Modelling the Telecommunication Market

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Abstract

Managing a telecommunication company requires, among others things, to evaluate the consequences of different alternatives to interconnection agreements and also design policies to improve profits from incoming calls. Product pricing and capacity acquisition are complex issues, because competitor's assets are complementary, as they bring more people to call and more calls back. Economies of scale and scope are also present because high investments are involved and firms trade between leaving "money on the table" or optical fiber underground, as market saturates. The conditions for the misperception of feedbacks, ***MOF,*** *are all present (Sterman 1998), exacerbated by call back misperception* ***COM,*** *when outgoing calls bounce back from other networks; so, additional charges to compensate expenses for calls terminating elsewhere, unexpectedly deteriorate net revenues. In order to understand this complexity a System Dynamics model of the telecommunication market was constructed, where customers choose among alternatives to call, mobile and fixed operators grow, merge, offer services and set prices. Regulators control prices for call termination and fixed telephony. Model generates profits, levels of consumption and surprises. Calling Party Pay billing practice is assumed, but it is easy to adapt the model to RPP (Receiving Party Pays) billing. The model is implemented in Vensim with data gathering in Microsoft Excel spreadsheet linked to corporate databases.*

Economy applies optimization, which is a powerful tool when used as a module of a SD model. Otherwise, it does not go beyond sub optimization: better parts and worse whole. But, Economy helps to choose the variables and table functions in the system and System Dynamics fine tune economic models to specific problems. Both disciplines work together to improve understanding of socio economic systems; so, changes are focused toward high leverage variables.

Economic models are useful, as long as System Dynamics never give up being the Fifth Discipline.

(Simulation, telecommunication, market, wireless, socioeconomic)

Industrial Dynamics was originally conceived to model a problem, but in the seventies Jay Forrester starts modelling a system: the National Model of US Economy. Such initiative improves the discipline, because the adopted system approach promotes the inclusion of levels and links that are not necessarily part of the problem but they are part of the solution.

Economy considers managers and customers as profit or utility maximizers; but, alternative behaviors are studied by System Dynamics; so, economic solutions are fine tuned to real operations. In the economic systems, variables and table functions have definite forms, although they are not meant to solve specific problems.

The supply and demand of telecommunication services are simulated. Elasticity and substitution parameters are calibrated. Marketing decisions are modelled, clients of different operators grow, prices for outgoing and incoming calls are set, monthly profits and minutes of consumption are calculated.

There are a lot of SD models regarding telecommunication business, but none that I know off address the problem of interconnection explicitly; however, their ideas certainly influence this work.

The model is implemented in Vensim, with data gathering from Microsoft Excel spreadsheet linked to corporate databases.

The Market Sector

Several operators participate in the Telecommunication Market offering fixed and mobile services. Customers of any operator may call to competitor's clients.

Operators expand capacity in order to preserve service quality at peak time. Usually, periods of expansion are followed by periods of lower prices, as operators use their spare capacity to attract new clients (Evans 2000, Baumol 1994). Feedbacks due to network positive externalities (Arthur 1994) are explicitly modelled.

A price is charged per outgoing minute to the party who makes the call, **CPP**. However, other billing practices charging calls to receiving party, **RPP,** are also used by mobile operators. Calls originate in an operator **i** and terminates in operator **j**. Demand is represented by monthly consumed minutes**, Mij**, from operator **i** to **j**.

Revenues for outgoing calls of the operator **i** are: **RO**i **= SUM(M**ij***P**ij **),** where **P**ij is the price per minute of the call from **i** to **j.**

Interconnection Charges

There is a price, **I**ij, for call termination from **i** to **j**. Thus, **j** receives a payment for every minute that ends in its network. Naturally, **I**ii is zero because the call is internal.

There are minutes from the rest of the operators that end in **i**. Those minutes pay a toll to terminate the call in **i;** so**,** revenues also come from incoming calls:

RIi = SUM (**M**ji***I**ji), where **I**ij is the charge to terminate a call from **j** to **i**.

Charges for call termination **I**ij are negotiated between operators as a part of the interconnection agreements. Sometimes, there is a different peak and off peak rate. Usually, long distance calls are part of the deal. The **I**ij pricing is a critical issue in the company survival (Salanie 1999).

