidence that links between students are not endogenous.

Finally, we used a fixed effects model to check the robustness of our models and the results of the QAP regressions are confirmed.

4.3 Malaysia

The Malaysian study was conducted at the University of Nottingham's campus in Malaysia (UNiM). Class sizes at the Malaysian campus are a lot smaller than in the UK and we therefore restrict ourselves to a graphical analysis of the data, as there are not enough

[15] The preferred IM client at the time in this sample was MSN, which was better for chatting than for voice communications.

observations for a formal statistical treatment. However, as can be seen in Figure 2, students in Malaysia coordinate their provider even more strongly than students in the UK.

Students that are connected in the network typically use the same provider. Again, ethnicity is a strong predictor of "friendship" (see e.g. the cluster of Chinese students at the top). All ethnic Chinese students use the biggest provider in Malaysia: Maxis. To the best of our knowledge, there are again no special offers or other company characteristics that could explain a general preference of Chinese mobile phone users for Maxis. Far fewer students in the sample use Celcom or DiGi, but the students who use them are generally connected to each other. Again, the social network seems to be the driving force behind the coordination of provider choice.

[Insert Figure 2 Class network Malaysia about here]

4.4 The Netherlands

As we pointed out earlier, the Netherlands is different from the other countries in that providers don't charge different prices for on- and off-net calls. The class sampled was very homogeneous in that there is only one student who does not have a Dutch nationality. Another important difference is the sparser class network. There is a bigger number of isolates who do not call any other person in the same class. This difference in network density is mainly due to the different education system in the Netherlands, which allows students greater flexibility in choosing their courses. Having said that, there is a core of students that interacts frequently with each other and we can analyze whether these students coordinate providers with each other. Table 9 shows the results of the regression for the Dutch data. As we do not have enough data to differentiate between communication intensity, we only use a dummy indicating whether two respondents communicate with each other or not.

same provider	Model 1: QAP regression	Model 2: Fixed effects
Friend	-.318 (0.355)	-.315 (0.169)
Same_course	-.222 (0.250)	-.256 (0.131)
Same_sex	-.090 (0.584)	-.127 (0.354)
Same_payment	.134 (0.568)	.747 (0.017)**
Provider dummies	Not reported due to space constraints	---
Individual dummies	---	Not reported due to space constraints
Constant	-2.404 (0.012)**	-1.333 (0.006)**
No of observations	2376	2376
Pseudo R^2	0.076	0.078
Log likelihood	-1059.0	-1057.1

Figures in brackets are p-values for the hypothesis that the coefficient is zero.

* Significant at 10%-level; ** Significant at 5%-level; *** Significant at 1%-level

Table 9 Determinants of choosing the same provider (The Netherlands)

Both the QAP and fixed effects regression lead to negative, but insignificant estimates for the *friend* parameter. Only the *same_payment* variable and the control dummies for providers are significant. We therefore conclude that the absence of induced network effects in the Netherlands removes the main incentive for coordinating provider choice within the social network.

4.5 Italy

The Italian part of the study was conducted in May 2006 at the University of Brescia in Northern Italy. Most students come from Brescia (84%), or from nearby Verona (7%). There are no international students and social networks can be expected to be a lot more stable than social networks in the UK sample, as students predominantly come from the town where they study. The large majority of students used tariffs that price discriminate between on- and off-net calls, the reason why we did not include a dummy variable for this.

Three different models for the Italian dataset are displayed in Table 10. The first model is closely related with the models estimated for the other countries and includes a *friend*

dummy. The *friend* parameter estimate in Model 1 is significant as before, but is lower than in the UK indicating that coordination might be lower in the Italian sample.

	Model 1: base estimate	Model 2: close friends	Model 3: Fixed effects
Friend	0.437 (0.002)***	---	---
Friend1 (< once a week)	---	0.303 (0.040)**	0.205 (0.112)
Friend2 (once a week)	---	0.348 (0.080)*	0.209 (0.243)
Friend3 (daily)	---	1.345 (0.000)***	1.363 (0.000)***
Same_sex	-0.097 (0.270)	-0.099 (0.266)	0.109 (0.051)*
Same_payment	0.080 (0.836)	0.089 (0.791)	-0.348 (0.438)
Provider dummies	Not reported due to space constraints	Not reported due to space constraints	---
Individual dummies	---	---	Not reported due to space constraints
Constant	0.557 (0.164)	0.550 (0.167)	-0.500 (0.367)
No of observations	8190	8190	8190
Pseudo R^2	0.058	0.059	0.165
Log likelihood	-5331.6	-5324.6	-4726.6

Figures in brackets are p-values for the hypothesis that the coefficient is zero

* Significant at 10%-level; ** Significant at 5%-level; *** Significant at 1%-level

Table 10 Determinants of choosing the same provider (Italy)

The second model investigates this finding more closely and now includes dummy variables capturing the strength of the relationship (the base category is no communication). As can be seen, the parameter estimate is positive and significant for all communication frequencies, but is four times higher for very close friends (daily communication). One reason for this finding is the higher inertia of provider choice in the Italian market. Students used their mobile phone provider already for an average of over five and a half years and thus coordination seems only likely with very strong contacts. As most students grew up in the vicinity of Brescia, it is quite reasonable to expect that their communication patterns did not change very drastically with entry into the university and that they only strongly coordinate provider choice with very close contacts. The fixed effects model of Table 10 again confirms the results from the QAP regression.

