Adoption and Discontinuance of Innovations

Javier Palacios Fenech

TESI DOCTORAL UPF / 2011

DIRECTORS DE LA TESI

Prof. Michael Greenacre

Prof. Nick Longford

Dipòsit legal:
ISBN:

A la meva familia.

Acknowledgments

This research project would not have been possible without the support of many people.

First of all, my sincerest gratitude to my supervisors Michael Greenacre and Nick Longford; they provided me with the necessary support throughout my thesis. I would like to thank them for their expertise, understanding, patience and assistance. I appreciate that they allowed me the liberty to work and develop this study, for this encouraged me to pursue with this thesis. It has been a real pleasure to have worked with such a friendly and stimulating supervision.

I am specially grateful to Antonio Ladrón for his knowledge and assistance at all levels of the research project. Without him this study would not have been successful.

It is an honor for me to have received the suggestions and help from Rosanna Garcia and Gerard Tellis, who showed interest in my work and encouraged me during the last phase of my writing. I highly appreciate the assistance received from Stefan Stremersch, and his kind invitation to attend to his PhD seminar on quantitative marketing at IESE Business school and the Tinbergen Marketing Research Camp at Erasmus University, which have been very instructive.

Many professors have contributed to my personal and professional growth during this years at UPF, through their course and seminars. I have specially enjoyed and learned from Benito Arruñada, Michael Bashshur, Gert Cornelissen, Javier Gil-Bazó, Robin Hogarth, Marc Lemenestrel, Jens Josephson, Helena Ramalhinho, Willem Saris and Kalyan Talluri. My gratitude to Albert Satorra, for inviting me to a course on modern computing with R at IDEC. And I am grateful to Gaël Le Mens for providing me good references about survival analysis.

I will always cherish the company and friendship of colleagues that I have met during my PhD studies. It has been a pleasure to share time with you. I owe a special thank to Piya Sereevinyayut for his guidance and assistance in my early steps with programming.

I recognize and express my gratitude for the financial assistance received from Universitat Pompeu Fabra which allowed me to conduct this research, and want to thank the tremendous support obtained from the GPEFM office; specially, from Marta Araqué.

Outside of the research world, I would like to thank my parents and extended family, specially to Manu. And with my greatest gratitude, my loving thanks to Nicté!

Abstract

Diffusion of 31 durable goods in 70 countries over a period of 32 years is analyzed using principal component analysis biplots. While marketers have focused on adoption of innovations, studying discontinuance provides an opportunity to explore the needs of the market and create a more sustainable approach to marketing activity. Discontinuance, disposal and dispossession are defined: Discontinuance is studied from a technology-centered point of view, and disposal and dispossession from an object-centered and a people-centered point of view. The discontinuance process is divided into five categories, and its relation to the adoption process is studied. Dive is a sudden increase in the rate of discontinuance of durable goods. A hidden incubation time which affects time-to-dive and may cause an over-prediction is found for every type of product category. Applications and extensions of these findings on products entering the decline stage of their life-cycle are discussed.

Resum

La difusió de 31 béns duraders a 70 països durant un període de 32 anys es analitzada utilitzant biplots basats en l'anàlisi de components principals. Mentre que els investigadors de màrqueting s'han centrat en l'adopció d'innovacions, l'estudi de la discontinuació proporciona una oportunitat per explorar les necessitats del mercat i crear un enfocament més sostenible a l'activitat de màrqueting. Es defineixen la discontinuació, la disposició i la despossessió: La discontinuació s'estudia des d'un punt de vista centrat en la tecnologia, i la disposició i la despossessió des d'un punt de vista centrat en l'objecte i les persones. El procés de discontinuació es divideix en cinc categories, i s'estudia la seva relació amb el procés d'adopció. La inmersió és un augment sobtat en la taxa de discontinuació de béns duraders. Es troba un temps d'incubació amagat que afecta el temps d'immersió i pot causar una sobre-predicció de temps d'inmersió per a cada tipus de categoria de producte. Es discuteixen les aplicacions i extensions d'aquestes troballes sobre els productes que estan a la fase de declivi del seu cicle de vida.

Foreword

What started as an exploratory exercise using statistical techniques for Prof. Greenacre's course *Methods of Marketing Research* in the Master of Science in Management at Pompeu Fabra University, and the *R-club*, coordinated by Prof. Longford, has become a dissertation that explores an unattended research area, the rate of discontinuance, due to an important bias in diffusion research: *Pro-innovation bias*. This bias, defined in the introduction of the first chapter, has several negative consequences. First, products are only designed for their useful life, and sometimes this is shortened with planned obsolescence schemes, in order to stimulate sales. This creates environmental hazard and an excessive use of limited resources which is profitable to companies in the short term, and which authorities have already started to regulate. Second, the dynamics of the decline stage of a product are not well-addressed in diffusion research. There is a confusion in the terminology, and maybe more importantly, there is not a clear understanding of what kind of factors affect the end of life of technologies. The lack of understanding of these dynamics has clear strategic implications that may affect directly the overall performance of a company.

The first chapter of this thesis, *Learning about the international diffusion of durable goods*, uses a large data set that includes the diffusion process of 31 durable goods from 1977 until 2008 in a set of 70 of countries. These data are analyzed visually using different types of graphs. This approach provides a unique opportunity to explore the way products diffuse. Principal component analysis biplots are used to answer traditional questions about international diffusion of innovations, but are also helpful to raise new questions. For instance, how products that are immersed in an adoption and a discontinuance process in different countries simultaneously are related? What kind of factors affect the rate of discontinuance? How can a rapid decline of a product's level of penetration be detected?

The following two chapters of the thesis address these and related questions. The second chapter, *The rate of discontinuance*, defines and discusses the meaning of the terms used for characterizing the end of life of a product: disposal, dispossession and discontinuance. It explains the relation between the types adopters and discontinuers based on (Rogers 2004), and how they affect the rate of penetration of a product. By using the Bass model, factors that affect the internal and external influences of the international rate of discontinuance of black-and-white television sets are explored. Also, the different characteristics of a household across countries that affect the level of penetration of black-and-white television sets are studied.

The third chapter, *Time to dive*, introduces a new method to detect a sudden decline of the level of penetration of durable goods based on the methodology of time-to-takeoff (Golder and Tellis 1997). Three products, starting their discontinuance process between 1977 and 2008 are used to test this method: Black-and-white televisions sets, cassette-radio players and CD players. A *hidden incubation time* that may affect the prediction of the remaining life of a product is found.

In summary, these three chapters complement the extant marketing literature about diffusion of innovations by overcoming pro-innovation bias, and call for further exploration of the end of life of a product as a key element to the full understanding of diffusion of innovations. Recently, a call for a better understanding of key turning points was made. Peres et al. (2010) ask for further research on takeoff, saddles and slowdown. Turning points are becoming increasingly important because the popularity of many products is threatened by a fast rate of technological change. Following this thesis, dive and landing need also to be taken into account.

Contents

List of Figures

List of Tables

Chapter 1

Learning from the International Diffusion of Durable Goods

The spread of an innovation has been usually modeled using regression techniques, and in particular, the Bass model has served as a framework to predict the rate of adoption and to study its relation with market characteristics. Using principal component analysis biplots, the diffusion of 31 durable goods in 70 countries over a period of 32 years is analyzed. This well established technique allows to observe how the spread of durable goods in less-developed and emerging markets share similarities and differ from developed countries. New insights can be gained from results on issues that help managers aiming for new markets decide on their internationalization strategies. Biplots graphically show inter-country distances that are based on the relative diffusion rates, and inter-product relations, in terms of correlations and variances of their respective levels of penetration.

Key phrases: Diffusion of Innovations, Principal Component Analysis, Rate of Adoption, Rate of Discontinuance, Rate of Penetration

Introduction

This article uses a large data set to analyze the diffusion process of durable goods from 1977 until 2008 in a set of countries. It allows us to visually explore the patterns of diffusion of 31 consumer durable goods amongst 70 countries and extract patterns of correlation of products and similarities among countries based on the diffusion of durable goods. The methodology used is principal component analysis (PCA) biplots and its main purpose is to visually find interrelations between countries and products.

In the marketing literature, diffusion of innovations has been one of the most researched issues but diffusion research has suffered from two different types of biases. First, the so-called "pro-innovation bias". Its original definition is the following: pro-innovation bias is the implication in diffusion research that an innovation should be diffused and adopted by all members of a social system, that it should be diffused more rapidly and that innovations should be neither re-invented nor rejected (Rogers 2004, page 106). This bias has limited marketing scholars to learning only about the dynamics of rapidly spreading innovations. Other diffusion processes like discontinuance, rejection, slowly diffusing innovations, products at a maturity stage or product failures have been less addressed in the marketing literature (Black 1983, Prins et al. 2009). Second, most articles have ignored developing economies, with very few exceptions (Dekimpe et al. 2000b, Talukdar et al. 2002, Desiraju et al. 2004, Kauffman and Techatassanasoontorn 2005, Sood et al. 2009). Amongst such countries, the so-called emerging economies are of special interest to firms that need to decide to which markets enter and allocate their limited economic and human resources, and how the life-cycle of products and markets evolve in these countries (Arnold and Quelch 1998). Furthermore, this study follows recent recommendations on new product and innovation management and international marketing (Guo 2008, Burgess and Steenkamp 2006), which propose that emerging countries represent a rapidly growing potential. It has been claimed that emerging markets are catching up and that there is a consumption convergence between developed and developing markets (Waheeduzzaman 2006, 2011).

In this article, both biases are overcome with the purpose of exploring the interrelations between countries and products from a global perspective. Including not only innovations allows us to explore how countries move from the discontinuance of certain products to the adoption and maintenance of other ones at different rates. From the 31 products that are analyzed in this study, eight appeared after 1977, and only they can be considered innovations for this time span. The 70 countries used in the analysis include all types of countries: developed, emerging and less-developed, and from all continents.

In diffusion of innovations the main issue has been to try to describe the shape of the sales curve at different stages of the launch of an innovation. It has been hypothesized that several factors may have an effect on the speed of adoption of a product and different modeling techniques have been used to understand this phenomena (see Peres et al. (2010) for a recent review.). The use of a model, particularly the Bass model (Bass 1969), has helped to understand the internal and external influences in a social system that affect the growth of a product. While it has been claimed that diffusion research in an international context has so far not produced any results that might challenge international marketers' wisdom (Krishnan and Thomas 2009), it has also been claimed that it has helped to understand complex diffusion processes (Peres et al. 2010, Chandrasekaran and Tellis 2007). Therefore, international diffusion of innovations is an area that needs further exploration with new methods. Current literature will benefit from this essay because with biplots (Greenacre 2010), an extension of a scatter plot with more than two variables, it is possible to study the relations among countries based on the diffusion of many durable goods at the same time. That is, with PCA (Jolliffe 2002), and especially the use of biplots, we can explore the patterns of rates of penetration and provide a visual interpretation of the interrelation among countries and products.

This article provides a global perspective of diffusion of durable goods which is not constrained to the strict assumptions of traditional diffusion models. On the contrary, the approach used is *letting data speak* (Volpato 2011). That is, through the use of dimension-reducing and careful graphical displays, a description is attained of the useful information in a large multivariate data set. Using this particular method, managers will be able to visualize the penetration of durable goods from a new perspective. In particular, how countries have been competing for different products at the different stages of their technology evolution for the last three decades. Certain countries, because of their particular social characteristics, have tended to adopt more a particular type of good, which in certain cases has created a new cultural acceleration. For instance, this is the case of satellite television sets and access to internet in Arabic countries. In other cases, a singular country characteristic, like climate, allows a product to have more variance among countries. For instance, this is the case of air conditioners, with a higher level of penetration in warmer countries than in colder ones. In general, however, a general ranking based on diffusion levels can be extracted and is highly correlated with the wealth of nations. PCA biplots allow us to see distances among these countries developing at a high speed. These distances have particular properties that allow us to extract new conclusions about the global diffusion of durable goods.

The following sections of this article are organized as follows. First, the related theoretical framework for international diffusion of innovations is outlined. Second, a description of the data set analyzed and a brief discussion on how it is adapted to be suitable for PCA is presented. Third, main results of the PCA of the international diffusion of durable goods are described. And finally, implications of these results and some possible extensions of this work are discussed.

1.1 Theoretical Framework

From a diffusion point of view, Chandrasekaran and Tellis (2007), Krishnan and Thomas (2009) and Peres et al. (2010) provide a recent and complete review of the literature on international diffusion of innovations. Current research on international diffusion of innovations is mainly concerned about describing and predicting the rate of adoption over time of a new product in different markets. This research has mainly tried to answer three traditional key questions: (1) does the diffusion process differ across countries and are these differences attributable to socioeconomic and cultural characteristics? (2) are there any differences in adoption timing and take-off periods that are attributable to socioeconomic and cultural characteristics? and (3) what is the inter-country diffusion impact? (Krishnan and Thomas 2009, Peres et al. 2010).

This type of research has historically suffered from various limitations (Mahajan et al. 2000). First, from a limited geographic scope, since it has mainly dealt with data sets from a limited set of industrialized countries. In this data set, countries in all stages of development are represented and some parallel research is also starting to address this issue. For instance, the diffusion of mobile phones has provided with new data sets that are being used by academic researchers to understand its distinct patterns of utilization (Kumar et al. 2007, Varadharajan 2007, Koski and Kretschmer 2007, Beise 2004, Banerjee and Ros 2004, Dholakia et al. 2004, Kauffman and Techatassanasoontorn 2005, Kamssu 2005, Andonova 2006, Baliamoune-Lutz 2003, Rouvinen 2006, Iyengar et al. 2009). Nonetheless, caution on their findings is advised since mobile phone penetration measures might be unreliable in these countries due to poor industry data, prepaid vs. postpaid deals or other schemes (James and Versteeg 2007, Iyengar et al. 2009, Mahajan 2009). Chircu and Mahajan (2009), describe how diffusion of mobile phones occurs in BRIC countries and how these countries have special usage characteristics, that are unlikely in developed economies, and might affect their diffusion patterns.

Second, even though durable goods is the most researched type of goods analyzed, many different types of durable goods are analyzed here, offering a new point of view of globalization potential and adding a great amount of information to current research. Talukdar et al. (2002), include countries from six continents and study the diffusion of six consumer durable goods. They report effects on potential penetration of country characteristics like purchasing power, international trade or level of urbanization. Waheeduzzaman (2006) includes six durable goods in 24 emerging economies, and Waheeduzzaman (2011), include four durable goods. Sood et al. (2009) use a data set comprising 21 products and 70 countries. And Lemmens et al. (2011) use six product categories across 79 countries.

Third, diffusion of durable goods has been analyzed mainly with the help of diffusion models, such as the Bass model, with an objective to forecast future sales or to test hypotheses about coefficients of innovation and imitation, and less research has been done from other perspectives (e.g., from a normative perspective (Kalish et al. 1995)). An important contribution of this analysis is that, consistent with previous literature, it is very easy to visualize diffusion processes and how they are related to the level of development of countries. However, the level of development of a country does not have a unique measure (Arnold and Quelch 1998, Burgess and Steenkamp 2006). For instance, what is an emerging economy is not clear, although a common characteristic of these countries is fast economic growth and industrialization (Barro and Sala-i Martin 2004). In this article, countries are classified into five categories according to income. These five groups of countries are created based on their gross domestic product (GDP) per capita at purchasing power parity (PPP) in 2008. This classification is supported by previous literature of diffusion of innovations, in which the factor that turns out to be relevant in many studies analyzing differences among countries in the diffusion process is GDP calculated as a per capita measure. This measure is found to be related to initial adoption, diffusion speed and penetration ceilings. Dwyer et al. (2005) find that wealth is positively related to the rate of technological diffusion. Likewise, a positive effect on growth *rate* and a negative effect on growth *duration* is found in Stremersch and Tellis (2004). Sundqvist et al. (2005) also find a positive effect of wealth on the potential level of adoption using the Bass model, and positive effects are also present on diffusion speed and penetration level (Desiraju et al. 2004, Sundqvist et al. 2005). Talukdar et al. (2002) and Van den Bulte and Stremersh (2004) find a positive effect on the ratio of external and internal influences that affect the diffusion process using the Bass model. Other economic, social, cultural, marketing mix and media relations have been found but their effects are yet to be established (Krishnan and Thomas 2009, Peres et al. 2010). Another result relevant to international diffusion research is that lag countries have quicker takeoff and faster diffusion. Tellis et al. (2003) find that wealth has a negative effect on the time-to-takeoff but in a complete model using factor analysis find that time-to-takeoff is not affected by wealth. Takeoff is defined as *the time at which a dramatic increase in sales occurs that distinguishes the cutoff point between the introduction and growth stage of the product life cycle* (Golder and Tellis 1997). Dekimpe et al. (2000a) and Kauffman and Techatassanasoontorn (2005) find that wealth is positively related to the early transition rates defined as the time between the introduction of the technology in the world and the initial adoption by the country-under-focus which has a mixed effect on second stage transitions, defined as the time between initial adoption in the country-under-focus and its full adoption. Dekimpe et al.

(2000b) also find that wealthier countries adopt innovations earlier. The inter-country diffusion impact has been modeled by testing empirically how diffusion in a lag country, which adopts a particular technology later, is affected by a lead country adding a parameter that represents cross-country effects (Ganesh and Kumar 1996, Ganesh et al. 1997, Putsis et al. 1997, Kumar and Kirishnan 2002, Elberse and Eliashberg 2003, Van Everdingen et al. 2005, van Everdingen et al. 2009).

PCA allows us to visualize international diffusion of durable goods simultaneously for several products and markets. Relevant information about the breadth across markets and the depth within different markets of the diffusion processes of several durable goods can be extracted. This method provides a visual historical representation of what has occurred between 1977 and 2008 with international diffusion of household durable goods in a single biplot and it is also applied to subsets of countries with similar income and subsets of products based on their diffusion stage. The result of the analysis are similarities among products based on their global diffusion processes marketing literature and complements the marketing literature stream that groups products from different perspectives. Pickering et al. (1973) group a set of products based on consumer perceptions. Bayus and Carlstrom (1990) extend this study for durable goods. Kumar et al. (1998) cluster products based on their diffusion parameters in a cross-national diffusion research. More recently, Sood et al. (2009) use functional data analysis, which is also based on the idea of dimension reducing techniques, and it substantially improves the prediction of diffusion of durable goods. And Lemmens et al. (2011) use a semi-parametric Hidden Markov Model that dynamically segments countries according to the rates of diffusion of several innovations.

1.2 Data Set and Methodology

The data on product diffusion have been collected by a private market research company: Euromonitor International[1]. The company collects every year a considerable amount of relevant information on each product and service industry. It uses several sources of information: national statistics offices, online databases, international and national trade associations, store checks carried out by the company's network of analysts based in different countries, trade surveys, company analysis of annual reports and market analysis conducted in each country form part of their international research methodology. A data set that contains the rates of penetration of 31 consumer durable goods for 70 countries between 1977 and 2008 will be analyzed. The list of products analyzed and their acronyms can be found in **table 1.1**.

[1] http://www.euromonitor.com

Table 1.1: Products.

A–C		D–P		R–W	
Air conditioner	air.c	Dishwasher	d.w	Refrigerator	refr
Bicycle	byc	Freezer	fr	Satellite TV system	sat.TV
Black-and-white TV set	bw.TV	Hi-fi stereo	hfs	Sewing machine	sew.m
Cable TV	cTV	Microwave oven	mo	Shower	show
Camera	cam	Mobile telephone	m.tel	Telephone	tel
Cassette-radio player	c.r.p	Motorcycle	mc	Tumble drier	tu.dr
CD player	CD.p	Passenger car	car	Vacuum cleaner	vac.cl
DVD player/recorder	DVD	Personal computer	PC	Video camera	v.cam
Color TV set	col.TV	Internet enabled computer	net.PC	Video game console	v.gam
Cooker	cooker	Piano	pian	Videotape recorder	v.rec
				Washing machine	w.m

Note: List of 31 products used in the analysis with their respective acronyms.