The economic problem of improving profits is more complex than making our own decisions; because growth and prices set by competitors also affect our own results. Besides, there is a trade off between short and long term performance.

Customer Call Decision

Customers make calls influenced by **P**ij prices and their preferences (Laffont 2000).

Cheaper fixed to mobile calls substitute mobile to mobile when possible. From the cost perspective the fixed mobile route use only one voice channel and the mobile mobile use two voice channels; therefore, calls fixed to mobile are cheaper than mobile to mobile. Elasticity and substitution parameters regulate those effects.

The following influences are explicitly considered:

Change in Clients From

More clients from, increase calls to other operators.

Change in Share To

The outgoing minutes from **i**, may go to several destinations **j**. More called client's fraction implies more minutes going to them. So, **Mij** minutes increases when **j** market share increases.

Change in MOU From

Usually higher consuming clients are enrolled first. As the penetration or % of clients is increased, the new clients tend to consume less. Therefore, the Minutes of Use per client per month, **MOU**i**,** decreases with penetration. As the company grow, the consumption per client goes down.

Changes in Price Gap From To

There is a gap between the call price from a mobile phone and the same call made from a fixed phone; usually, mobile to mobile calls are more expensive. Therefore, when possible, a fraction of mobile to mobile calls are substituted by fixed to mobile alternatives.

Changes in Price From To

Higher prices decrease the number of calls from to.

Minutes From to

Clients of company **i** call **M**i minutes a month to all destinations **j**, the minutes from **i** to **j** are **M**ij. Therefore,

$$M_i = SUM(M_{ij}), \text{ for all } j \text{ destinations.}$$

But, $M_i(t) = N_i(t) * MOU_i(t)$,

Where, **Ni** is the clients of company **i**, and **MOU**i are minutes per month per client.

In general, $M_{ij} = M_i * f_j$, where **f**j is the fraction of minutes coming from **i**, that goes to **j**, if prices and preferences are equal to all destinations; then, the fraction of outgoing minutes from **i** to **j** is similar to **j**´s market share**:** $f_j = MS_j = N_j(t)/N(t)$, however, customer preferences may require a correction factor, **Pref** ij,

So, outgoing minutes from **i** to **j**, at time t are:

$$M_{ij}(t) = N_i(t) * MOU_i(t) * (N_j(t)/N(t)) * Pref_{ij}$$

Where, **N(t)** is the total number of lines.

At **t-1** :

$$M_{ij}(t-1) = N_i(t-1) * MOU_i(t-1) * (N_j(t-1)/N(t-1)) * Pref_{ij}$$

So,

$$M_{ij}(t) =$$

$$M_{ij}(t-1) * (N_i(t)/N_i(t-1)) * (N_j(t)/N_j(t-1)) * (MOU_i(t)/MOU_i(t-1)) * (N(t-1)/N(t))$$

Or $M_{ij}(t-1) * Growth_i * Growth_j * Growth\ MOU_i / GrowthMarket$

Minutes from to grow with origin, destination, **MOU** and decrease with market growth. Note that **Pref** disappears imbedded in **M**ij. So, calls´ inertia rises minutes, as shares and consumption grow.

Price Elasticity and Substitution

The quantity of minutes from **i** to **j**, **Q**ij, depend upon changes of price **P**ij. Lower prices increase calls. Duration of calls increases with flat rates, but it is relatively insensitive to price changes. Some calls made from mobiles are substituted by calls from fixed, at higher price gaps between mobile_mobile and fixed_mobile.

Let **Alfa** be the price elasticity and **Beta** the substitution elasticity.

Let the sub index 2 designates the fixed network.

Substitution at Call Destination:

$$Q_{ij} = M_{ij} * (\text{Factor Price}) * (\text{Factor Substitution})$$

Qij = Mij*(Price(t-1)/Price(t)) ^ Alfa * (PriceGap(t-1)/PriceGap(t)) ^ Beta

Qij = Mij *(Price(t-1)/Price(t))) ^ Alfa * ((P(t-1)ij / P(t-1)2j)/ (P(t)ij / P(t)2j)) ^ Beta

Fixed network is represented by 2. If i=2, then the formula reads:

Qij = Mij *(P(t-1)2j /P(t)2j) ^ Alfa

So fixed network elasticity has no substitution effect.