In contrast to the UK, where respondents mainly use multiple providers to take advantage of special offers, the use of multiple providers is more of a coordination mechanism in Italy.

Respondents who would have a rather high number of off-net contacts when only taking into account the main provider used, tend to use a second or third provider to be on the same network as their friends.

Another interesting aspect of coordination in Italy is highlighted when comparing coordination by provider. Table 11 shows the degrees of coordination α for each of the four providers. For the largest provider, TIM, coordination is low and insignificant. The smaller the market share of the provider, the higher the degree of coordination and H3G users are twice as likely to have the same provider with a friend as with a non-friend. As TIM has a market share of about 50%, it is much less important for TIM users to coordinate their provider choice than for users of smaller providers.

	TIM	Vodafone	Wind	H3G
Degree of coordination (α)	1.11	1.58***	1.79**	1.96*

Table 11 Degree of coordination (Italy) by provider

In the Italian study, we also analyzed whether students coordinated their provider choice with their family members. One reason for doing so was the absence of international students in the sample and our assumption of a stronger family orientation in Italy. Using χ^2-tests of cross tabulation, it turns out that students significantly coordinate provider choice with their partners, with their siblings and with their mother, but that this coordination is lower and statistically insignificant with their fathers. The expected value of using the same provider based on the national provider market shares is 38.5%, while by comparison, the observed percentages of using the same provider are: partners (77.4%), siblings (54.1%), mothers (56.8%) and fathers (52.5%).

4.6 Cross-country comparison

Finally, we can directly compare the results from the different studies. We here focus again on the degree of coordination as measured by α (see Table 12) and note that the results are consistent with the one from the different regression tables.

Degree of coordination (α)	UK 2005	UK 2006	Netherlands	Malaysia	Italy
All	2.40***	1.93***	0.68	5.92***	1.28**
communicate seldom	n/a	1.84***	0.67	2.71	1.11
communicate occasionally	n/a	1.89***	0.50	5.11***	1.17
communicate frequently	n/a	2.14***	1.44	10.17***	3.17***

Table 12 Degree of coordination in different countries

Another alternative is a comparison of the observed percentages of same_provider dyads in the samples with the expected values when assuming random mixing of respondents based on nationwide provider market shares (see Table 13).

	UK 2005	UK 2006	Netherlands	Malaysia	Italy
Observed % same provider	44.5%	43.8%	15.0%	78.4%	53.0%
Expected % same provider	24.6%	27.0%	20.5%	47.3%	38.7%
χ^2-test	111.8***	48.2***	2.5	64.3***	8.7***

Table 13 Observed vs. expected % of same provider dyads among friends

Both tables show a very strong coordination of provider choice for all countries with tariff-mediated network effects. For the Netherlands where there are no tariff-mediated network effects, we only observe a small and insignificant coordination of providers for very close relationships. Taken as a whole, these observations indicate the main drivers of our results are network effects and not information contagion effects.

5 Discussion

We have shown that consumers not only coordinate their choice of mobile phone providers within households (like in Birke and Swann, 2006), but also in their wider social network. We further found that this depends on the price difference between on- and off-net calls induced by most providers. This casts doubt on the traditional assumption in the network effects literature that overall network size rather than local social networks are important for consumer choice.

The study shows that besides peer group effects and information contagion processes, local network effects can be a powerful economic source for consumer choice to be interdependent in a social network. Although the results in this study pertain to tariff-mediated network effects, it can be expected that consumer coordination is even stronger if different networks are technologically incompatible.

As we do not have a temporal dimension to the data, we can not ultimately decide on the causality between provider coordination and the existence of a communication relationship. Throughout the paper, we have argued that two consumers who interact with each other a priori will tend to coordinate their choice of mobile phone provider. However, there are two potential endogeneity problems. First, people could also choose the people they communicate with based on their usage of certain mobile phone providers. While not completely dismissing this possibility, we think that it is unlikely to explain the magnitude of the effect. Second, people might substitute communicating by mobile phone with other communication media and their social network, as approximated by mobile phone interactions, might be biased towards communications with people using the same network provider. We have controlled for the second effect by using a network measure (instant messaging) which is orthogonal to choice of mobile phone provider and found that the main direction of causality is from friendship to provider coordination. We also note that both directions of causality support our main hypothesis that tariff-mediated network effects are at the heart of the observed coordination of provider choice.