The data set has is, therefore, in a three-way form, often called a data cube with time, product category and type of country. In the data set, each value represents the percentage of households of each country that possess at least one of the listed good. this value is referred as *level of penetration*. A data set overview is given in **figures 1.1 and 1.2** [2], but before proceeding to summarize its main characteristics, it is necessary to include a note on the diffusion terminology we use. The *rate of penetration* is the relative speed at which members of a social system change their level of penetration of a product, idea, or service. In our case, each country represents a separate social system. Three main types of products can be differentiated based on their rate of penetration: products that are clearly in a growth stage, which is the case of *innovations*, and it is possible to define their increasing rate of penetration as *rate of adoption*; products with a more or less constant level of penetration, that is, in a maturity stage, and these products are called *maturities*; and products that have a declining rate of penetration, that is, a *rate of discontinuance* and are called *discontinuances*. Innovations can be subdivided in two groups: *newer and older*. To simplify, in this article older innovations are products that were introduced in the market before the start of the time period (1977) used in this essay but still have a growth pattern, and newer innovations are products that have been introduced later. These definitions depend on the diffusion stages of a given product in a given market, and since differences in the macro-environment of each country affect the diffusion stage of each product, durable goods tend to be discontinued in some countries, where economic conditions are better, while in poorer countries these technologies are still in the growth stage.

Figures 1.1 and 1.2 provide us with the first overview of the rate of penetration of each type of

[2] A detailed view of the rate of penetration product by product and country by country is available in **figure 1.13** included in the appendix, with a dynamic plot (only visible with the digital version).

product. The 70 countries are classified into five categories according to their GDP per capita at PPP in 2008, and the lines in each panel of **figures 1.1 and 1.2** connect the annual rates of penetration of products. The list of countries inside each category is presented in **table 1.2**. The country with the highest wealth is Norway and the country with the lowest wealth is Nigeria [3].

Table 1.2: Categories of Countries.

Categories									
1		2		3		4		5	
Norway	NOR	Finland	FIN	Estonia	EST	Mexico	MEX	Colombia	COL
Kuwait	KWT	United Kingdom	GBR	Portugal	PRT	Bulgaria	BGR	Ecuador	ECU
Singapore	SGP	Germany	DEU	Saudi Arabia	SAU	Kazakhstan	KAZ	Ukraine	UKR
United States	USA	Japan	JPN	Slovakia	SVK	Romania	ROU	Egypt	EGY
Ireland	IRL	France	FRA	Hungary	HUN	South Africa	ZAF	China	CHN
Hong Kong	HKG	Spain	ESP	Latvia	LVA	Belarus	BLR	Jordan	JOR
Switzerland	CHE	Italy	ITA	Lithuania	LTU	Brazil	BRA	Bolivia	BOL
Austria	AUT	Greece	GLC	Poland	POL	Turkey	TUR	Morocco	MAR
Netherlands	NLD	Taiwan	TWN	Croatia	HRV	Turkmenistan	TKN	Indonesia	IDN
Canada	CAN	Israel	ISR	Russia	RUS	Azerbaijan	AZE	Philippines	PHL
Australia	AUS	New Zealand	NZL	Malaysia	MYS	Algeria	DZA	India	IND
Denmark	DNK	Slovenia	SVN	Chile	CHL	Thailand	THA	Pakistan	PAK
Sweden	SWE	South Korea	KOR	Argentina	ARG	Peru	PER	Vietnam	VNM
Belgium	BEL	Czech Republic	CZE	Venezuela	VEN	Tunisia	TUN	Nigeria	NGA

Note: Categories of countries based on gross domestic product per capita (GDP) at purchasing power parity (PPP). Acronyms based on ISO 3166-1 alpha-3: Three-letter country codes.

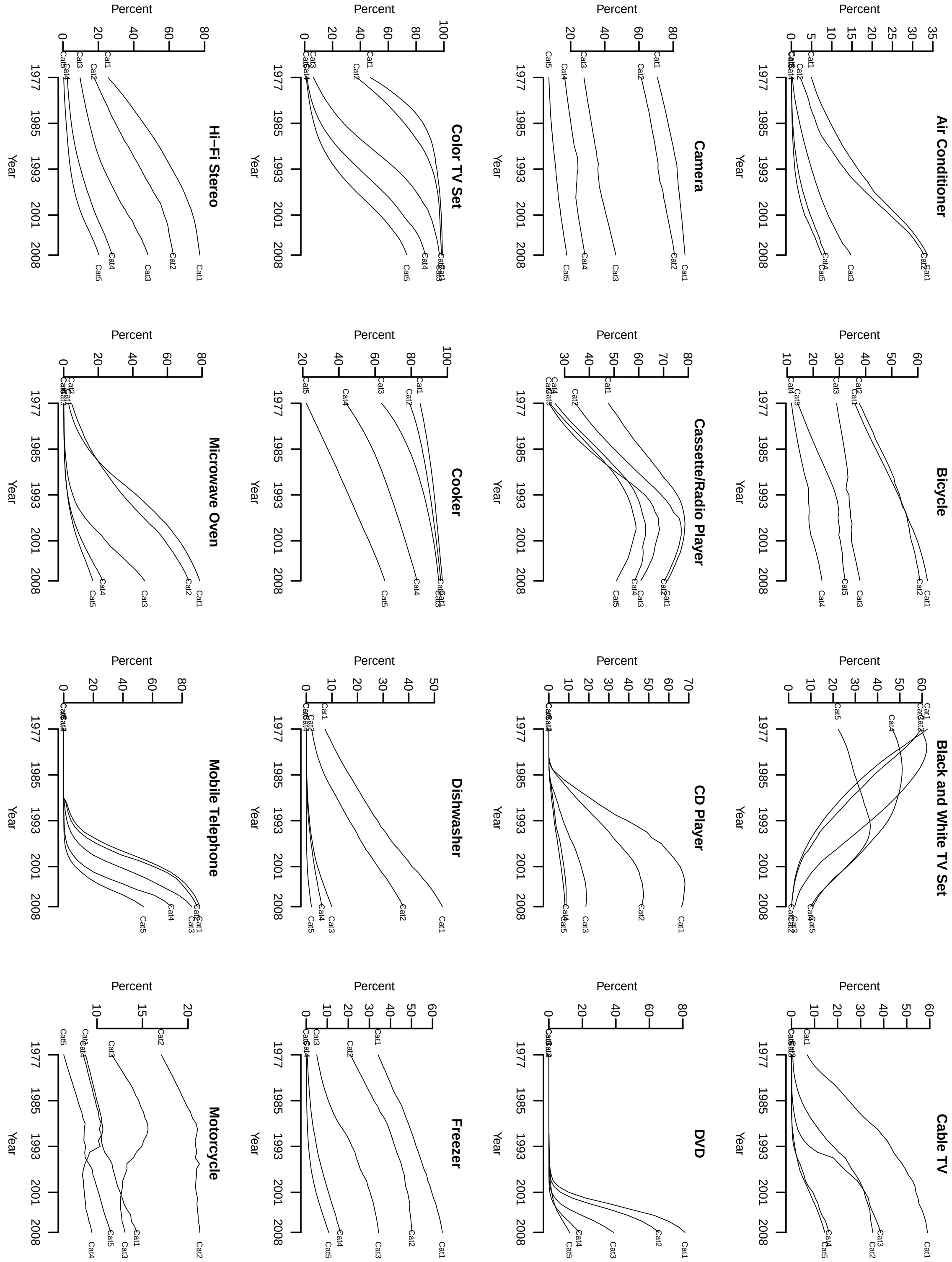
In the data set, there are some missing values. All missing values that exist before the introduction of a given product have been converted to 0% [4]. For Sweden, there is a missing intermediate value for Piano in 1994. In this case, the missing value is substituted by the mean of the values in 1993 and 1995 (linear interpolation).

Plots prepared in **figures 1.1 and 1.2** allow the observer to see how categories of countries interrelate according to a certain durable good. They clearly show the pattern of each of the categories of countries by product. Each category of countries is represented by a number. The value used in the graphs is the mean of the countries inside each category. For all the graphs the acronyms on the left represent the level of penetration of the product in 1977 while the the acronyms on the right represent the level of penetration of products in 2008. The line that connects these acronyms represent the rate of penetration from 1977 until 2008.

[3] In the lists of countries based on GDP per capita that are prepared by different organizations, such as the World Bank or the International Monetary Fund, Nigeria ranks around the third quartile. World's poorest countries, such as Zimbabwe, Congo or Burundi, are not included.

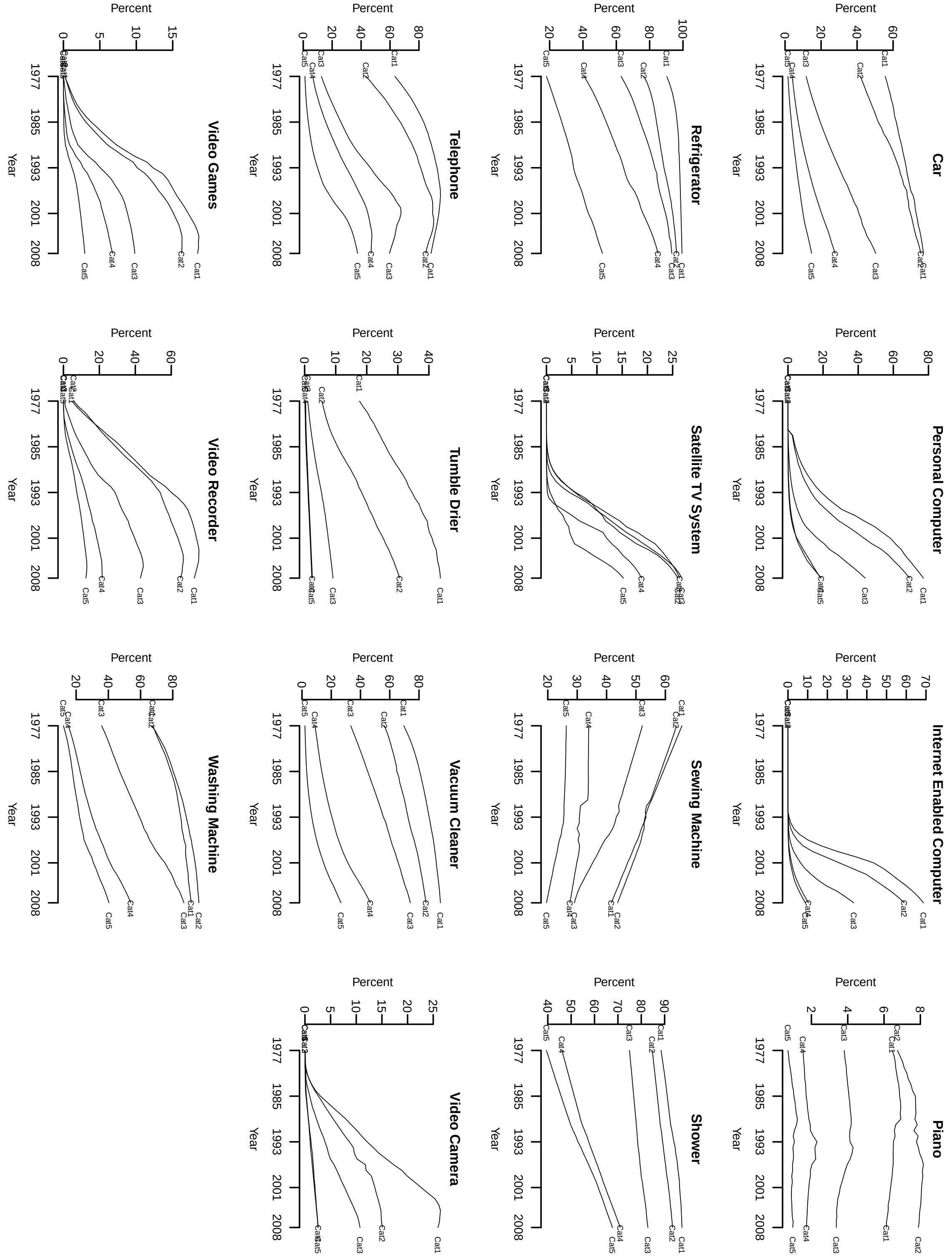
[4] 0% means that no one in a country had that specific product and it might be an erroneous assumption. They are rounded to 0% despite that for a given country (i.e. Canada), a given product (i.e. video game) and a given year (i.e.1977) some households may already have that product but it is not representative enough to be included in the analysis.

Figure 1.1: Rate of Penetration of Durable Goods (A–M).



Note: Percentage of households that have a durable good by categories of countries (Cat). Products from "Air Conditioning" until "Motorcycle".

Figure 1.2: Rate of Penetration of Durable Goods (P–W).



Note: Percentage of households that have a durable good by categories of countries (Cat). Products from "Passenger Car" until "Washing Machine".

For almost all products, the higher the GDP per capita the higher the level of penetration in their households of any product. There are a few exceptions: black-and-white television sets and sewing machines for the last years, and cable TV, motorcycle, satellite TV, piano, and washing machine for one category of countries.

Newer innovations stand out because they appeared on the market only after 1977. Some of them have faster rates of adoption than others. A good example is mobile telephones. In the case of video game consoles, however, the rate of adoption raises more slowly and a smaller percentage of households finally adopt this innovation. While some innovations simply diffuse at a greater speed to reach their maximum level of adoption in a few years, the vast majority need to be reinvented in order to continue their diffusion process. In fact, the only durable good that has a more or less flat rate of penetration for the five categories of countries is the piano, a technology present for at least 300 years (Erlich 1990). For other older innovations, like passenger cars, bicycles or cameras, it can be observed a steady and more or less parallel growth of the rates of penetration among categories of countries. While for newer innovations the slope is steeper for richer categories, for older innovations the slope is more or less the same. For some products, such as cooker, refrigerator or shower, it is greater for poorer categories. These products have generally reached their saturation point in richer countries while in poorer countries they are still diffusing.

In the graphs, two products that are being discontinued can be observed: black-and-white television sets and sewing machines. For black-and-white television sets, the order of categories of countries in 1977 is completely reversed in 2008. Furthermore the level of penetration of black-and-white television sets in poorer countries reaches a peak while in 29 richer countries the technology has already started to disappear before 1977. Category 3 peaks in 1980 with a level of penetration of 62%, category 4 peaks in 1984 with 52% and category 5 peaks in 1995 with 36%. In the plot for sewing machines, their level of penetration in 1977 is ordered according to their GDP per capita. In 2008, however, category 1 has fewer sewing machines than category 2, and category 3 nearly catches up with the levels of penetration of category 4.

Some products enter into a rate of discontinuance after reaching a peak before 2008. All the categories of casette/radio player reach a peak in their rate of penetration. They range from 59% for category 1 in 1999 and 78% for category 5 in 2000. For CD player, all the categories reach a peak before 2008 as well. They range from 68% for category 1 in 2004 and 7.7% for category 5 in 2006. For categories 3 and 4, motorcycle reaches a peak in 1989 and 1991 of 15.6% and 10.5% respectively. Telephone reaches a peak for categories 1 to 4, (category 1: 1998, 94.8%; category 2: 2002, 99.2%; category 3: 2001, 87.3%; category 4: 2005, 47.5%). Meanwhile, for category 5 telephone is still in a growth stage of the diffusion process. Another product that seems to start being discontinued is videotape recorder, with a peak in all categories except category 4.(category 1: 2003, 75.4%; category 2: 2005, 66.7%; category 3: 2006, 44.5%; category 5: 2005, 13%). These peaks show how interesting the dynamics of relations of global rates of adoption and discontinuance are and why marketing literature should overcome its pro-innovation bias and employ greater effort on the understanding of the rate of discontinuance dynamics.

Figures 1.1 and 1.2 allow us to explore the relation of categories of countries product by product but they are not sufficiently helpful to understand the relation of categories of countries when they depend on a group of products at the same time. With PCA, it is possible to retain as much as possible of the variation of the 31 products for the 70 countries and 32 years and reducing the dimensionality to understand how countries interact between themselves when comparing the rates of penetration for the different products. That is, it is also possible to observe how products are related in terms of diffusion and these relations can be clearly observed in terms of correlation and variance of levels of penetration among products.

1.2.1 Principal Component Analysis

PCA (Pearson 1901, Hotelling 1933) reduces the dimensionality of the data, specifically, the relative position of each country regarding the consumer durable goods indicators while retaining most of the information of 31 products and 70 countries between 1977 and 2008. Advancements in this technique facilitate a visual representation of the data set in a few dimensions, allowing us to analyze the data set in a single graph (biplot, or specifically in this case, principal component biplot) (Greenacre 2010). This method is based on the singular value decomposition (SVD) which provides a solution in a format leading directly to the biplot display.

In our data, the figures are the percentages of households that possess each product. Countries-by-year are treated as observations, and products as variables. The result is the set of coordinates of each country-by-year and the set of coordinates of products within the graph. For any single country, the points that represent the values of that country from one year to the next are connected, creating the trajectory by which the country moves across time. Products are plotted as arrows from the origin to the resulting coordinates. The size of these arrows reflects the relative sizes of their variance. Countries that are located in the direction of a given product present the highest rates of penetration of that product. Reduced dimensionality is useful for detecting patterns. If the data is well represented by only a few dimensions, most of the variation is accounted for by the first principal components and a plot gives a realistic reflection of the data. (The interested reader is referred to Jolliffe (2002) and Greenacre (2010).) A brief explanation on how to interpret biplots and an example including twelve countries and five durable goods is provided in Appendix 1.

A preliminary analysis which explored the distribution of the level of penetration of each product suggested a relationship between the mean and the standard deviation typical of a binomial distribution. Parts of the data with the higher and lower means would be less explained if principal components were applied without standardization. At the other extreme, the data is not standardized the usual way by the standard deviation of each product, since this equalizes the variances artificially. As a compromise, each product is standardized by the estimate of a standard deviation of a binomial, $\sqrt{p(1-p)}$, where p is the average proportion of adopted durable goods across the countries. Those goods that have a higher natural variance than would be expected from the binomial will have larger variance than those with lower natural variance. That is, some products have a higher standard deviation despite having a much lower mean. For example, CD player has a similar average level of penetration than sewing machines, but its standard deviation is almost doubled. With this type of standardization this information is not lost in the biplot.

1.3 Results

The analysis of the data set is structured as follows. The first six biplots in **figure 1.3** are representations of the international level of penetration of durable goods year by year. **figures 1.4 – 1.7** contain two types of biplots. The first biplot contains a country-by-year analysis, and the second biplot contains a five category-by-year analysis. In **figures 1.8 – 1.10** each biplot represents a category and contains 14 countries. In **figures 1.4** and **1.8** all 31 durable goods are included in each biplot. In **figures 1.6** and **1.9** the analysis is based on 8 innovations. And in **figures 1.7** and **1.10** the analysis is based on 23 maturities and discontinuances. In **figure 1.11**, all the scree plots, which are a type of plot that shows the total variance explained in the data by each principal component, of each of the principal components analysis realized in this essay are available. In **tables 1.3 – 1.7** results of each PCA computed are included.

1.3.1 Level of Penetration of Durable Goods (Year by Year)

Figure 1.3 presents six biplots that represent household durable goods consumption for six separate years: 1977, 1985, 1990, 1995, 2000 and 2008[5]. They are helpful to explore the level of penetration of durable goods for each year. In the first two columns of **table 1.3**, the results of the PCA for 1977 and 2008 are given; and in **table 1.4**, the results for the other five years included in **figure 1.3** are also given. For years 1977 and 2008, the first component explains 56.5% and 60.3% of the variance and the second component 9.2% and 8.7%. The two components together explain around two thirds of the data variation in each graph. In **tables 1.3 and 1.4**, are also listed the results for their third component.