Mij(t) = Mij(t-1)* (Ni(t)/Ni(t-1))* (Nj(t)/Nj(t-1))* (MOUi(t)/MOUi(t-1))*

(N(t-1)/N(t))(P(t-1)ij /P(t)ij) ^ Alfa * ((P(t-1)ij / P(t-1) 2j)/ (P(t)ij / P(t)2j)) ^ Beta

Mij(t) = Mij(t-1)*(Ni(t)/Ni(t-1))* (Nj(t)/Nj(t-1))* (MOUi(t)/MOUi(t-1))*(N(t-1)/N(t))*

(P(t-1)ij /P(t)ij) ^(Alfa+Beta)(P(t)2j / P(t-1) 2j)^Beta

Fixed to Mobile calls substitutes Mobile to Mobile calls, when possible and cheaper.

But there is also a substitution at the origin; so, calls Mobile to Mobile are also substituted by Mobile to Fix, when possible and cheaper, especially indoors.

Mij(t) = Mij(t-1)*(Ni(t)/Ni(t-1))*(Nj(t)/Nj(t-1))*(MOUi(t)/MOUi(t-1))*(N(t-1)/N(t))*

(P(t-1)ij /P(t)ij) ^(Alfa+Beta) * (P(t)2j / P(t-1) 2j) ^ Beta1* (P(t)i2 / P(t-1) i2) ^ Beta2

Beta1 and **Beta2** are not necessarily the same; but, empirical evidence rejects the hypothesis that they are different.

In general, the minutes called from **i** to **j**, **M**ij change with time. From time, **t-dt**, to time **t**, has the following influences:

Mij(t) = Mij(t-dt)* ChangeInClientsFrom*ChangeInShareTo*

ChangeInMOUfrom*ChangeInPriceGap/(ChangeInPriceGapTo*ChangeInPriceGapFrom)

Alternative Formulation to the Relationship between Variables

Economist usually represents the influence from X to Y as:

$$Y(t) = Y(0)*(X(t)/X(0))^E,$$

Where, **E** is the elasticity of the transmission of the changes from **X** to changes in **Y**. When there are many **X´s**, like in the Cobb_Douglas function, factors are multiplied to make production.

This formulation is entirely equivalent to the following one, where products are turned into sums:

$$dY/dt = Y*E* (dX/dt)/X = Y*E*\text{Fraccional Change Of } X$$

This formulation is more appropriated for SD models, because it makes explicit that **X** and **Y** are levels, so they may interact with each other by a dynamic usually missed in economy

For instance, the Cobb_Douglas production function uses labor and capital as factors. James Lyneis 1980, describes how labor and capital interact to make production, a whole lot of possible behaviors emerge from labor and capital being levels whose incoming and outgoing rates are explicitly linked resembling the real productive activities.

In vensim, the previous expression reads, using **company** sub index to name operators:

The sub indexes **from** and **to** have to map to company, **company<-> from** and **company <-> to**

```
Change Price [from, to] =
        (New Price[from,to]-Prices[from,to])/TimeToPerceivePrice
        ~
        ~               |
FractionalChangeOFprice[from,to]=
        ChangePrice[from,to]/Prices[from,to]
        ~
        ~               |
ChangeOfMinutes[from,to]=
             - FractionalChangeOFprice[from,to]* (Alfa+ Beta)
             + FractionalChangeOFprice[fixed1,to]*Beta
             + FractionalChangeOFprice[from,fixed1]*Beta
             + FractionalChangeOfMOU[from]
             + FractionalChangeOfClients[from]+FractionalChangeOfClients[to]
             -  FractionalChangeOfTotalClients
                ~~|
```

Personal consumption MOU falls with penetration, **TotalClients/Population**, clients grow at lower prices but fall with penetration, so the factors are far from being independent, a bunch of interactions are present.

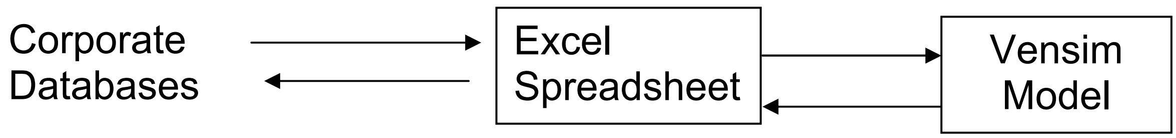
Alfa and **Beta** are calibrated to fit historical data.