As discussed earlier, the samples on which this paper is based are far from random and it is therefore difficult to generalize the findings to, say, the British population. The high percentage of international students might have favored the results to a certain extent. However, results consistent with the hypothesis that induced network effects is the driving force behind the coordination of provider choice have been found across time and across several countries. It can be assumed that a significant part of a student's communication takes place outside the class room. Results from the survey (and common sense) suggest that, for example, calls to the partner are a significant share of all calls. Consequently our results might rather understate the extent of coordination.

Finally, the results described here are highly relevant to some of the recent policy debates

about whether the price discrimination between on-net and off-net calls is anti-competitive and welfare-reducing. Harbord and Pagnozzi (2010) have argued that some features of mobile telephony regulation in the UK have increased provider incentives to engage in this form of price discrimination. Moreover, they argue that when this on-net/off-net price differential has an important effect on provider choice and/or calling behavior, then this strategic creation of tariff-mediated network effects can be an important strategy for attracting and retaining market share and for deterring entry by new providers or retarding the growth of smaller networks.

Our findings accord a very important role to tariff-mediated network effects. For that reason, the concerns raised by Harbord and Pagnozzi (2010) are very apposite. However, in mitigation, we would note that our earlier work (Birke and Swann, 2006) found that individual choice of provider was much more heavily influenced by choices of other family members than total network size and moreover that there had, in the UK at least, been a trend towards equalization of market shares rather than increasing concentration. These observations suggest that small providers are not necessarily operating at an insuperable disadvantage.

[Insert Appendix: Interaction network of students (UK 2005) about here]

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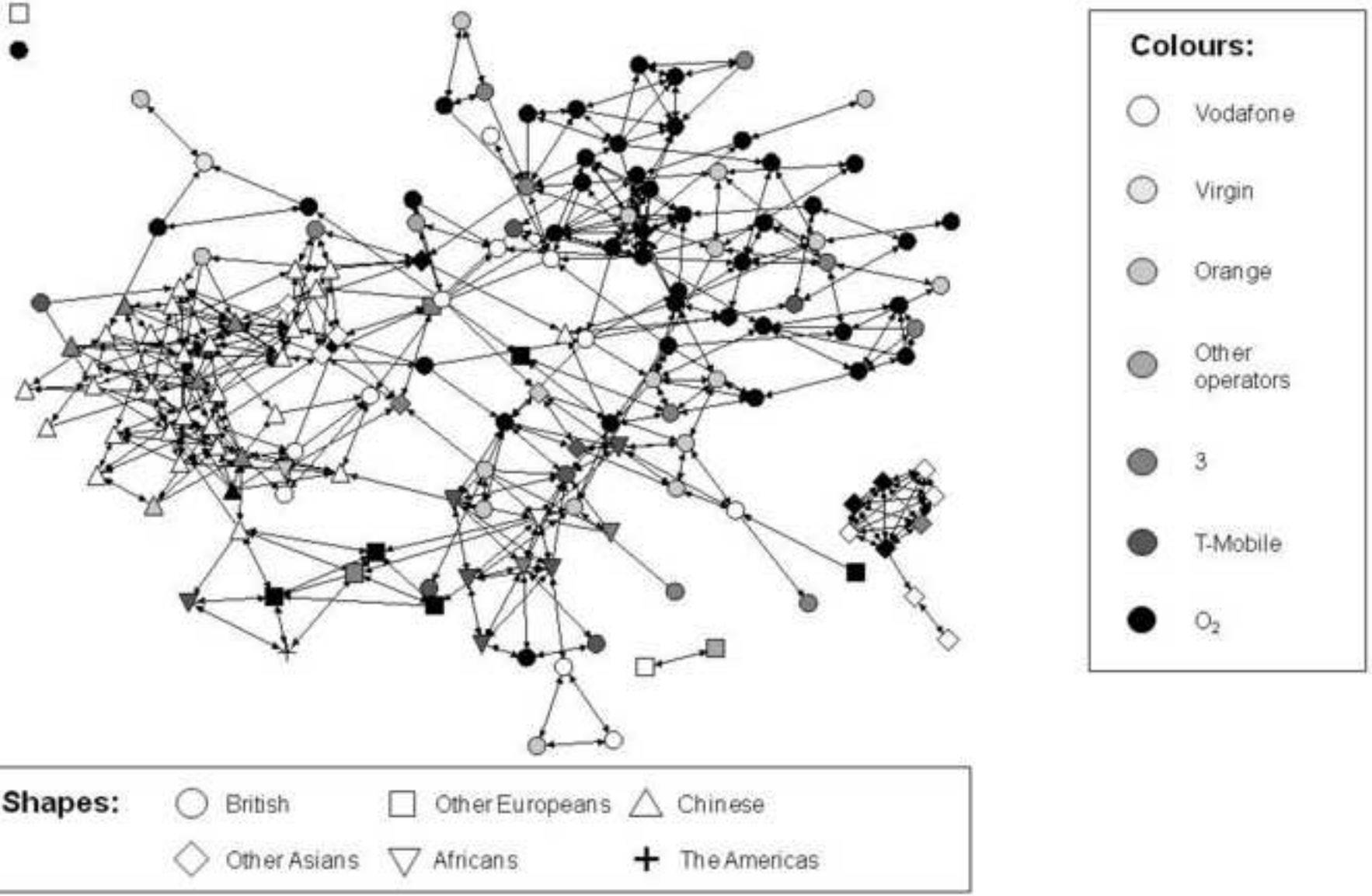
Figure 1 Interaction network of students (UK 2005)