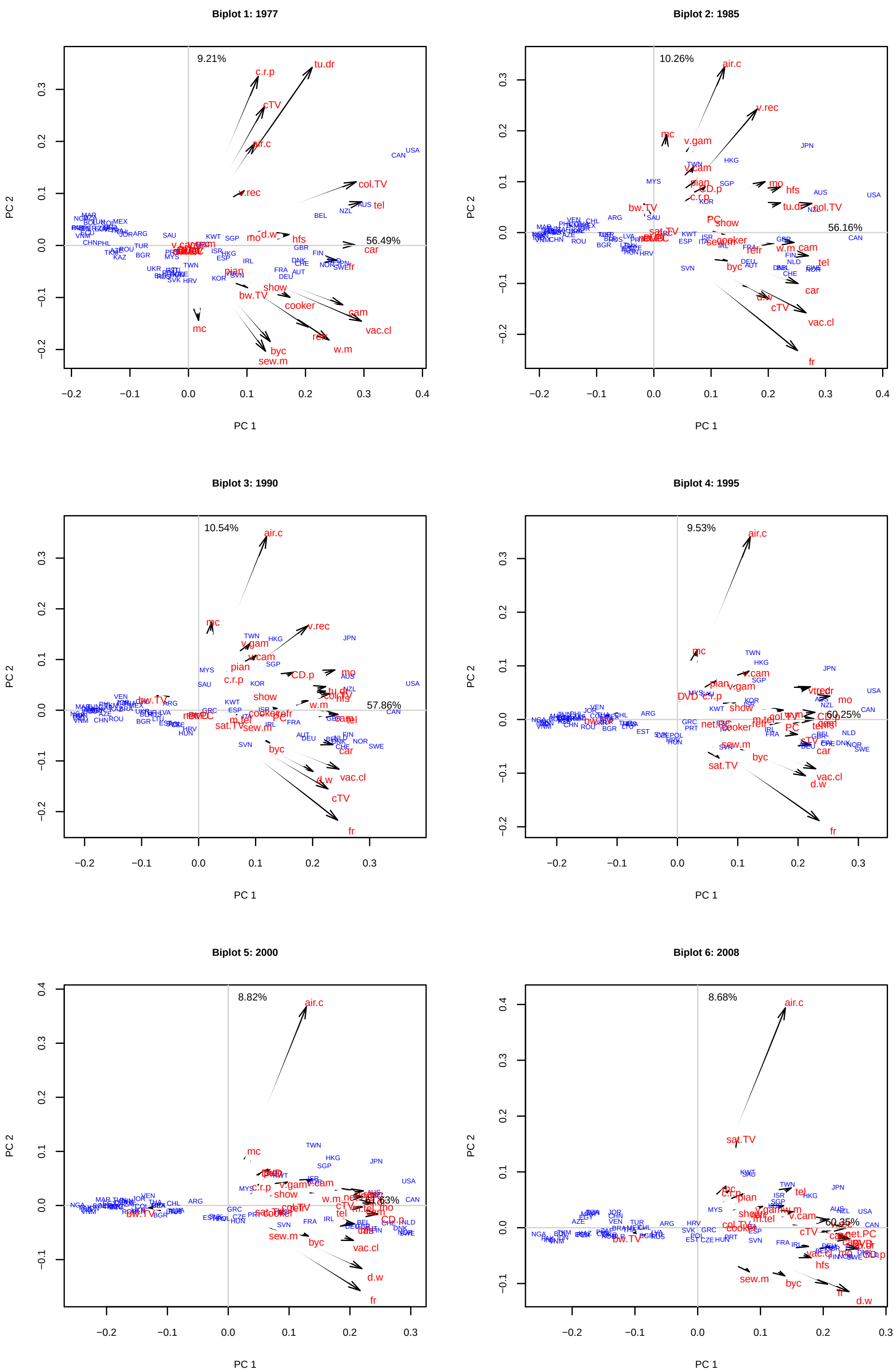
[5]Biplots for all years are included in Appendix 2, with a dynamic plot. (Only visible with the digital version.)

In the biplots in **figure 1.3**, countries align mainly in the horizontal dimension, which represents the first component. Poorer countries are on the left of the plot while richer countries are on the right[6]. In 1977, households have a higher quantity levels of penetration of durable goods in Canada, USA, Australia, Japan, New Zealand, Sweden, Netherlands, Norway, Belgium and Finland. The ten countries with the lowest levels of penetration of durable goods in 1977 are India, Pakistan, Vietnam, Indonesia, Peru, Ecuador, China, Bolivia, Algeria and Morocco. There are some differences between 1977 and 2008; for instance, China, Kuwait or Saudi Arabia are situated a little bit more to the right of the plot. This means that their rate of penetration of durable goods has increased faster than other countries.

A possible interpretation of principal components is as follows: in these biplots, the first principal component describes the actual *relative quantity level* of penetration of consumer durable goods by households. The rest of the components represent the *diversity* on the levels of penetration of consumer durable goods by households meaning that specific combinations of products with higher variance among countries will affect the rest of dimensions. The attention in these biplots, though, is focused in the relation between the first and the second dimensions. In 1977, on the vertical axis, Canada and USA are separated from the rest of the countries (see bottom right of the first biplot). These are closer to the direction defined by color television set (and other products), which implies that they should have higher average scores in these products. In 1977 almost all newer innovations are missing. In 2008, newer innovations align mainly to the first dimension. Air conditioner has higher variance than the rest, and it reduces the distance between countries in a second dimension. The main difference between the two years is the position of black-and-white television set, especially, the direction of the arrow. In 1977, countries from poorer categories were aligned towards the line of black-and-white television set and this product shows a positive correlation with refrigerator, washing machines, cookers, showers, cameras, bicycles and sewing machines. That is, the arrow of black-and-white television set is aligned with the rest of products. In contrast, in 2008, black-and-white television set has a negative correlation with all other products, especially, with latest innovations, like internet PC. Countries align over the line representing first component and point toward the direction of latest innovations.

[6] Biplot solutions are invariant to reflection of the axes. All biplots have been reflected to have a comparable interpretation.

Figure 1.3: Principal Component Analysis of 31 Durable Goods in 70 Countries for Years 1977, 1985, 1990, 1995, 2000 and 2008.



Each biplot represent the level of penetration of 31 durable goods in 70 countries.

In **figure 1.3**, only four intermediate years are included: 1985, 1990, 1995 and 2000. The panels for these years show how the position of countries and products evolve year by year. This is useful for exploring the relation among the countries and products in a given year. For instance, in the year 2000, CD player was the product that explained more percentage of the first component, while in year 1990, vacuum cleaner and telephone were more important. Also, when comparing different years, innovations tend to gain importance with time on the explanation of the variance of the biplots. By comparing different years the evolution of importance of durable goods over time can be observed. For instance, when satellite TV was introduced, a radical innovation, only richer countries could afford it, but when the product was cheaper, it became an important technology for Arabic countries.

Despite of the information obtained by these biplots, the time-series component of data is lost and the interpretation about what occurs in between 1977 and 2008 is limited. Two solutions are available with PCA. The first prepares a different biplot for every year separately and the second observes the trend of the international diffusion of durable goods simultaneously and presenting all the time-series data in a single biplot. This is accomplished by performing a PCA of the full country-by-year-by-product data set and the result is a biplot that tells a more complete story and shows interrelations of countries and products over time. That is, it allows us the exploration of different rates of household adoption, maintenance and discontinuance of consumer durable goods at the same time.

1.3.2 Diffusion of Durable Goods

The two biplots in **Figure 1.4** represent patterns of association among countries and products over time. A natural distribution of countries according to the relative changes in the rates of penetration is provided in these biplots. Biplot 1 represents the full picture of the data set including almost 70,000 values ($31 \times 32 \times 70$). It includes all years, countries and products. That is, this biplot permits us to visualize the rate of penetration of 31 durable goods in 70 countries between 1977 and 2008 simultaneously representing the international diffusion of household durable goods for the last three decades. The results of the PCA are given in the last three columns of **table 1.3**. The variance explained by the first component is 56.7% and the variance explained by the second component is 11.2%. The percentage of variance explained by the first two components is 67.9% and 73.4% in the first three components.

Table 1.3: First Three Principal Components: 1977 – 2008.

	Year 1977			Year 2008			Years 1977 – 2008*		
Product	1	2	3	1	2	3	1	2	3
air.c	0.13	–0.26	0.32	0.15	0.79	–0.23	0.16	–0.12	0.71
byc	0.15	0.24	0.05	0.15	–0.17	–0.19	0.12	0.12	–0.12
bw.TV	0.11	0.11	0.10	–0.11	–0.02	0.05	–0.12	0.12	0.04
cTV	0.14	–0.35	0.02	0.18	0.01	–0.34	0.21	0.02	–0.04
cam	0.29	0.15	0.05	0.25	–0.03	–0.18	0.18	0.26	0.02
c.r.p	0.13	–0.43	–0.04	0.05	0.13	0.13	0.08	0.02	0.14
CD.p	0.00	0.00	0.00	0.28	–0.07	–0.01	0.25	–0.06	–0.03
DVD	0.00	0.00	0.00	0.26	–0.03	0.05	0.23	–0.40	–0.16
col.TV	0.32	–0.16	0.21	0.06	0.03	0.02	0.19	0.13	0.13
cooker	0.19	0.13	0.06	0.07	0.02	0.04	0.09	0.12	0.05
d.w	0.14	–0.04	–0.19	0.27	–0.23	0.16	0.21	0.06	–0.27
fr	0.28	0.04	–0.42	0.23	–0.20	0.23	0.21	0.22	–0.34
hfs	0.19	–0.03	0.31	0.20	–0.11	0.04	0.21	0.11	0.00
mo	0.11	–0.03	0.18	0.24	–0.07	–0.08	0.27	–0.05	0.00
m.tel	0.00	0.00	0.00	0.11	0.05	0.03	0.26	–0.38	–0.07
mc	0.02	0.19	0.42	0.05	0.15	–0.17	0.03	0.01	0.27
car	0.31	0.00	–0.20	0.22	–0.01	0.21	0.20	0.22	–0.06
PC	0.00	0.00	0.00	0.23	–0.01	–0.08	0.26	–0.21	–0.05
net.PC	0.00	0.00	0.00	0.26	0.00	–0.12	0.25	–0.32	–0.10
pian	0.08	0.05	0.17	0.08	0.12	–0.13	0.05	0.07	0.15
refr	0.23	0.21	0.02	0.10	0.06	0.10	0.11	0.16	0.07
sat.TV	0.00	0.00	0.00	0.07	0.32	0.71	0.13	–0.19	0.01
sew.m	0.14	0.27	0.16	0.09	–0.16	–0.13	0.04	0.20	–0.04
show	0.15	0.09	0.07	0.08	0.07	0.05	0.08	0.10	0.09
tel	0.33	–0.11	–0.21	0.16	0.14	0.01	0.19	0.22	0.08
tu.dr	0.23	–0.45	–0.01	0.27	–0.04	0.07	0.20	0.13	0.03
vac.cl	0.33	0.19	–0.15	0.19	–0.07	0.06	0.19	0.27	–0.11
v.cam	–0.01	–0.01	0.00	0.17	0.06	0.01	0.15	–0.05	0.11
v.gam	0.02	–0.01	0.12	0.11	0.08	–0.02	0.12	–0.03	0.14
v.rec	0.10	–0.14	0.36	0.23	0.03	–0.02	0.22	0.05	0.18
w.m	0.26	0.24	0.00	0.15	0.08	0.04	0.16	0.19	0.10
Eigenvalue	1.29	0.52	0.49	1.38	0.52	0.46	9.59	4.26	2.98
% Explained**	56.48	9.21	8.15	60.35	8.68	6.59	56.74	11.19	5.48

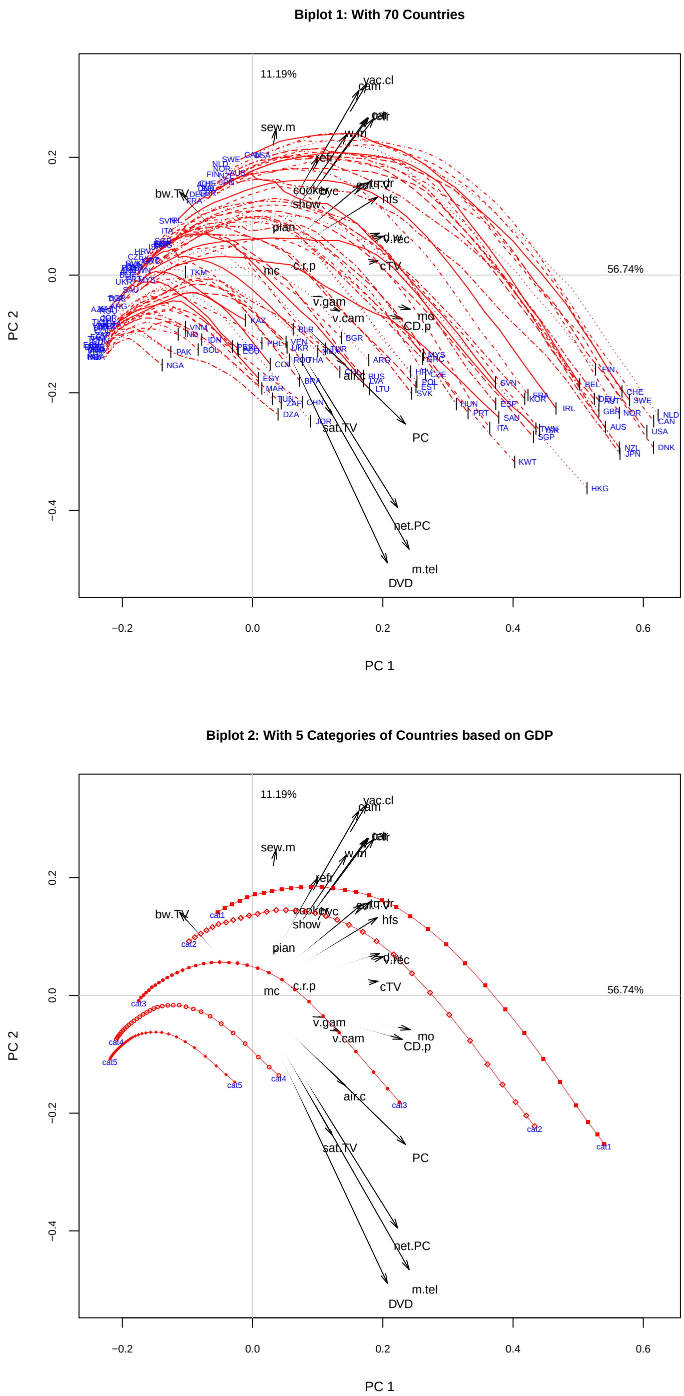
* Between 1977 and 2008. ** Percentage of variance explained.

Table 1.4: First Three Principal Components: 1985, 1990, 1995 and 2000.

	Year 1985			Year 1990			Year 1995			Year 2000		
Product	1	2	3	1	2	3	1	2	3	1	2	3
air.c	0.14	–0.50	0.07	0.13	0.58	–0.05	0.13	–0.70	0.10	0.14	0.79	–0.11
byc	0.14	0.09	–0.17	0.14	–0.11	0.11	0.14	0.12	–0.03	0.14	–0.12	0.17
bw.TV	–0.02	–0.09	–0.16	–0.08	0.05	0.12	–0.13	–0.02	0.00	–0.14	–0.01	0.10
cTV	0.22	0.20	0.46	0.25	–0.26	–0.37	0.22	0.06	–0.04	0.19	0.02	0.05
cam	0.27	0.03	–0.11	0.26	–0.01	0.10	0.25	0.00	0.01	0.24	–0.01	0.12
c.r.p	0.08	–0.11	0.27	0.06	0.11	–0.15	0.06	–0.10	–0.04	0.05	0.08	–0.03
CD.p	0.10	–0.14	0.03	0.18	0.13	–0.13	0.25	–0.03	–0.23	0.27	–0.03	0.22
DVD	0.00	0.00	0.00	0.00	0.00	0.00	0.02	–0.11	0.03	0.07	0.14	0.14
col.TV	0.30	–0.09	–0.10	0.24	0.06	0.18	0.18	–0.03	0.23	0.11	0.02	–0.14
cooker	0.14	0.01	–0.17	0.11	0.01	0.19	0.10	0.01	0.19	0.08	–0.01	–0.12
d.w	0.19	0.17	0.20	0.22	–0.21	–0.23	0.23	0.22	–0.27	0.24	–0.25	0.15
fr	0.28	0.35	0.03	0.27	–0.37	0.05	0.26	0.39	0.05	0.24	–0.34	–0.19
hfs	0.24	–0.14	0.09	0.25	0.06	–0.14	0.25	0.00	–0.16	0.23	–0.07	0.06
mo	0.21	–0.15	0.15	0.26	0.14	–0.26	0.28	–0.09	–0.31	0.26	0.01	0.19
m.tel	0.00	0.00	0.00	0.07	–0.01	–0.09	0.14	–0.02	–0.03	0.22	0.01	–0.13
mc	0.02	–0.29	–0.32	0.03	0.30	0.28	0.04	–0.27	0.22	0.04	0.22	0.04
car	0.28	0.15	–0.01	0.26	–0.12	0.08	0.24	0.10	0.14	0.22	–0.08	–0.22
PC	0.11	–0.05	0.08	0.14	–0.01	–0.09	0.19	0.01	–0.12	0.24	0.06	0.12
net.PC	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	–0.06	0.22	0.05	0.16
pian	0.08	–0.16	–0.09	0.07	0.15	0.07	0.07	–0.15	0.06	0.07	0.14	0.04
refr	0.18	0.04	–0.23	0.15	0.01	0.24	0.14	0.00	0.26	0.11	0.01	–0.22
sat.TV	0.02	–0.02	–0.01	0.05	–0.03	0.04	0.08	0.15	0.24	0.07	0.00	–0.57
sew.m	0.12	0.01	–0.23	0.10	–0.04	0.19	0.10	0.07	0.10	0.09	–0.10	0.08
show	0.13	–0.04	–0.08	0.12	0.06	0.07	0.11	–0.06	0.07	0.09	0.06	–0.05
tel	0.30	0.07	–0.07	0.27	–0.01	0.15	0.23	0.00	0.19	0.19	–0.01	–0.19
tu.dr	0.24	–0.09	0.38	0.25	0.08	–0.34	0.24	–0.13	–0.38	0.24	0.04	0.28
vac.cl	0.29	0.24	–0.20	0.27	–0.20	0.29	0.25	0.19	0.30	0.23	–0.14	–0.26
v.cam	0.08	–0.20	0.06	0.11	0.18	–0.10	0.13	–0.19	–0.08	0.15	0.10	0.05
v.gam	0.08	–0.27	–0.02	0.10	0.22	–0.04	0.11	–0.14	0.00	0.11	0.09	0.00
v.rec	0.20	–0.37	0.07	0.21	0.28	–0.04	0.24	–0.12	–0.02	0.23	0.06	0.02
w.m	0.23	0.03	–0.32	0.21	0.03	0.37	0.19	–0.04	0.37	0.17	0.04	–0.25
Eigenvalue	1.38	0.59	0.51	1.42	0.61	0.50	1.45	0.58	0.45	1.47	0.56	0.46
% Explained*	56.16	10.26	7.67	57.86	10.54	7.02	60.25	9.53	5.81	61.63	8.82	5.95

* Percentage of variance explained.

Figure 1.4: Principal Component Analysis of 31 Durable Goods in 70 Countries (1977 –2008).



Note: Biplot 1 uses the rate of penetration of durable goods for 70 countries. Biplot 2 uses the same rate of penetration of durable goods divided into five categories of countries based on GDP at PPP. Each category represents fourteen countries ordered according to GDP per capita at PPP.

The acronyms of the countries on the left-hand side of the biplot represent their position in 1977 while the acronyms on the right-hand side represent their position in 2008. The red line that connects these two points is the relative overall rate of penetration of durable goods of each country during 32 years. The combination of the first component, the horizontal axis, with the second component, the vertical axis, describes the evolution of the market for household of durable goods. In the top-left hand side of the biplot products that tend to disappear from the market are situated, and in the bottom-right hand side innovations are situated.