Monthly consumption **MOU**i, is the average duration of the call multiplied by the number of calls, **MOU = Duration*Calls**, where calls are sensitive to average per minute price, and **Duration** is sensitive to marginal per minute price. So, flat rates encourage longer calls. **MOU** is Gamma distributed with parameters **Duration** and **Calls,** where **calls = (MOU/Duration)**.

Telecommunication budget is a fraction of personal income, so when income increases more calls are made. Therefore, calls tend to follow a statistical Paretto distribution function, where, at higher prices fewer calls are made. The duration of the call tend to follow an exponential distribution, at lower marginal prices the length of the call increases. Price is usually organized in a monthly rent, a cost per minute and a lot of free minutes. The average price is revenues divided by minutes. The marginal price is the cost per additional minute. The Duration of the call is important because longer calls tend lo decrease service quality in mobile services. The scarce resource is spectrum, longer calls occupy frequencies for more time, so they are not available when new calls arrives. Calls are interrupted when a person call from a moving object, because the phone needs a new frequency in the next base station.

The model

The model receives data from the company databases to an Excel spreadsheet, and then they are read by the vensim model.



It may sound complicated the lot of sub indexes used in the paper, but interconnection requires the identification of the origin and destination of calls. In Vensim the model is very simple, because its power to handle sub indexes.
The model has two views, the economic and the financial. In the economic view, customers (demand) choose among alternatives offered by operators (supply). However, instead demand or supply being a simple downward or upward slope curve, it is a complex dynamic matrix of possibilities, where the choices of customers and services offered by operators unfold into unexpected paths to the future. How your prices, growth, consumption patterns, investments and other factors affect competition and how competitors´ decisions affect your results, build a difficult game to play. Model allows managers understand traffic data, to respond the moves of competition.