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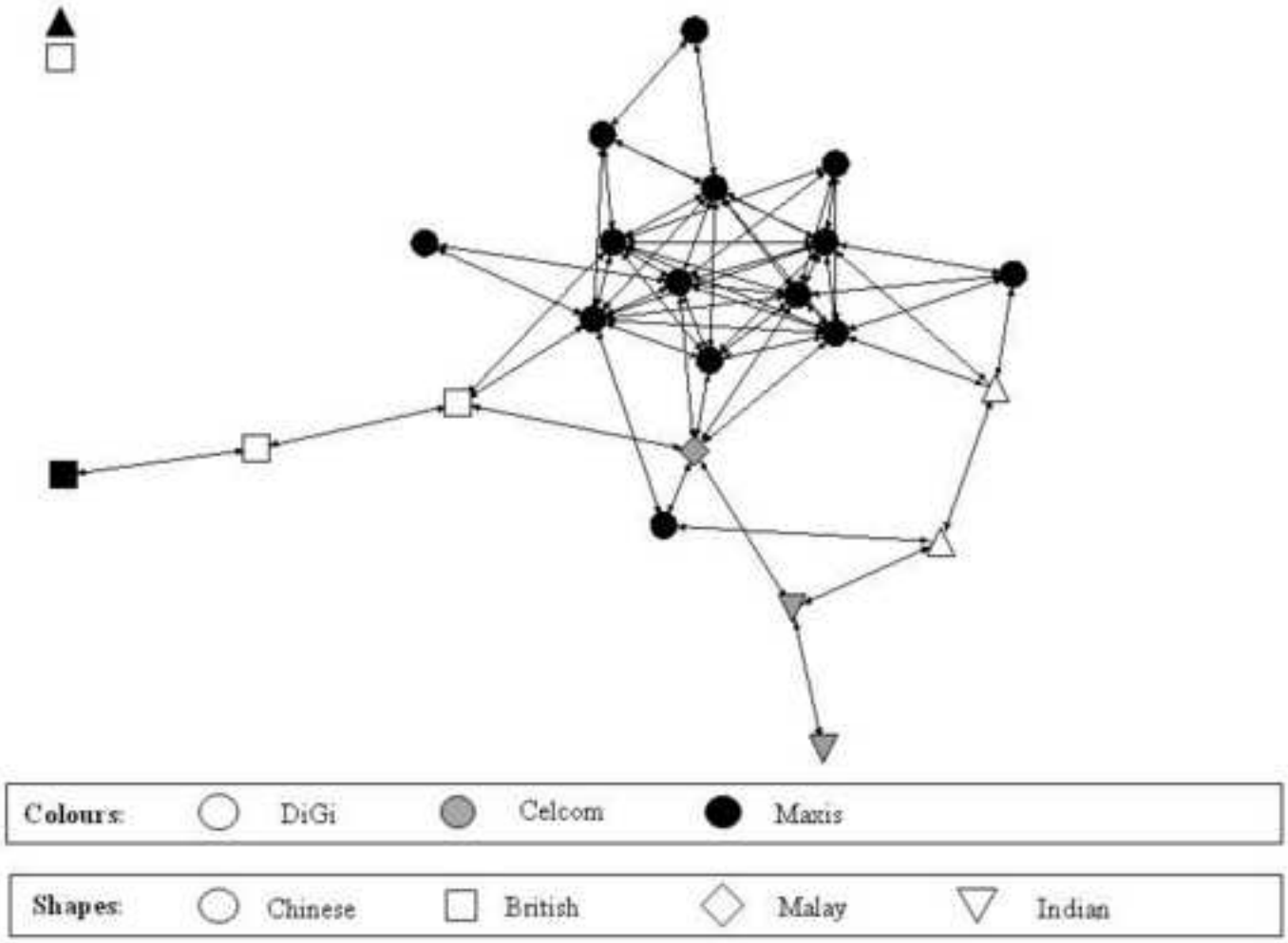

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