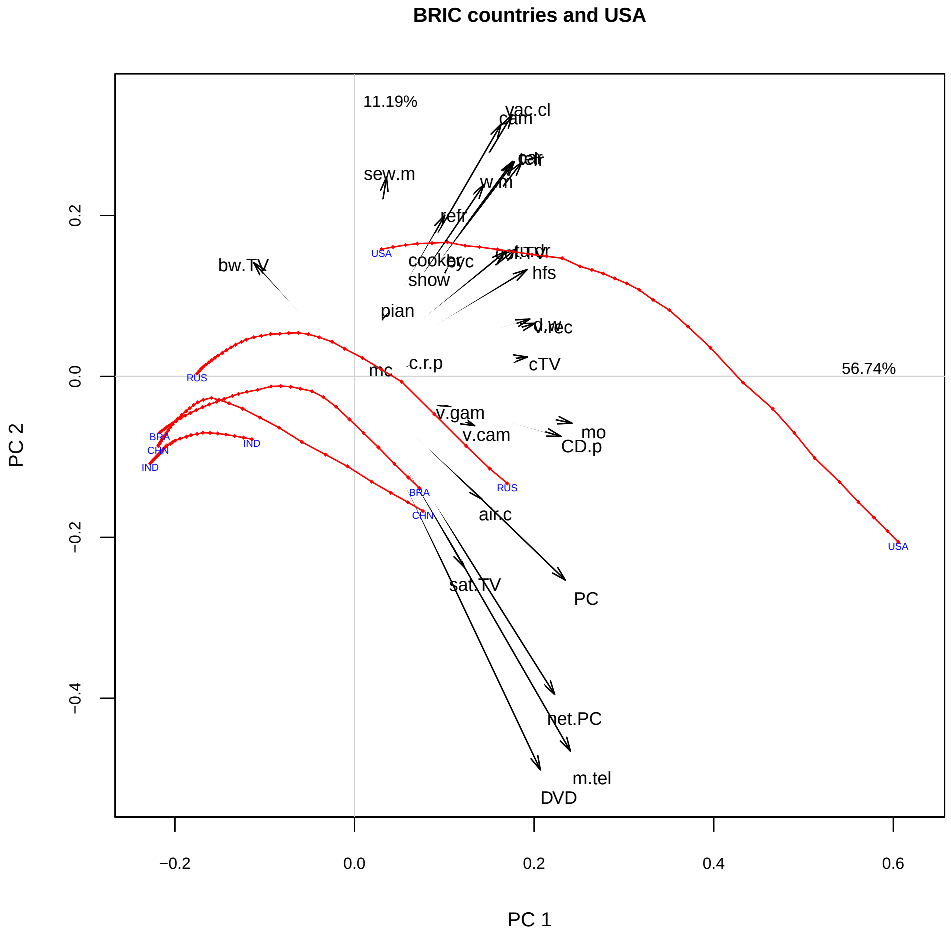
The trajectory of each country is in the shape of an arch. At first, coordinates of countries are situated close to products that in leading countries are entering in the maturity stage but are still in the growth stage in lagged countries. Then they move toward the lower right quadrant where newer innovations are situated. The arrow for black-and-white television sets points to the opposite side of innovations, reflecting the negative relation between their respective rates of penetration. The countries' positions in the graph tend to move first to the right and upwards, where products that are still in a growth stage are situated, even though they were introduced in the market before 1977. These products are vacuum cleaner, camera, refrigerator, washing machine, passenger car, telephone, freezer, bicycle, shower, cooker, color television set, tumble drier, hi-fi stereo, dishwasher and video tape recorder. While these products were still in a growth stage of the diffusion process in 1977, they were already in the market. Close to these products are sewing machine, piano, motorcycle, cassette-radio player and cable TV. Piano, motorcycle, and cassette-radio player are strongly related to the group of older innovations, but their variance, represented by the length of the arrow, is smaller. Piano's rate of penetration is flat because it is a product that in 1977 had already reached its maximum level of diffusion. On the other hand, the rates of penetration of sewing machines have a higher variance among countries and its arrow aims towards the arrow that represents black-and-white television set, a product being discontinued. It is slowly becoming a discontinued technology. In the lower left side of the biplot the following products are situated: video game, video camera, microwave oven, CD player, air conditioner, personal computer, personal computer with internet, satellite TV, mobile telephone and DVD. Note that cable TV is in between older and newer innovations. The coordinates of products, from left to right, follow an almost perfectly ordered distribution from products with rates of discontinuance to rates of adoption. Products that have faster rates of adoption are at the bottom right quadrant, while products that have a less pronounced slope, like video game or cable TV, tend to be clustered in the middle of the plot.

All the 70 countries represented in the graph have their initial position (1977) on the left. This is because the level of penetration was lower in households for all countries in 1977. In the first year of the analysis countries rank according to their wealth in the direction of older innovations meaning that in 1977 the direction of countries is related with older innovations. In 2008, on the other hand, countries are placed horizontally. Poorer countries tend to have shorter lines than richer countries from 1977 until 2008 and almost all countries tend to exhibit an arch shape. Turkmenistan is an exception because it started to adopt innovations much later than other countries. From this analysis, the detail of each country can be extracted and compared with other countries. For BRIC countries, Russia has the longest curve in the plot and India the shortest. China and Brazil lie in between these countries, but Brazil seems to have a higher overall level of maturity products, while China has a higher level of newer innovations (see **figure 1.5**). Although this level of country information detail allows us to compare the countries' positions, dividing countries into categories permits a more refined comparison between groups of countries based on a particular characteristic. As stated above, for the purpose of this study, GDP per capita at PPP is used as an approximate measure of economic development of a country.

In biplot 2 of **Figure 1.4**, countries are divided into five categories based on GDP per capita at PPP. Wealth is used as a measure to group countries because it is the country characteristic that is more related to the diffusion process (Krishnan and Thomas 2009, Peres et al. 2010). The objective is to have a simpler perspective of the graph. The mean of the coordinates of countries is plotted in each category based on GDP per capita. This map shows that wealth is a good correlate of the international rate of penetration of durable goods and being able to plot it. This biplot, though, omits detailed information like the one of Turkmenistan or BRIC countries that can be extracted from biplot 1 in **figure 1.4**. Nonetheless, it shows the general trend. The points over each line represent the years from 1977 until 2008. In the first year, categories of countries were closer to each other, and the distance between points forming a time trajectory grows as they approach 2008.

The interpretation is that the distance based on the quantity levels of penetration among categories of countries has increased. To understand the information of the biplot, it is helpful to look at **figures 1.1** and **1.2** again. While the difference of the level of penetration in older innovations has remained more or less stable among the five categories, the difference of penetration of newer innovations increases year by year. Richer categories of countries, 1 and 2, achieve higher levels of household penetration of newer innovations faster. At a certain point, categories start to change smoothly their directions and point to newer innovations. The distance between them in the last year is greater at the end of the line, in 2008, because the relative difference of the levels of household penetration of newer innovations is retained in the biplot.

Figure 1.5: BRIC Countries and USA (1977 – 2008).



This biplot uses the rate of penetration of durable goods for 70 countries. Only BRIC countries and USA are presented.

Several core findings can be extracted from these biplots. Evaluating the diffusion curves, we first see that categories 4 and 5 are close to each other, as are categories 1 and 2. We can interpret this as the rates of diffusion of categories 1 and 2 are very similar to each other and very dissimilar to categories 4 and 5; and likewise categories 4 and 5 are very similar to each other and very dissimilar to categories 1 and 2. The distance between these two groups of categories is very high, and it is mediated by category 3, which has a large distance with both groups of categories. The interpretation is that there is a large difference on the level of development between the two wealthier groups, that can be classified as developed economies, and the poorer groups, which can be classified as developing economies, that clearly affects the rate of penetration of durable goods.

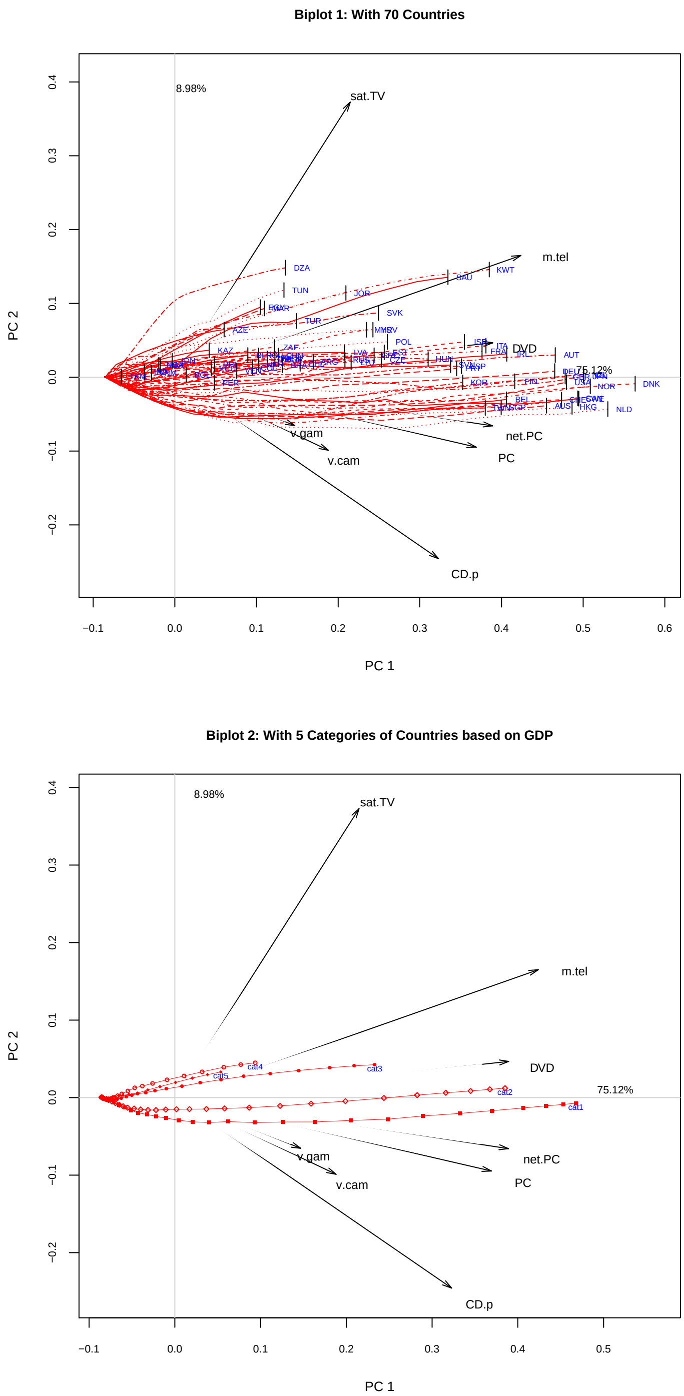
Category 3 falls between these two disparate groups. Second, countries in categories have a large variance on their respective adoption processes. As mentioned above, BRIC countries have different levels of penetration of durable goods (e.g., China and India). Third, certain products align together and the direction of their arrows can be interpreted as a correlation. In these biplots, these correlations seem to be based on life-cycle stage of durable goods. Black-and-white television sets are being discontinued and DVDs have just been introduced; in between, the rest of products are located. And fourth, the length of the arrow reflecting the variance of the level of penetration of goods among countries shows that newer technologies have a great variance, reflecting a large gap between developed economies and less-developed economies. Certain technologies have a lower variance because it depends on the distribution of levels of penetrations which is also related to the intrinsic characteristics of each product. For example, the oldest technology in this sample is piano, which does not show a high variance among levels of penetration in different countries, and lies close to motorcycle, which has the lowest relative variance among all products.

These results include innovations, maturities and discontinuances. In the following two sections products are separated according to their life stage.

1.3.3 Diffusion of Innovations

Eight durable goods from the previous analysis were not in the mass market in 1977: mobile telephone, CD player, satellite TV, video camera, video games, DVD, internet PC and PC. In 1977, their level of penetration was less than 2% in any of the countries used in the analysis. Therefore, these products are considered innovations for the time period between 1977 and 2008. The first biplot of **figure 1.6** permits us to visualize the rate of adoption of these innovations in 70 countries from 1977 until 2008. At the same time, that is, the international diffusion of these eight innovations for the last three decades is summarized in the biplot. The result of the PCA of this data set is displayed in the first part of **table 1.5**. The first component explains 75.1% of the variance, and the second component 10%. The percentage of variance explained of the first two components is 84.1% (and 92.2% by the first three components). In the first dimension, DVD, mobile telephones, PC and internet PC account for the largest part of the variance. These four products are newer innovations with very high penetration rates in richer countries. In the second dimension, satellite TV, mobile telephones and CD players are those coefficients with a bigger contribution to the variance. Biplot 1 represents the global diffusion of innovations.

Figure 1.6: Principal Component Analysis of 8 Innovations in 70 Countries (1977 – 2008).



Note: Biplot 1 uses the rate of adoption of durable goods for 70 countries. Biplot 2 the same rate of adoption of durable goods divided into five categories of countries based on GDP at PPP. Each category represents fourteen countries ordered according to GDP per capita at PPP.

Table 1.5: First Three Principal Components between 1977 and 2008.

	Innovations			Maturities and Discontinuances		
Product	1	2	3	1	2	3
Innovations						
CD.p	0.36	–0.49	0.46			
DVD	0.43	0.09	–0.59			
m.tel	0.47	0.33	–0.09			
PC	0.41	–0.19	0.06			
net.PC	0.43	–0.13	–0.24			
sat.TV	0.24	0.74	0.50			
v.cam	0.21	–0.20	0.26			
v.gam	0.16	–0.13	0.22			
Eigenvalue	6.45	2.23	2.12			
% Explained*	75.12	8.98	8.12			
Maturities and Discontinuances						
air.c				0.17	–0.71	0.26
byc				0.15	0.14	–0.01
bw.TV				–0.13	0.15	0.32
cTV				0.25	–0.10	–0.25
cam				0.25	0.12	0.17
c.r.p				0.10	–0.16	–0.06
col.TV				0.24	–0.06	0.13
cooker				0.12	0.05	0.18
d.w				0.26	0.13	–0.33
fr				0.27	0.35	–0.14
hfs				0.26	–0.02	–0.11
mo				0.30	–0.18	–0.28
mc				0.04	–0.17	0.29
car				0.26	0.15	0.07
pian				0.07	–0.07	0.16
refr				0.15	0.08	0.26
sew.m				0.07	0.21	0.24
show				0.11	–0.01	0.13
tel				0.26	0.05	0.17
tu.dr				0.25	–0.08	–0.19
vac.cl				0.26	0.26	0.18
v.rec				0.27	–0.21	–0.05
w.m				0.21	0.07	0.33
Eigenvalue				7.93	3.07	2.71
% Explained*				58.90	8.85	6.89

* Percentage of variance explained.

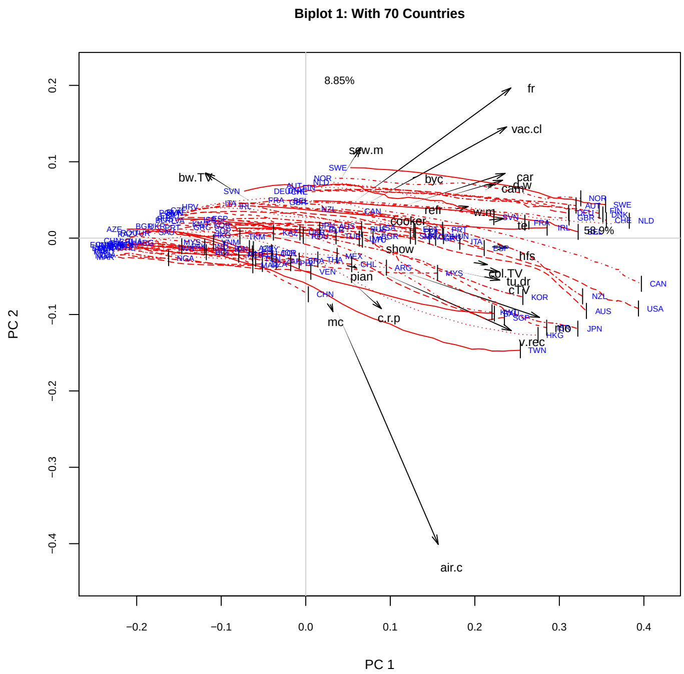
In biplot 1, the first component describes the actual *relative quantity level* of adoption of innovations by households, that is, countries align in the order of their level of penetration of innovations. In **table 1.5**, all the coefficients of the first component are positive, and consequently, their arrows point to the right part of the biplot. The rest of the dimensions, accounting for 24.9% of the total variance explained, represent the diversity of diffusion of innovations. For instance, certain countries cluster closer to satellite TV and mobile telephones and far from CD players in the second dimension. These countries are Turkey, Morocco, Egypt, Tunisia, Algeria, Saudi Arabia and Kuwait and Slovakia. In **table 1.5**, satellite TV, mobile telephone and DVD have a different sign than the rest of innovations in the second dimension. This means that these products have different characteristics when compared with the rest of innovations. In the third dimension, satellite TV, DVD and CD player explain most of the variance. In this case, satellite TV has a different sign than CD player and internet PC and mobile telephone. Video games and video cameras have lower variance than other products. In the first dimension satellite TV has a low variance, but in the second one it has the largest one. This shows that the level of penetration of this product is not driven by the level of wealth of a country, and other causes, such as political environment, drive its growth.

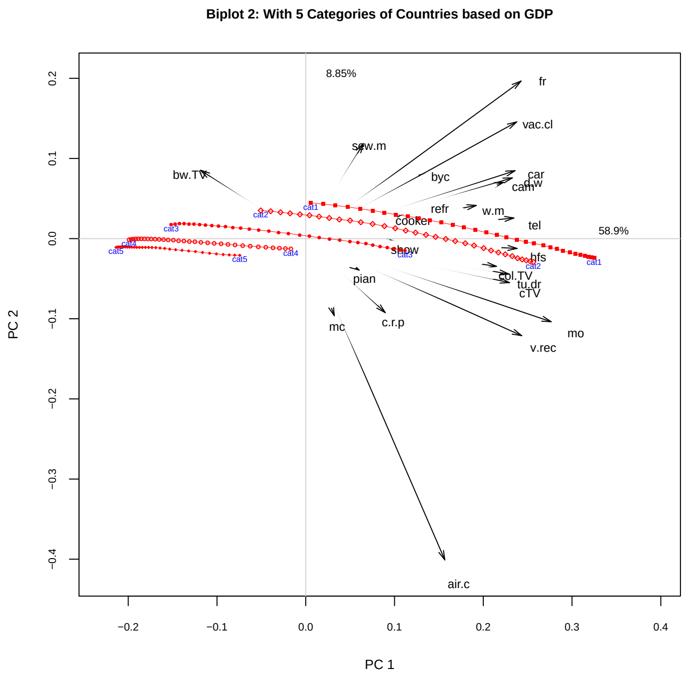
In the second biplot of **figure 1.6**, categories of countries based on GDP are used like in **figure 1.4**. The mean of the coordinates of countries is plotted within these categories only for the eight selected innovations. Each of the points over the lines represents a different year. Richer categories have longer lines because of a higher rate of adoption of these innovations. The biplot also shows how wealth affects the initial timing of adoption. Richer countries have had innovations for a longer time span. Wealthier countries have access to newer technologies much faster than poorer countries. Therefore, consistent with previous literature, adoption timings are related to wealth. Finally, category 4 lies above category 5 influenced by the situation of satellite TV and mobile telephones. From a horizontal perspective, richer categories are closer to products situated in the lower-right quadrant of the plot and poorer categories are closer to the upper-right quadrant of the plot.

1.3.4 Diffusion of Maturities and Discontinuances

The first biplot in **figure 1.7** shows 23 durable goods in 70 countries from 1977 until 2008, which are either a maturity or a product being discontinued. The result of the PCA of this data set is available in the second block of **table 1.5**. The first component explains 58.9% of the variance and the second component explains 8.8%. Two and the three dimensions explain 67.7% and 74.6% of the variation respectively.

Figure 1.7: Principal Component Analysis of 23 Maturities and Discontinuances in 70 countries (1977 – 2008).