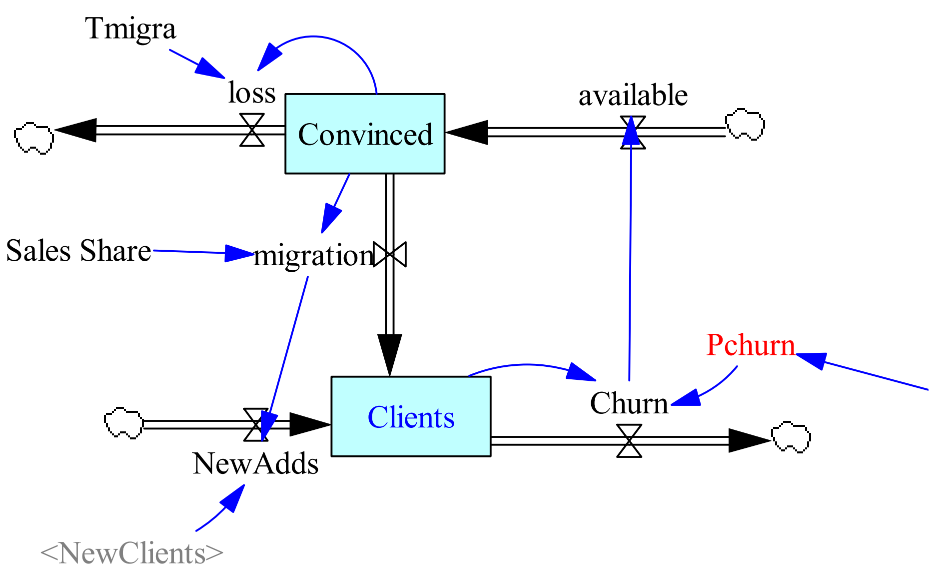


Figure 1. Growth, Penetration and Consumption

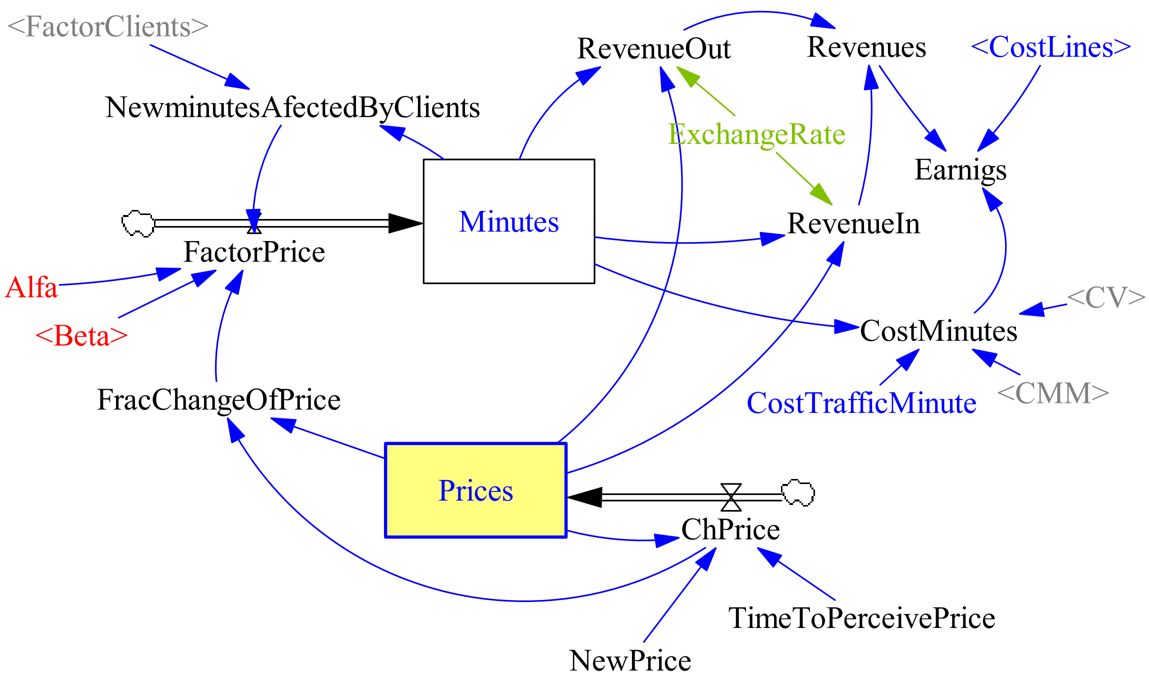


Figure 2. Prices, Minutes From To, Revenues and Costs

Customers enter into the system either from the population or from the pool of former customers of any of the operators. Customers leaving one operator may switch to another one or return to the original, depending upon actual sales effort. (Barron 1998). New customers consume less than old ones; so, per capita average consumption **MOU**i for any operator i goes down as penetration increases. Prices from_to affects the monthly consumption **M**i for any operator **i**. Minutes and prices make revenues, minutes and clients make costs, profits measure the consequences of decisions.

Four mobile and two fixed operators are considered, but the model can be extended to almost any number of operators. Elasticity fits real data using non linear parameter calibration. The model has been used to design interconnection contracts, to study business cases, to design prices for calls and to assist players in the telecommunication game.

Policy Design

Managers set prices for From_To calls, and control growth in fixed and mobile services. The more desired growth, the higher the advertising and customer acquisition cost. But new customers consume less; so, there is a profit trade off, to what point more people is better. Lower prices from_to, encourages outgoing calls to and increase incoming calls from; but, decrease outgoing revenues and increase costs. Lower fixed to mobile prices increase fixed to mobile traffic; but, it substitutes mobile to mobile calls.

Low mobile to fix price is surprisingly found to be a powerful lever to increase profits. It improves fixed penetration, because mobile behaves like a fixed phone when calling to fix. So, mobile phone satisfies for new fixed lines and saves money on the last miles (Vogelsang 1997); in addition, call back from fixed networks increases revenues.

One of the mobile competitors charges a 30% premium to call other operators to compensate for the interconnection charge when calls terminate elsewhere. As a result, outgoing calls went down, incoming calls from other operators also went down. Thus, revenues decrease 17%. Model shows that this strategy is wrong, because it closes the stable door with the horses outside.

Economy applies optimization, which is quite powerful when used as a part of a SD model. Otherwise, it does not go beyond sub optimization: better part and worse whole.

Jay Forrester enhances the scope of System Dynamics, when he calls a system to solve a problem and challenges the clouds to make room for improvements.

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