Note: Biplot 1 uses the rate of penetration and discontinuance of durable goods for 70 countries. Biplot 2 the same rate of penetration and discontinuance of durable goods divided into five categories of countries based on GDP at PPP. Each category represents fourteen countries ordered according to GDP per capita at PPP.

As in **figure 1.4** and **1.6**, the first component describes the actual *level of penetration* of maturities and discontinuances and the rest of the components represent the *diversity* on the diffusion of maturities and discontinuances. In the first dimension, only black-and-white television sets has a negative sign. All the rest of products are situated in the right part of the plot toward which the countries are heading. Microwave oven, freezer, videotape recorder, vacuum cleaner and dishwasher, cable TV, camera and tumble drier have a greater influence in the first dimension.

In the second dimension, air conditioner weights much higher than the rest of products and its sign is negative; therefore, it is situated in the lower part of the biplot. Colder countries are situated near the top. In the second block of **table 1.5**, we can see that freezer is the durable good that has the next highest contribution to the variance after air conditioner and has a positive sign, lying very close to vacuum cleaner. In the third component, products that carry a greater weight are dishwasher, washing machine and black-and-white television sets.

Categories of countries based on GDP are displayed in biplot 2 of **figure 1.6**. The space between points represents the rate of penetration for a given year of those products included in the biplot. For maturities and discontinuances, this space is greater in richer categories of countries, meaning faster rates of adoption of maturities and also faster rates of discontinuance of older technologies.

In 1977, richer categories are situated at the top of the biplot and poorer categories are closer to the bottom. The oldest technologies being discontinued in richer countries are sewing machines and black-and-white television sets. These products were still innovations in the countries in poorer categories in 1977, while richer countries were heading to increase consumption of newer durable goods like color television sets and videotape recorders.

Analyzing goods from a global perspective hides certain information among the relation of a country with countries in the same category based on income. It is not the same to compare Norway's patterns of consumption with all the world's countries than comparing it only with richer countries. The interpretation of results will be different. That is, the level of penetration of products among countries will correlate and vary differently among countries. Therefore, interpretations of distances among countries will also be different. The key advantage is that countries can be compared with their respective groups and the level of products can be compared among distinct groups, refining the analysis.

1.3.5 Diffusion of Durable Goods by Categories of Countries

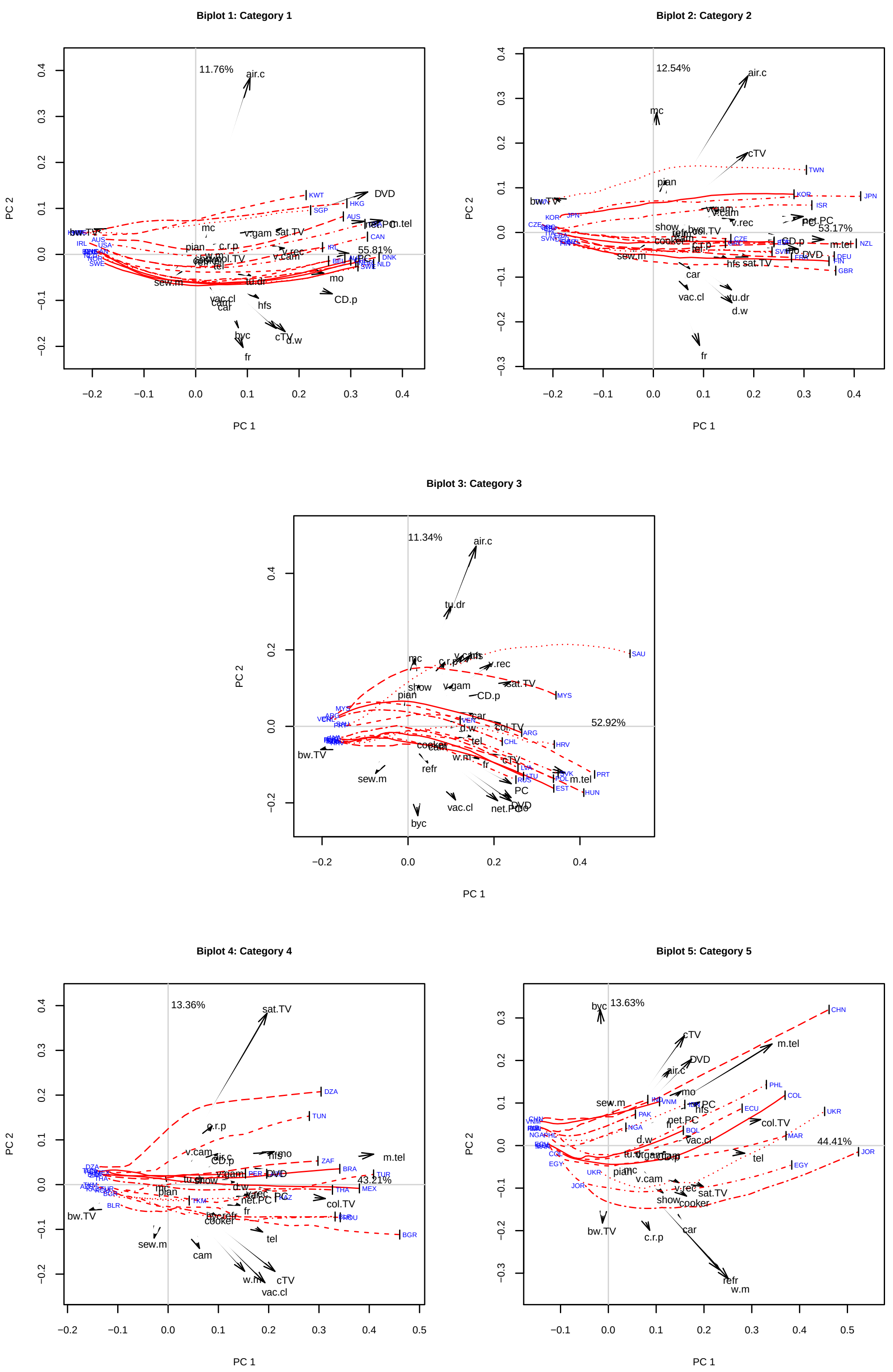
There are five plots in **figure 1.8**, one for each category based in GDP per capita at PPP. This allows us control for wealth and obtain a separate perspective about the diffusion of durable goods for every category. The results of the two first principal components for each category are listed in

table 1.6. For every category of countries, the variance explained by the first two components is the following: category 1, 67.6% (55.8% & 11.8%), category 2, 65.7% (53.2% & 12.5%), category 3, 64.2% (52.9% & 11.3%), category 4, 56.6% (43.2% & 13.4%), and category 5, 58.0% (44.4% & 13.6%).

In each biplot of **figure 1.8**, mobile telephone has the highest weight in the first dimension. Personal computers, internet, CD players and DVD have more weight in the first dimension of biplot 1 and 2. In biplot 3, DVD, color television set, satellite television set and microwave oven are more important in the first component with mobile telephone. And in biplot 4 and 5, color television set is more important (see **table 1.6**). While mobile telephones have spread with the same amount of variance across each of the five categories of countries, other products are accessible only in the richest countries. This reflects how less-developed countries can access only a certain type of innovations. Marketing certain type of goods in less-developed countries would add a lot of value to people's quality of life. Products that do not impact the distribution of countries in richer categories because they have already achieved a saturation level, such as telephone, color television set, refrigerator and washing machine, have a great potential in poorer countries.

In the biplots of **figure 1.8** we see only one more component. In the first three biplots, air conditioner has a greater part of its variance explained by the second component. In biplot 4, the coefficient for satellite TV explains the largest part of the variance followed by vacuum cleaners. And in biplot 5, bicycles, refrigerators and washing machines contribute more to the percentage of the variance explained of the second component. Note that China and Vietnam lies closest to bicycle.

Figure 1.8: Principal Component Analysis of 31 Durable Goods in 14 Countries (1977 – 2008).



Note: Each biplot represents the rate of penetration of 31 durable goods in 14 countries.

Table 1.6: First Two Principal Components for Every Category of Countries (31 durable goods).

	Cat 1		Cat 2		Cat 3		Cat 4		Cat 5	
Product	1	2	1	2	1	2	1	2	1	2
air.c	0.12	–0.64	0.21	0.56	0.17	0.52	0.11	0.11	0.14	0.21
byc	0.09	0.27	0.08	0.02	0.03	–0.26	0.09	–0.10	–0.02	0.38
bw.TV	–0.22	–0.09	–0.22	0.12	–0.22	–0.07	–0.17	–0.09	–0.01	–0.22
cTV	0.17	0.27	0.21	0.28	0.24	–0.08	0.23	–0.31	0.18	0.31
cam	0.05	0.15	0.06	–0.01	0.07	–0.05	0.07	–0.23	0.13	–0.02
c.r.p	0.06	–0.04	0.10	–0.03	0.09	0.19	0.10	0.21	0.10	–0.24
CD.p	0.29	0.14	0.28	–0.02	0.19	0.09	0.11	0.09	0.13	–0.02
DVD	0.37	–0.23	0.32	–0.06	0.26	–0.21	0.22	0.05	0.19	0.24
col.TV	0.07	0.00	0.11	0.02	0.24	0.01	0.34	–0.05	0.35	0.07
cooker	0.02	0.00	0.03	–0.01	0.06	–0.04	0.10	–0.11	0.18	–0.14
d.w	0.19	0.28	0.17	–0.25	0.14	0.01	0.14	0.01	0.08	0.03
fr	0.10	0.34	0.10	–0.40	0.18	–0.09	0.16	–0.07	0.13	0.07
hfs	0.13	0.16	0.16	–0.09	0.16	0.21	0.21	0.11	0.20	0.11
mo	0.27	0.07	0.28	–0.05	0.26	–0.22	0.23	0.12	0.17	0.15
m.tel	0.40	–0.12	0.37	–0.03	0.40	–0.13	0.45	0.11	0.38	0.29
mc	0.02	–0.11	0.01	0.43	0.02	0.20	–0.01	0.00	0.05	–0.06
car	0.06	0.17	0.08	–0.13	0.16	0.04	0.17	–0.02	0.17	–0.21
PC	0.33	0.00	0.31	0.05	0.26	–0.17	0.23	–0.02	0.21	0.12
net.PC	0.36	–0.12	0.33	0.06	0.23	–0.22	0.18	–0.04	0.16	0.08
pian	0.00	–0.04	0.03	0.18	0.00	0.09	0.00	–0.01	0.03	–0.06
refr	0.01	0.01	0.05	0.01	0.05	–0.11	0.12	–0.09	0.26	–0.35
sat.TV	0.18	–0.09	0.21	–0.09	0.26	0.13	0.22	0.62	0.22	–0.12
sew.m	–0.05	0.08	–0.04	–0.07	–0.08	–0.14	–0.03	–0.19	0.01	0.12
show	0.02	0.00	0.03	0.03	0.03	0.12	0.08	0.03	0.13	–0.13
tel	0.04	0.02	0.09	–0.04	0.16	–0.03	0.21	–0.17	0.31	–0.02
tu.dr	0.12	0.08	0.17	–0.20	0.11	0.35	0.05	0.03	0.05	–0.01
vac.cl	0.05	0.14	0.08	–0.20	0.12	–0.21	0.21	–0.35	0.19	0.03
v.cam	0.18	–0.01	0.14	0.08	0.14	0.20	0.06	0.13	0.09	–0.08
v.gam	0.12	–0.08	0.13	0.09	0.11	0.12	0.12	0.05	0.09	–0.02
v.rec	0.19	–0.02	0.18	0.05	0.21	0.18	0.18	–0.02	0.16	–0.10
w.m	0.04	–0.01	0.06	0.01	0.13	–0.08	0.17	–0.31	0.28	–0.38
Eigenvalue	3.36	1.54	3.40	1.65	3.31	1.53	2.83	1.57	2.96	1.64
% Explained*	55.81	11.76	53.17	12.54	52.92	11.34	43.21	13.36	44.41	13.63

* Percentage of variance explained.

1.3.6 Diffusion of Innovations by Categories of Countries

Using the same approach as in the previous figure, **figure 1.9** focuses on innovations. The first two principal components of each category are presented in the first block of **table 1.7**. For every category of countries the variance explained by the first two components is the following: category 1, 87.3% (78.1% & 9.2%), category 2, 86.3% (77.4% & 9.9%), category 3, 88.2% (77% & 11.2%), category 4, 87.5% (63.2% & 24.3%), and category 5, 86.7% (70.5% & 16.2%).

The first component of every biplot of **figure 1.9** represents the level of adoption newer innovations. Mobile telephones in poorer categories are relatively more important than in richer categories in the first dimension. The second components of biplots 1, 3, 4 and 5 are largely dominated by the rate of adoption of satellite TV. In biplot 2, the second dimension is dominated by the contrast between the rates of adoption of CD players and DVD.

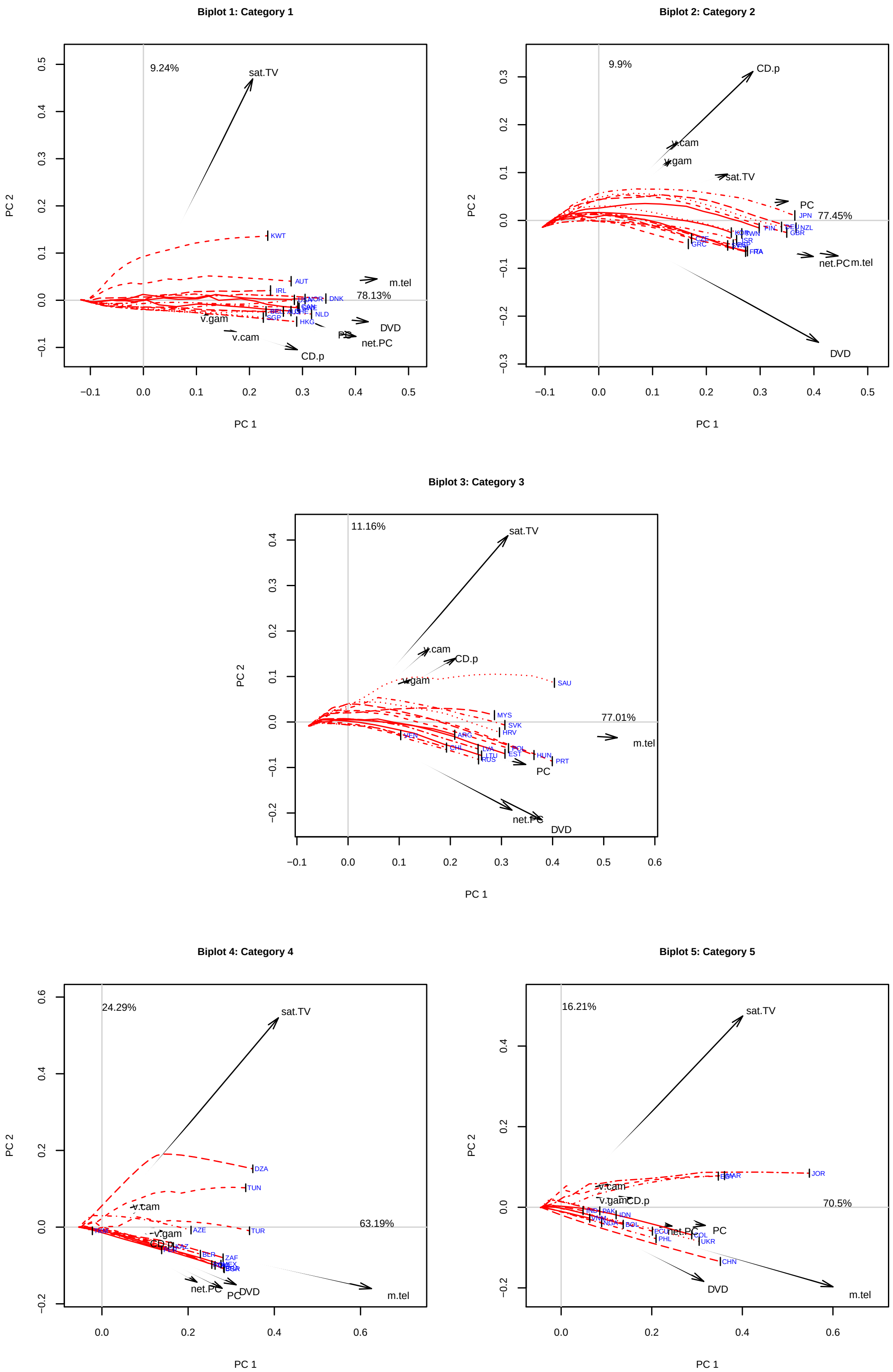
1.3.7 Diffusion of Maturities and Discontinuances by Categories of Countries

In **figure 1.10** maturities and discontinuances are included. The second part of **table 1.7** contains the results of the two first principal components of each category. For every category of countries the variance explained by the first two components is as follows: category 1, 65.7% (43.8% & 21.9%), category 2, 65.4% (43.6% & 21.8%), category 3, 60.7% (45.2% & 15.5%), category 4, 56.9% (42.3% & 14.6%), and category 5, 58.6% (43.5% & 15.1%).

The first component of every biplot of **figure 1.10** orders countries according to their level of penetration of products. In this case, the discontinuance of black-and-white television set plays a major role in the description of the first component. While in richer countries the position of black-and-white television sets is situated in the left hand-side, in poorer countries it is situated in the middle. In contrast, color television set is situated in the right part of the plot in poorer countries while in richer countries is closer to the mean. In biplot 1, video recorder, cable television sets and microwave oven are the durable goods that explain the largest part of the variance of the first component with black-and-white television set. In biplot 5, refrigerators, telephones and washing machines are the most influential coefficients of the first component with color television set. In between, the pattern of durable goods of each of the remaining biplots shows the progression from how products influence on the first principal component changes from poorer countries in biplot 5 to richer countries in biplot 1. For instance, in biplot 3 black-and-white and color television set share a very similar amount of variance of the first principal component.

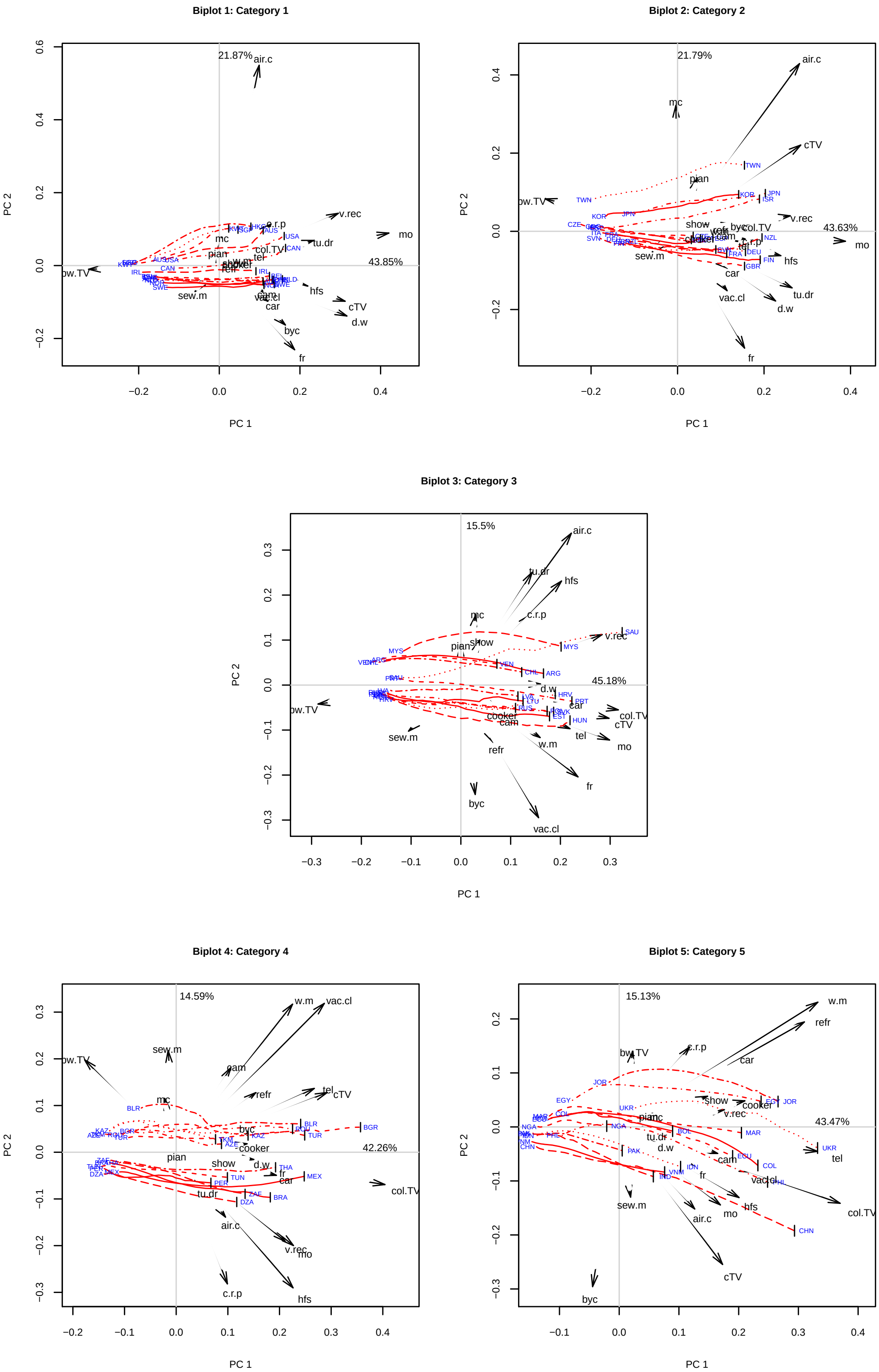
The second component in richer countries is dominated by air conditioner. In biplot 5, products with the largest percentage of variance of the second component are bicycles and cable television set, which contrast with the position of black-and-white television set.

Figure 1.9: Principal Component Analysis of 8 Innovations in 14 Countries (1977 – 2008).



Note: Each biplot represents the rate of adoption of 8 innovations in 14 countries.

Figure 1.10: Principal Component Analysis of 23 Maturities and Discontinuances in 14 Countries (1977 – 2008).



Note: Each biplot represents the rate of penetration and discontinuance of 23 durable goods in 14 countries.

Table 1.7: First Two Principal Components for Every Category of Countries: innovations, Maturities and Discontinuances Separated.

	Cat 1		Cat 2		Cat 3		Cat 4		Cat 5	
Product	1	2	1	2	1	2	1	2	1	2
Innovations										
CD.p	0.32	–0.21	0.32	0.65	0.23	–0.25	0.14	0.05	0.17	0.04
DVD	0.47	–0.09	0.45	–0.54	0.42	0.38	0.34	0.24	0.35	–0.33
m.tel	0.48	0.09	0.49	–0.16	0.58	0.06	0.69	0.25	0.66	–0.36
PC	0.38	–0.12	0.39	0.08	0.38	0.17	0.31	0.25	0.35	–0.08
net.PC	0.44	–0.15	0.44	–0.16	0.35	0.34	0.24	0.23	0.27	–0.08
sat.TV	0.23	0.94	0.26	0.20	0.34	–0.73	0.45	–0.87	0.44	0.86
v.cam	0.19	–0.13	0.16	0.34	0.17	–0.29	0.10	–0.09	0.11	0.10
v.gam	0.13	–0.06	0.15	0.26	0.13	–0.17	0.15	0.02	0.12	0.04
Eigenvalue	2.85	0.98	2.73	0.97	2.40	0.91	1.98	1.23	1.91	0.92
% Explained	78.13	9.24	77.45	9.90	77.01	11.16	63.19	24.29	70.50	16.21
Maturities and Discontinuances										
air.c	0.11	0.78	0.31	0.58	0.24	0.44	0.11	–0.17	0.14	–0.23
byc	0.18	–0.23	0.14	0.03	0.03	–0.32	0.14	0.07	–0.05	–0.45
bw.TV	–0.36	–0.01	–0.34	0.11	–0.32	–0.06	–0.20	0.24	0.03	0.22
cTV	0.34	–0.14	0.31	0.30	0.33	–0.10	0.32	0.16	0.19	–0.39
cam	0.12	–0.10	0.11	0.00	0.10	–0.09	0.12	0.22	0.18	–0.08
c.r.p	0.14	0.16	0.17	–0.03	0.15	0.20	0.11	–0.35	0.13	0.23
col.TV	0.13	0.07	0.18	0.03	0.35	–0.07	0.44	–0.09	0.41	–0.22
cooker	0.04	0.02	0.05	–0.01	0.08	–0.07	0.15	0.02	0.23	0.07
d.w	0.35	–0.20	0.25	–0.24	0.18	0.00	0.17	–0.02	0.08	–0.04
fr	0.21	–0.33	0.17	–0.40	0.26	–0.27	0.21	–0.04	0.14	–0.12
hfs	0.24	–0.08	0.26	–0.08	0.22	0.30	0.25	–0.36	0.22	–0.20
mo	0.46	0.13	0.43	–0.03	0.33	–0.16	0.25	–0.25	0.19	–0.22
mc	0.01	0.11	0.00	0.44	0.03	0.21	–0.02	0.14	0.06	0.04
car	0.13	–0.14	0.13	–0.13	0.23	–0.05	0.21	–0.06	0.21	0.19
pian	0.00	0.05	0.05	0.18	0.00	0.12	0.00	0.00	0.05	0.04
refr	0.03	0.00	0.10	0.02	0.07	–0.17	0.17	0.16	0.34	0.30
sew.m	–0.07	–0.10	–0.06	–0.07	–0.12	–0.13	–0.02	0.27	0.02	–0.20
show	0.04	0.02	0.05	0.04	0.04	0.13	0.09	–0.02	0.16	0.09
tel	0.10	0.05	0.15	–0.03	0.24	–0.13	0.29	0.17	0.37	–0.07
tu.dr	0.26	0.10	0.29	–0.20	0.16	0.33	0.06	–0.09	0.06	–0.01
vac.cl	0.12	–0.10	0.13	–0.21	0.17	–0.39	0.32	0.39	0.24	–0.13
v.rec	0.32	0.20	0.29	0.05	0.31	0.15	0.23	–0.23	0.19	0.05
w.m	0.06	0.03	0.10	0.01	0.18	–0.15	0.25	0.39	0.37	0.35
Eigenvalue	2.08	1.47	2.30	1.62	2.44	1.43	2.28	1.34	2.52	1.48
% Explained*	43.85	21.87	43.63	21.79	45.18	15.50	42.26	14.59	43.47	15.13

* Percentage of variance explained.

1.4 Discussion

The purpose of this article is to show how different durable goods interact in a global framework and associate according to their rates of penetration among countries. Biplots allow us to explore diffusion from a new perspective and extract useful conclusions about patterns of international diffusion of durable goods.

PCA biplots help answer key questions about international diffusion of innovations. The diffusion process of multiple household durable goods share a common characteristic: differences on the diffusion process of durable goods are attributable mainly to wealth. This is consistent with previous literature on international diffusion of innovations (Krishnan and Thomas 2009, Peres et al. 2010). In **Figures 1.4 – 1.7** we observe the historical trend of the world's rate of penetration of consumer durable goods and they show that this trend has been dominated by income.

With this approach, we analyze the diffusion process of these durable goods across the full breadth of countries. In biplot 2 of **figures 1.4, 1.6**, and **1.7** time points can be compared among categories of countries and the separation between points is smaller for poorer categories of countries. This shows that richer countries consume a larger portion of products in every time period. Also, in biplot 2 of **figure 1.6**, representing innovations, richer countries have more years represented. This suggests that innovations in poorest countries are introduced later and slower. This is confirmed by **figures 1.1** and **1.2**, where every product can be seen for every category of countries. Furthermore, inter-country diffusion impact is not shown in biplots but countries can be visualized based on the diffusion of certain goods which shows this type of impact. For instance, Arabic countries cluster close to satellite television sets (see biplot 1 of **figure 1.6**). This is an example of how groups of countries are related based on the diffusion process of a specific durable good caused by cultural and social characteristics of countries. In this case, the political environment of most Arabic countries has pushed households to seek entertainment and information outside their countries, where government control of media is less tight (Ghareeb 2000).

Businesses and academic researchers might use biplots to aid traditional schemes of research in the area of international diffusion of durable goods and help to show relationships between diffusion processes and socioeconomic and cultural characteristics of countries. As a complementary tool, biplots help not only to answer traditional diffusion questions but also to explore multiple countries and products. Extensions of dimension reducing techniques are used in the diffusion literature to help predict and analyze patterns of different goods in different countries (Sundqvist et al. 2005, Sood et al. 2009), but none of the previous studies has used biplots to understand possible interrelations among countries and products. These biplots show a clear gap between rich (categories 1 and 2) and poor economies (categories 4 and 5). In less-developed categories, a large variance exists among countries that have already entered into an emerging process and countries that are still struggling to enter it. A clear example is China, which in 1977 had similar levels of penetration of durable goods as Nigeria, but in the last years its development process has taken off and this is reflected on the rate of adoption of durable goods, specially, on innovations. Inter-category competition for certain types of goods is also identified and reflects the potential of emerging countries. While certain categories of countries do not show too much variance in the level of penetration of certain goods among developed countries because saturation levels have already been reached, in categories of less developed economies these same products show a great amount variance.

Biplots can also help to understand how growth, maturity and discontinuance of durable goods are distributed among different countries. First, multiproduct interactions (Mahajan et al. 2000) in a international framework are transparent in biplots. In our sample sets of products can be compared by their correlation and variance. For instance, in **figure 1.10**, a technological product substitution between color and black-and-white television sets can be observed for each category of countries. In the first biplot, the two products point in opposite directions. By contrast, in the biplot representing the category of poorest countries, the direction between these products is almost the same. This means that the process of replacing black-and-white television sets has been slower in poorer countries since the initial appearance of color television sets. Moreover, in biplot 5, we can identify countries in which this effect is stronger, namely, countries whose positions are closer to black-and-white television sets. Second, in **figures 1.8 – 1.10** biplots from different categories based on GDP can be compared. The main finding here is that countries in different categories compare also on different products. For instance, in biplot 1 of **figure 1.8** richer countries compare mainly on the level of penetration of mobile telephones and personal computers, but color television sets and telephones do not represent a major source of variance among countries. On the other hand, in biplot 5, color television sets and telephones have a high variance among the countries. Third, the world market potential of different products can be visualized. Businesses that have reached a maturity level in a country might be interested to expand their activity and enter new markets. In **figure 1.10**, maturities and discontinuances are plotted with the relative position of countries.

In **figure 1.11**, a scree plot[7] of the percentage of variance explained of every biplot is presented. We observe that in almost every biplot most of the variance is explained in two or three dimensions. The other dimensions could be a representation of noise. In biplots of **figure 1.10**, a possible extension could be to plot different dimensions and compare the position of countries relative to the position of products. It would also be useful to analyze how many dimensions are worthwhile to be considered. **Figure 1.11** shows that in almost every biplot a three-dimensional plot could add valuable information and in **figure 1.10**, for instance, many dimensions account for less than

[7] see Appendix 1.

five percent of the variance explained.

Extensions of this approach could be conducted also for other types of goods or services such as non-durable goods and services. Also, a multi-region analysis of a particular area would result to useful visualizations of the diffusion of products. Key decision makers can use this type of analysis to help them choose policies that improve diffusion of innovations among regions.

A limitation of this analysis is that only GDP is used to classify countries. Extensions of this approach, using other classifications could help rank markets in terms on development. For instance, using categories based on infrastructure, income inequality or cultural factors. On the other hand, analyzing consumption goods with PCA can be useful to perform indexes of economic development.

Finally, dimension-reducing techniques can lead us to understand better international diffusion of durable goods. First, a method that takes into account the spatial information of countries and associates it with the multiproduct data set can be of interest to understand whether countries adjacent to each other have similar patterns of diffusion of durable goods (Dray 2011). This method is promising for studying inter-country diffusion impacts and building a regionally-spatial theory of technology diffusion (Kauffman and Techatassanasoontorn 2005). Second, here a two-way matrix is created by concatenating the year-by-year matrices of a three-way array (country by year by product) and performed PCA on it. As an extension an alternative decomposition method, such as PARAFAC or tucker3 (also called three-mode PCA), could be applied to obtain *loadings* that would describe the data in a more condensed manner (Kroonenberg 2008).

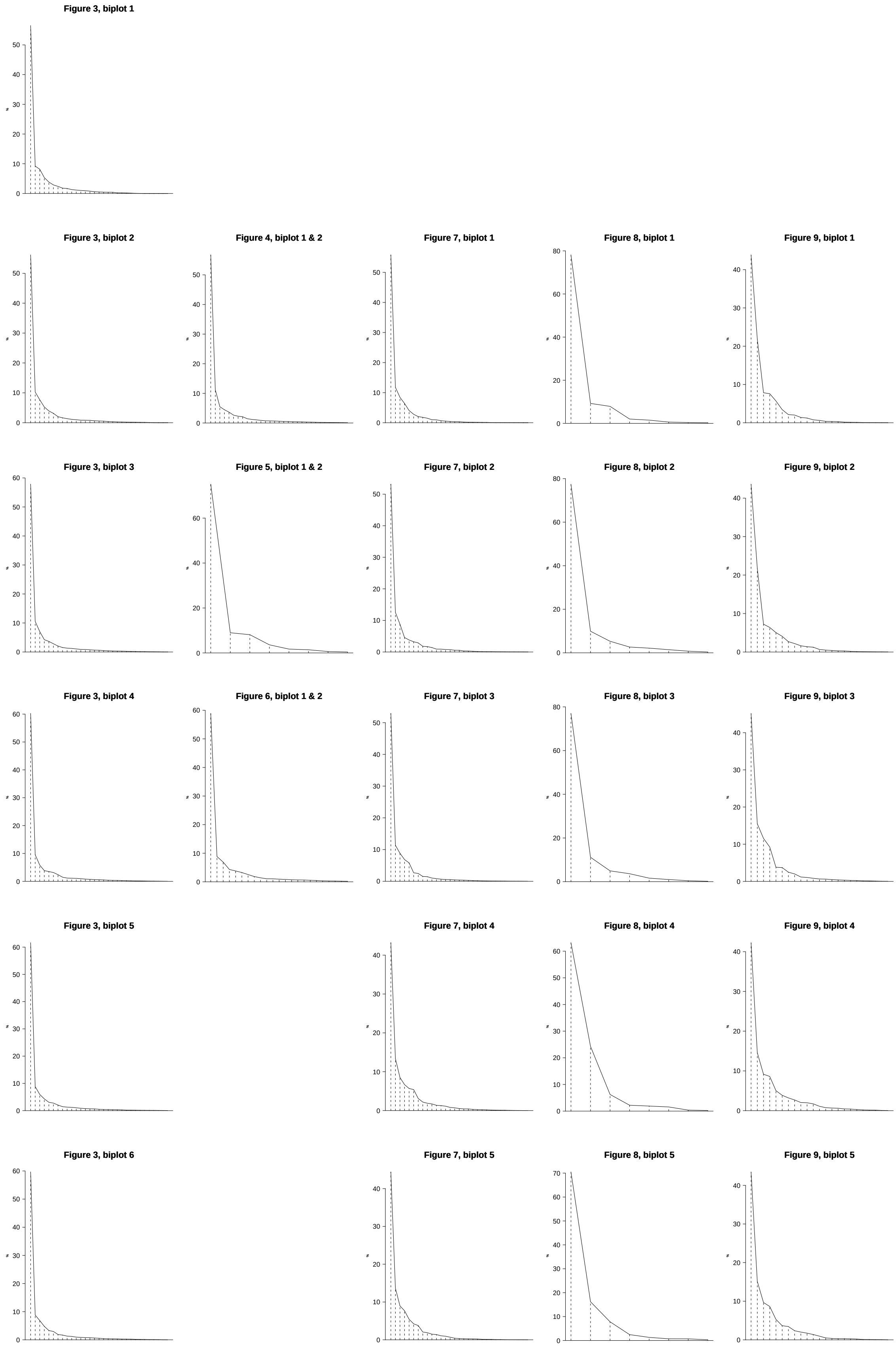
1.5 Conclusion

PCA reduces the dimensionality of 31 durable goods among 70 countries between years 1977 and 2008. Marketers can see the relative positions of less-developed, emerging and developed economies based on the variances and correlations of the rates of penetration of durable goods between 1977 and 2008. This technique allows us to compare multiproduct and multicountry diffusion simultaneously. The global picture enables marketers to make better decisions and develop a better strategy, especially, in managing products over time, identifying potential new markets and estimating these markets potential.

The level of penetration of durable goods in the world is mainly explained by income. In these biplots the development gap between countries is visible, especially among the richer an poorer categories. The role of marketers and public policy makers should help to reduce this gap in a sustainable manner and approach better decisions based on the particular needs of regions. The second main finding is that countries of different categories compare on the level of penetration of different durable goods (see **figure 1.8**). This is specially important to marketers because it means that the variance of certain products in countries from the same category based on wealth is based on other factors that are different from income which is consistent with previous research (Krishnan and Thomas 2009, Peres et al. 2010). Third, it provides a visual explanation of new possible markets for new categories of durable goods and their market potential.

PCA is applied to a wide range of products and countries to obtain a perspective from a international diffusion theory point of view. This provides a visual perspective of countries based on international diffusion of household durable goods. From a particular industry point of view it is more interesting to focus on fewer countries or products. The same methods might be used for other particular business and public policy interests. Many limitations of this essay are related to the availability of more data on products or services or the use of other types of classifications based on other country characteristics. Nonetheless, researchers and academics might find this approach valuable for further research on international diffusion of durable goods, and may extend this analysis by using new data sets and variations.

Figure 1.11: Percentage of Variance Explained by Each Principal Component.



Note: Each scree plot represents a different principal component analysis.

Appendix 1: Interpretation of Principal Component Analysis

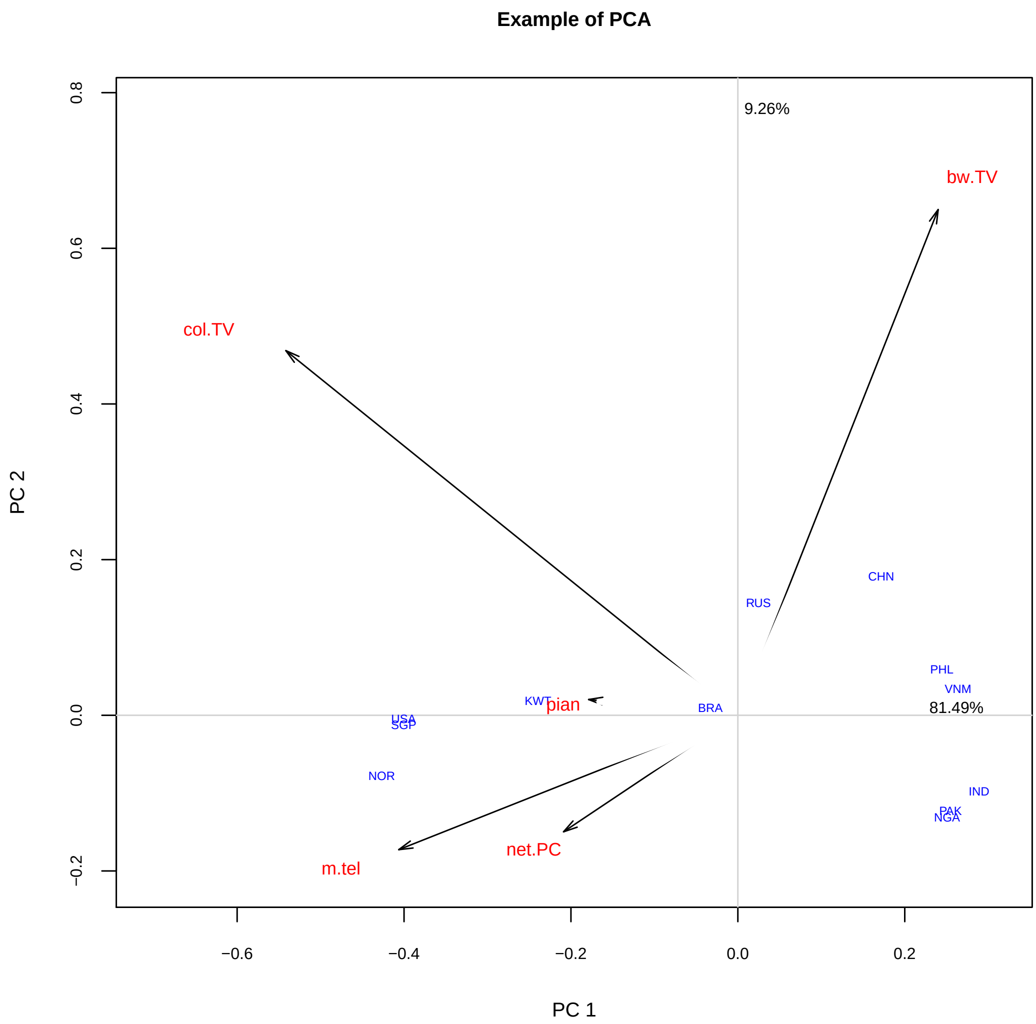
PCA biplot is a method related to the solution of singular value decomposition (SVD)[8]. The SVD solution leads directly to the display of a biplot. Once a data matrix, **X** , with *I* rows, or countries, and *J* columns, or durable goods, has been properly centered, $\mathbf{Y} = [\mathbf{I} - 1/n\underline{1}\underline{1}^T]\mathbf{X}$ where **I** is an identity matrix, resulting in a new matrix **Y** with rank *r*, it can be expressed as a product of three matrices, $\mathbf{Y} = \mathbf{U}\mathbf{D}_\beta\mathbf{V}^T$, where **U** is $n \times r$, **V** is $m \times r$ and **D** is an $r \times r$ diagonal matrix containing singular values in descending order. The columns of **U** and **V** are orthonormal and orthogonal; this property can be written as $\mathbf{U}^T\mathbf{U} = \mathbf{V}^T\mathbf{V} = \mathbf{I}$, and they are called left and right singular vectors respectively. For drawing a biplot, only the two first components of each matrix the SVD solution are used. For this article, to calculate the coordinates of the biplots, $\mathbf{F} = \mathbf{U}\mathbf{D}_\beta$, provides the solution for countries, and $\mathbf{G} = \mathbf{V}$ gives the solution for durable goods. The eigenvalues, which are the squared singular values, inform how well the data matrix is represented in the biplot. The eigenvalues as percentages of the total of each principal axis are displayed in the biplot close to each axis, and a bar chart of each analysis containing the same information for every eigenvalue is given in the *scree plot* (see **figure 1.11**). The contribution of each durable good to each principal axis of the biplot can be extracted from the eigenvectors and they are available in **tables 1.3–1.7**.

A small example is provided to guide on the interpretation of principal component biplots. The interrelations of twelve countries with five products are analyzed for year 1996 in **figure 1.12**. One third of the countries belongs to category 1 of **table 1.2**, Norway, Kuwait, Singapore, and United States, another third to category 5, Nigeria, Vietnam, Pakistan, and Philippines, and the last third are the so-called BRIC countries, or big emerging economies, India, China, Brazil, and Russia. Products mapped in **figure 1.12** include: black-and-white television, a technology in increasing discontinuance; the piano, a mature technology; color television, which represent an older innovation; and two newer innovations: personal computer with internet, or internet PC and mobile telephones.

Durable goods are plotted as arrows from the origin to the resulting coordinates. Each of the arrows represents a biplot axis onto which the set of countries can be projected by dropping the country perpendicularly onto the arrow. The origin coincides with the mean value of countries on each product or biplot axis. These arrows can be interpreted as follows: their size represents the variance of penetration each durable good among countries; and their directions, how correlated are products between each other based on their level of penetration in each country. Countries are located in the biplot based on their relative penetration of the analyzed durable goods.

[8] For an interesting perspective, visit the following link: **It had to be U**

Figure 1.12: Principal Component Analysis of 5 Durable Goods in 12 Countries (1996).



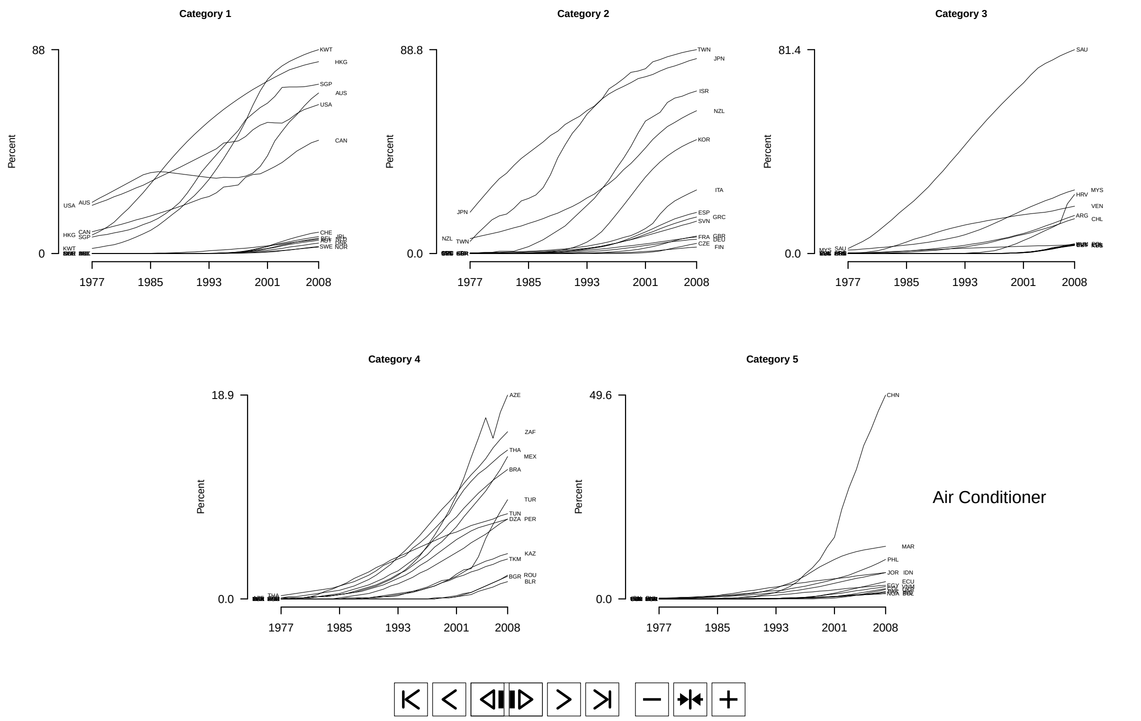
Note: This biplot represents the level of penetration of 5 durable goods in 12 countries. Country and product acronyms are presented in **tables 1.1 and 1.2**, respectively.

The two principal axes are represented by an horizontal and a vertical gray line. The first component explains 81.5 % of the variance contained in the data set and 9.3 % is explained by the second component. Poorer countries are on the right-hand side of the plot while richer countries are on the left-hand side. That is, based on the first axis, the position of countries which is based on the level of penetration of products is highly related to wealth. Richer countries lie nearer to innovations while poorer countries are closer to black-and-white television sets. The first component is strongly related to wealth. The second component is dominated by the level of penetration of black-and-white television sets. If countries were projected perpendicularly to the biplot axis that represent black-and-white television sets, we would observe that China, Russia, Philippines and Vietnam have a higher level of penetration. The position of Brazil slightly above and to the right from the origin of the biplot shows that it is close to the overall mean level of penetration of durable goods. The distance between countries also has an interpretation; in the biplot, richer and poorer countries are closer to each other, but a large distance separates among them. Brazil has a large distance from every group countries, and only Russia is close to Brazil in the first dimension. These distances are understandable since Brazil and Russia are the only countries from the fourth and third category from **table 1.2**, respectively.

Figure 1.12 contains 90.75 % of a twelve by five matrix in one graph. A reader might focus on a particular interest because the amount of information of each biplot is very large. For instance, a reader interested in pianos would notice that it is the only product that lie on the first principal axis which is related to wealth. It coincides with the most mature and stable technology, not involved in any particular dynamic of growth or decline of penetration. And it also has the lowest variance among all the products. In contrast, someone interested in the contrast between innovations and discontinuances would notice that the levels of penetration of innovations, internet PC and mobile telephones, are positively correlated while they are negatively correlated with a global discontinuance, black-and-white television sets.

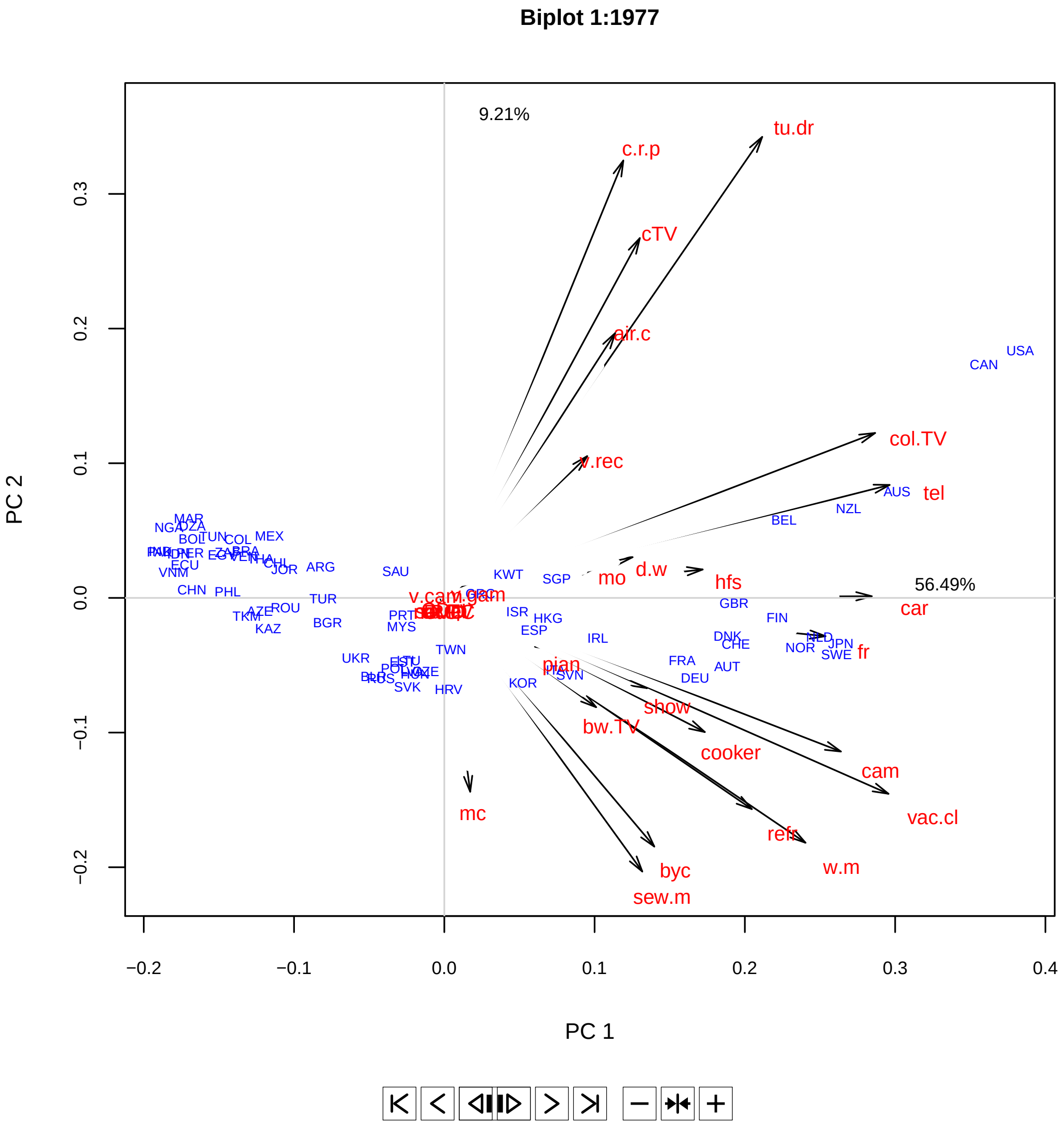
Appendix 2: Animations

Figure 1.13: Products and Countries (1977–2008).



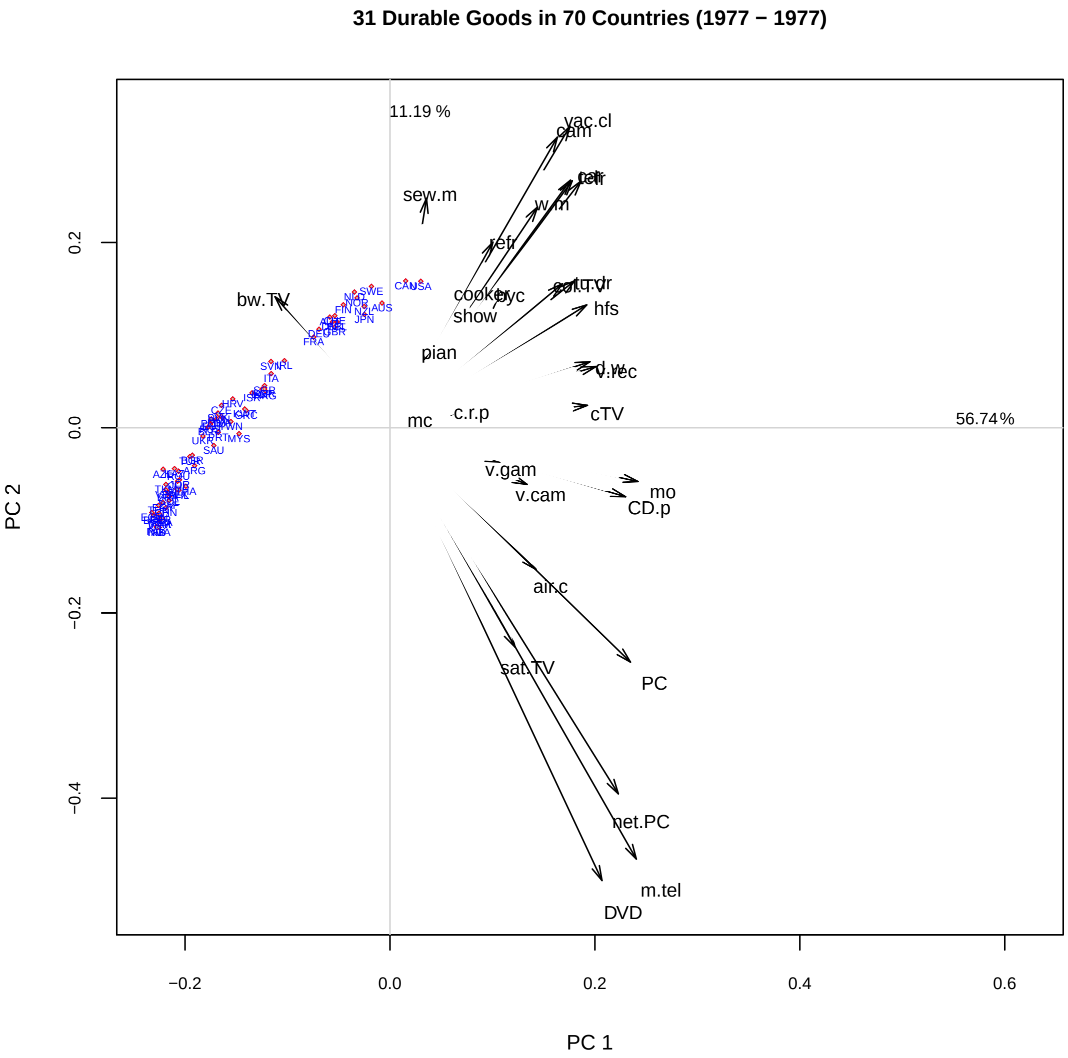
Note: Only available in the electronic version of the document.

Figure 1.14: Principal Component Analysis from 1977 until 2008.



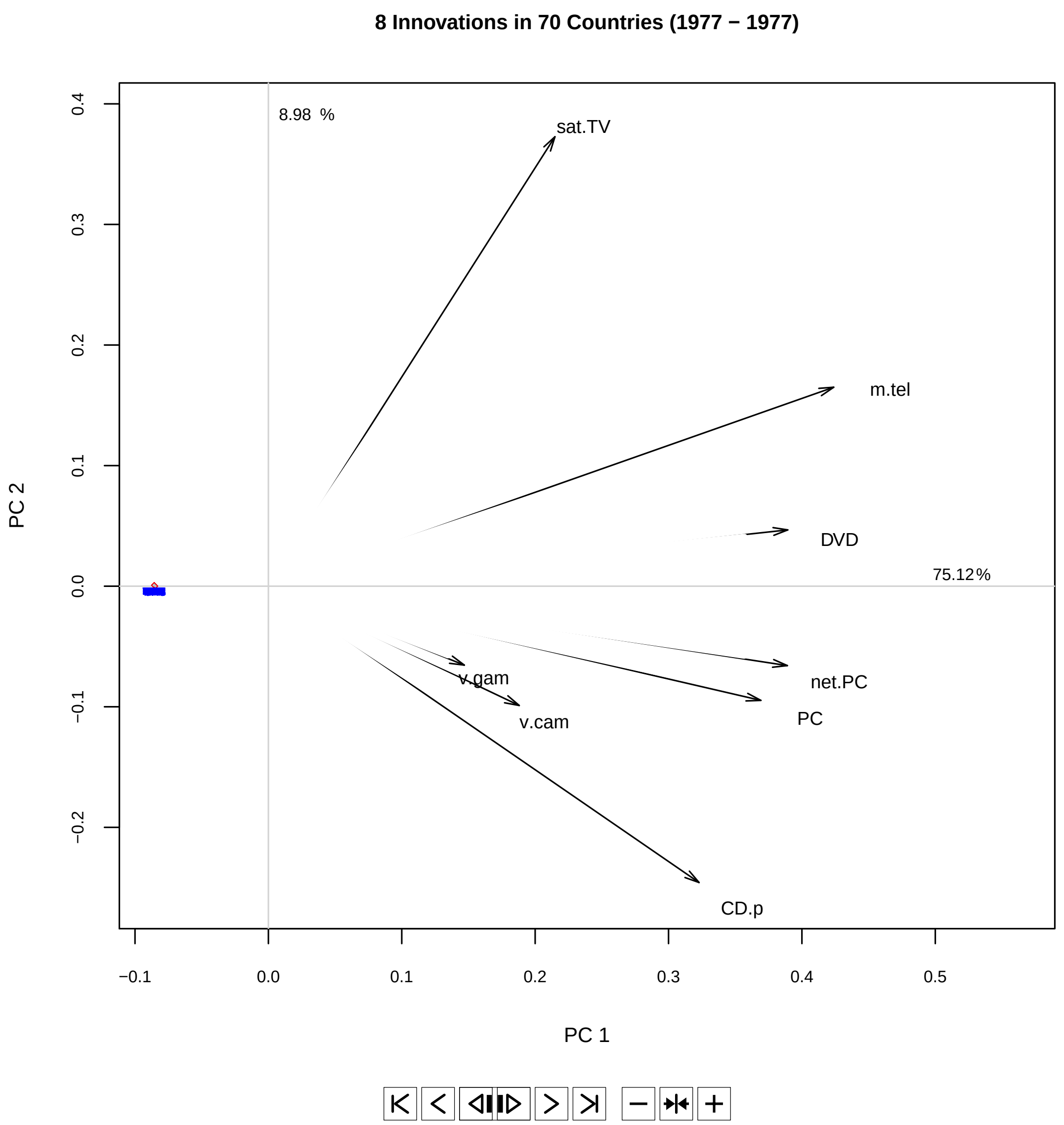
Note: Only available in the electronic version of the document.

Figure 1.15: Principal Component Analysis (1977 – 2008).



Note: Only available in the electronic version of the document.

Figure 1.16: Principal Component Analysis (1977 – 2008; Innovations).



Note: Only available in the electronic version of the document.

Chapter 2

The Rate of Discontinuance

The discontinuance process is divided into five categories based on Rogers (2004) and its relation to the adoption process is described in this article. While marketers have focused on diffusion of innovations, studying discontinuance provides an opportunity to explore the needs of the market and create a more sustainable approach to marketing activity. Discontinuance, disposal and dispossession are different processes: discontinuance is studied from a technology-centered point of view, and disposal and dispossession from an object-centered and a people-centered point of view. Using diffusion models, the internal and external influences that affect members of a country before discontinuing black-and-white television sets between 1977 and 2008 are studied. The level of discontinuance and household characteristics are also analyzed. Six household characteristics are helpful to understand the level of discontinuance in a household: age, economic status, income, household size, tenure of residence and household composition.

Key phrases: Diffusion of Innovations, Rate of Adoption, Level of Penetration, Rate of Discontinuance, Disposal, Dispossession

Introduction

The rate of discontinuance, and its relation to the rate of adoption, is described. Using categories of adopters defined by Rogers (2004), the discontinuance process is divided into five categories of discontinuers. Marketers have focused on the adoption process of diffusion of innovations, and due to *pro-innovation bias* have ignored the study of the rate of discontinuance. However, this type of study is necessary to understand diffusion dynamics.

Discontinuance, disposal (or disposition) and dispossession are explained, as well as, why they are important in the marketing field. For a better understanding of the dynamics of discontinuance two methods are used: diffusion models are used to explore the rate of discontinuance of black-and-white television sets in 41 countries in which a peak on the level of penetration occurred after 1977. Also, the different levels of penetration of black-and-white television sets in 70 countries based on the characteristics of the household are explored. Six types of characteristics are helpful to understand the level of discontinuance in a household: age of the head, economic status, income, household size, tenure of household and the type of household. Finally, it is discussed how these approaches are relevant to the marketing literature.

In the following section, the terminology associated with three concepts related to the end of life of a product is considered: discontinuance, disposal and dispossession. Examples of how they have been used inconsistently in the marketing literature are provided. The motivation to understand what occurs in the final life-stage of a product and review the marketing literature related to it is described. Next, the discontinuance process, its categories and its relation with the adoption process, is explained. Also, the Bass model, and how it can be easily adapted to study the rate of discontinuance, is described. In the following two sections, the international rate of discontinuance of black-and-white television sets in 41 countries between 1977 and 2008 and the effect of aggregate household characteristics on the level of discontinuance in 70 countries in 2008 are analyzed. A discussion of marketing implications and limitations is presented.

2.1 Discontinuance, Disposal and Dispossession

The terminology about disposal, dispossession and discontinuance has been used inconsistently and applied to different meanings and in different manners when the product's end-of-life is studied. The latest effort to put order and to define this terminology is due to Ekerdt (2008). He separates the *object-centered* point of view, i.e. a view that is based on the life of a thing around which people come and go, and for instance, when disposed objects may reappear to interact with people in new ways (O'Brien 1999), from *people-centered* point of view of things where things are occupants of people's behavior and an object comes and goes from their world. He says: "I also prefer the term dispossession rather than disposal", because the latter has a material connotation while the former suggests a personal disengagement from things. His approach is consistent with a people-centered analysis. He also specifies that only items qualified as possession stay long enough with an individual to require a "labor of possession". And he uses the word *thing*, because according to *thing theory*, objects are mere materiality and things are consumer items invested with a subject-object relation (Brown 2004).

Before proceeding with this essay, a definition of discontinuance, disposal (or disposition) and dispossession is presented as follows: when referring to the act of disposing a thing, from an object-centered perspective, the word *disposal* will be used, instead of disposition, because it rules out a conflict with other meanings of disposition, like temperament or inclination. If looking at the parting of people from their thing at the end of the consumption cycle (Ekerdt 2008), that is, from a person-centered perspective, Ekerdt's terminology is followed by using *dispossession*. And when referring to a decision unit from a social system that discontinues an innovation, from a technology-centered perspective, *discontinuance* will be used. While the word "disadoption" (Athiyaman 2008, Redmond 1996, Hogan et al. 2003, Prins et al. 2009) has been used in the marketing literature, discontinuance (or discontinuation) is the appropriate English term (Black 1983, Rogers 2004). Yet another term has been applied to discontinuance in social science: abandonment (Berger and Le Mens 2009).

2.1.1 Marketing Relevance

Jacoby et al. (1977) revealed the lack of understanding of the real final use of a product: its disposal. Marketing scholars for a variety of reasons have been more interested in the adoption of products than in disposal, dispossession or discontinuance altogether. For instance, the only marketing paper included in the 10 most influential papers published in the 50-year history of *Management Science* in connection with the 50th anniversary of the journal is Bass (1969)'s article: "*A new product growth for model consumer durables*". The paper proposes "a growth model for predicting the initial purchase of new products related to the number of previous buyers", called the Bass model (see Mahajan and Peterson (1985), Mahajan et al. (2000), Chandrasekaran and Tellis (2007), Peres et al. (2010) for a review). Rogers (2004) estimated that marketing and management are responsible for 16% of all published articles on the topic of diffusion of innovations, surpassed only by the field of rural sociology.

While marketers have only recently started to appreciate the need to understand how disposal, dispossession or discontinuance work, in other fields it has been an important area of research. For instance, in anthropological sciences disposal is "implicated in the maintenance of a recognizable state of social order" (Hetherington 2004). In the business framework, companies can now make profitable, pro-social and ecological actions in creating added value through reverse logistics (Fleischmann et al. 1997, Rubio et al. 2008, Atasu et al. 2008, Pokharel and Mutha 2009) and more and more they need to understand what happens to products that consumers no longer need and how the life cycle of these products affects the process of reverse logistics (Tibben-Lembke 2002). Newer regulations (CEC 2003) have established the requirements to reduce e-waste (WEEE[1]) in the case of durable goods. Apart from these obligations that companies have to accomplish, it is immoral not to care for the environment and society (Raghavan 2010). Durning (1994) is a good summary of how consumption affects our natural environment.

While recycling and reusing is one of the reasons that justify research on the end of life of products, the marketing concept has been amplified, as firstly demanded by Wiebe (1951), Kotler and Levy (1969) and extended to many nonprofit areas (Kotler 1991). Its philosophy has expanded to meet a pro-social activity full of challenges in international settings (Carrigan et al. 2005) and to deal with several aspects of corporate social responsibility and socially responsible business practices (Kotler and Lee 2005). A good example related to consumer goods is the *well-being marketing* philosophy explained in Sirgy and Lee (2008). The relation that marketing and business practices have with global consumption and the moral conflicts of consumption (Wilk 2001) addresses interest to understand how disposal options that extend the life of a product can also meet social needs, like charity donations (Hibbert et al. 2005), and create secondhand markets (Green et al. 2001, Chu and Liao 2007) and alternative uses (Ekerdt 2008, Hetherington 2004). Therefore, recognition of such complex marketplace dynamics that occur after the sale and the use of a product, and of a need to fully understand the processes that a product passes until it is no longer needed for the consumer's original purpose of use, accompanied by general confusion in marketing literature about the end of life of a product, is the motivation of this piece of research.

Even though there are reasons for thinking that the dynamics of discontinuance is an important subject in which marketing academics should invest at least as much research effort as in the diffusion of innovations, it is not likely to become a highly researched area. The main reason is the pro-innovation bias, i.e. *the implication in diffusion research that an innovation should be diffused and adopted by all members of a social system, that it should be diffused more rapidly, and that the innovation should be neither re-invented nor rejected* (Rogers and Shoemaker 1971, Rogers 2004), and it makes researchers suffer a type of myopia that does not let them be interested in the

[1] electronic and electrical waste

understanding of how innovations might be reinvented, rejected and discontinued. This creates several problems; for instance, it leads to a failure to evaluate anti-diffusion programs, prepared by social marketing campaigns to prevent consumption with negative effects (i.e. tobacco). One of the main causes for this bias is the selection of innovation products studied. The selection of innovations studied might be sponsored by a particular interest of a private company for a particular product innovation. If the sponsor is not the cause of the bias, researchers might find more interesting and dynamic diffusion with rapid rates of adoption. But one problem that researchers need to acknowledge is how a product disappears, that is, to explore and fully understand the dynamics of discontinuance. The international marketing field is also bounded by the innate human tendency to focus on winners and there is a need to modify this behavior (Czinkota and Ronkainen 2003). For instance, Prahalad and Hart (2002), Prahalad (2009) concentrate their research on the unserved majority of consumers.

2.1.2 Literature Review

This literature review covers three topics: disposal, dispossession and discontinuance, to emphasize the lack of importance attributed to these topics in the marketing literature. Research on discontinuance in the marketing field has been very scant and this article offers three contributions to it. In this section, we explain how interest in the end-of-life of a product started with research in disposal, and how these initial efforts evolved, slowly until now, when different perspectives are used to analyze disposal. Findings about dispossession are summarized, and marketing literature about discontinuance is discussed.

Disposal has received a lot of attention only in environmental and waste literature [2]. Many conclusions in this literature are of interest to businesses and marketers. For instance, Cooper and Mayers (2000) investigate the purchase, use and disposal of household appliances from a consumer perspective in the UK, provide quantitative information on product ownership, lifetime use and disposal and identify the likely effectiveness of different approaches to reduce WEEE. Other related topics to the end of life of a product are those of second hand markets (Herrmann and Soiffer 1984, Sherry 1990, Purohit 1992, Herrmann 1996, Green et al. 2001, Lastovicka and Fernandez 2005, Hibbert et al. 2005, Chu and Liao 2007, Olavarrieta et al. 2008), replacement of goods (Bayus 1988, 1991, Marell et al. 1995, Okada 2001, Fernandez 2001, Grewal et al. 2004, van Nes and Cramer 2008, Huh and Kim 2008, Prince 2008, Glassmeyer et al. 2009, Roster and

[2] Pieters (1991), Shim (1995), Van Houtven and Morris (1999), Cooper and Mayers (2000), Cooper (2000), Vencatasawmy et al. (2000), Cooper (2003), Saied and Velasquez (2003), Cooper (2004), Linton et al. (2004), Mannetti et al. (2004), Cooper (2005), Darby and Obara (2005), Hicks et al. (2005), van Nes and Cramer (2006), Osibanjo and Nnorom (2007), Gregson et al. (2007), Gunter (2007), Nixon and Saphores (2007), Shinkuma (2007), van den Bergh (2008), Knussen and Yule (2008), Nnorom and Osibanjo (2008), Osibanjo and Nnorom (2008), Alexander et al. (2009), van Birgelen et al. (2009), Kagawa et al. (2009), Murray (2009)

Richins 2009) and substitution of technology (Norton and Bass 1987, 1992, Mahajan and Muller 1996, Van den Bulte 2000, Stremersch et al. 2010), which have received a lot attention from marketers. These topics are closely related to disposal, dispossession and discontinuance of products, but they are out of the scope of this article.

The origin of the studies regarding the end of life of a product can be traced to four publications concerning disposal (Jacoby et al. 1977, Burke et al. 1978, DeBell and Dardis 1979, Conn and Warren 1979) and one related to discontinuance (Midgley 1976). To understand innovative behavior, Midgley (1976) studies the relation between discontinuers and adopters. Jacoby et al. (1977) create a taxonomy for describing consumer disposal behavior where people either keep a product, get rid of it temporarily or get rid of it permanently. They perform an exploratory research based on six durable goods with a sample of 134 participants, and define what factors influencing disposal decisions are either psychological, intrinsic to the product or situational and extrinsic to the product. Burke et al. (1978) investigate the factors that motivate the length of "product lifetimes" based on a survey given to 311 respondents from California in 1977 in which they answer which criteria they had in mind when they disposed one of the selected products. They classify products into those that are either rapid technological innovations, stylistic innovations, fads or stable products. In a regression analysis, the dependent variable is how disposal is operationalized and independent variables are demographic and psychographic variables. They use discriminant analysis to differentiate among eight factor solutions based on survey subjects' responses. They find that age is significant to differentiate among two types of disposers, labeled as *trashers* and *pack rats*. DeBell and Dardis (1979) argue that while product durability can be achieved, extending the life of products is another matter. In fact, Burke et al. (1978) find a motivation for research on disposal behavior for the same reason, stating that "there is no reason to persuade or force manufacturers to make products last longer if, in reality, consumers discard products before they reach the technical limits of their durability". They explain that extending life cycle should lead to a reduction of demand for scarce resources, a reduction of solid waste disposal and of cost to consumers, and an overall saving to the total economy. They propose that disposal is a replacement/disposal decision that will occur when the marginal costs from ownership exceed marginal benefits, and see disposal as the action taken by a consumer when he decides to replace an appliance, regardless of a motive. They differentiate the time of disposal between fashion and mechanical obsolescence of the product. Conn and Warren (1979) perform an exploratory study of the frequency distribution of consumer disposal choices and the variables that are associated with the particular disposal options. The dependent variable is disposal choice and independent variables are socioeconomic characteristics, product characteristics, sentiments and perceptions of the consumer. They do not find any relations between socioeconomic variables and the disposal option. But they find that the higher the price the longer the use, and that people who paid a higher price have higher probability to store the product as a disposal option. They also find that satisfaction is related to the length of use and that older people tend to have products for a longer time. They find a relation between the disposal option used and consumer satisfaction and years of use. People who threw items away were less satisfied than others. In the eighties, Hanson (1980), Box (1983), Antonides (1989, 1991) continue with research on disposal of products. Hanson (1980) prepares a model based on Jacoby et al. (1977) in which person, product and situation are viewed as components influencing the disposal process, and defines a paradigm of factors that create a disposal decision. The exploratory research for four durable products by Box (1983) finds that motives for disposing different products differ, and he concludes that technical life should be extended only to products whose practical life is determined by their technical life. Antonides (1989, 1991) creates a model of disposal behavior that includes a defect of a good, and compares the utility of repairing it against the utility of scrapping and replacing it. In the nineties only Harrell and McConocha (1992) and Boyd and McConocha (1996) extend the theory of disposal. Harrell and McConocha (1992) investigate how rationales relate disposal behavior tendencies and find a relation between thirteen rationales and six disposal options. Boyd and McConocha (1996) build a model of management of household goods and study the frequencies of anecdotes of 130 students. They define disposal as the process of getting rid of an item by intentionally moving it to the ownership of another person or entity. In the new millennium, the amount of work related to disposal of products with a marketing focus has also been scarce (Green et al. 2001, Coulter and Ligas 2003, Hibbert et al. 2005, Paden and Stell 2005, Walker 2006, Morgan and Birtwistle 2009, Sego 2010). Green et al. (2001) investigate the methods, behavior and motives of consumers who engage in the disposal of goods in *car boot sales*. A marketing institution facilitates the process after a macroeconomic shock occurred in an emerging market, specifically, in Thailand. They find how conspicuous "under-consumption" become fashionable in upper-middle classes and second-hand sales pass from being seen as unacceptable to be seen conspicuously appealing in forty in-depth interviews with vendors. Coulter and Ligas (2003) distinguish among *packrats*, people who keep things and are unwilling to dispose of them, and *purgers*, people who are readily willing to dispose them. Hibbert et al. (2005) present a descriptive study based on a survey of 210 households and investigates disposal behavior from a charity retailers' perspective. They distinguish households in terms of goods discarded and channels used. They explore two situational factors: 1) events that prompt disposal, and 2) the competition that charities face for used goods: new users and trash can. Paden and Stell (2005) extend the model created by Boyd and McConocha (1996) and describe factors that affect consumer disposal behavior in the selection of redistribution channels. They distinguish between recycling behavior and disposal behavior. Walker (2006) is the first study of product disposal by an experimental approach. She analyzes how dispossession of a good has an effect on the disposal option and identifies four dimensions on which four disposal methods of interest differ: ease, ethicality, control and monetary compensation. Morgan and Birtwistle

(2009) study consumer disposal habits and relate them to fashion innovativeness, awareness of the environment and recycling behavior. Sego (2010) relates mother's dispossession of their children's things to their final disposal channel. She defines four types of products, rubbish, wares, mementos and intended heirlooms, based on their relative personal value and their relative value to others.

Dispossession research in consumer sciences is not a highly investigated area but it has received some attention (Young and Wallendorf 1989, Young 1991, Rucker et al. 1992, Sherry et al. 1992, Curasi 1999, Stevenson and Kates 1999, Price et al. 2000, Kates 2001, Roster 2001, DeLorme et al. 2005, Lastovicka and Fernandez 2005, Ekerdt and Sergeant 2006, Walker 2006, Baker et al. 2007, Belk 2007, Sneath et al. 2009, Bradford 2009). Young and Wallendorf (1989) investigate how disposition of belongings represents a difficult process of detachment from self and use death as a metaphor to explain the dispossession process and Young (1991) relates dispossession of goods to role transitions of individuals of a social system. Rucker et al. (1992) classify ways of how consumers deal with unwanted gifts and Sherry et al. (1992) investigate gift dispossession from an ethnographic perspective. Curasi (1999) models intergenerational transfer of cherished possessions. In Stevenson and Kates (1999) and in Kates (2001), dispossession of goods as special gifts is studied in the context of dying of AIDS. Price et al. (2000) help to define the nature of older consumers' disposition of special possessions and identify tactics and heuristics employed to select recipients, time transfers and effect these transfers. Roster (2001) presents a model of the psychological process of dispossession and identifies three factors: critical events, distancing behaviors and value and performance assessments. DeLorme et al. (2005) investigate consumer reactions to involuntary disposition of products in a natural disaster. Lastovicka and Fernandez (2005) reveal three alternative paths through which a consumer might pass when meaningful possessions are being passed to a stranger in second-hand markets. Ekerdt and Sergeant (2006) study the role of family attendance in elder's household disbandment. As mentioned above, Walker (2006) relates dispossession to disposal. Baker et al. (2007) investigate how dispossession in a natural disaster creates consumer vulnerability as a shared experience in a community and provide public policy implications to improve consumers experience. Belk (2007) discusses types of sharing and provides a preliminary framing of the issues about sharing compared to possessing a thing. Sneath et al. (2009) shows how disaster victims engage in different purchasing behaviors (impulsive and compulsive buying) to cope with its emotional effects (stress and depression). Bradford (2009) demonstrate how an asset transitions between inalienable and alienable states in intergenerational gift giving. Dispossession is mainly associated with four areas: 1) the events that stimulate a disposal decision about a special or cherished good, 2) the emotions associated with disposal decisions, 3) the meanings that special possessions have, and 4) consumer disposal goals and tactics to accomplish this goals. A recent literature review is found in (Ekerdt 2008).

The dynamics of discontinuance of products have been almost completely disregarded in the marketing literature, with extremely few exceptions (Midgley 1976, Black 1983, Redmond 1996, Hogan et al. 2003, Athiyaman 2008, Palacios Fenech 2008, Berger and Le Mens 2009, Prins et al. 2009). Midgley (1976) studies the role of interpersonal communications between adoption and discontinuance. Black (1983) prepares an interdisciplinary review of literature of post-adoption decisions and a conceptual model of the post-adoption process. Redmond (1996) takes a market approach and uses adoption and diffusion theories to study the quit ratio of smokers and uses the Bass model to understand the diffusion process of how active smokers quit every year. Hogan et al. (2003) prepare a model for the effect of discontinuance on the value of a lost customer and apply it to the online banking market. Athiyaman (2008) explores the discontinuance of animal-based traditional medicine in China, and calls last decision units that decide to discontinue medicines derived from tiger parts as *persistors*. While Athiyaman (2008) and Redmond (1996) frame the time of discontinuance with a negative connotation, due to the nature of their empirical research consisting of demarketing (Kotler and Levy 1971), Palacios Fenech (2008) frames the categories of a discontinuance process with a positive connotation and suggests that units that decide to continue using a product enlarge the life of itself, therefore contaminating less and creating more sustainable consumption. Those who are are the last to discontinue are called *romantics* and those who never discontinue a product, even when the rest of the population has discontinued the innovation, are called *collectors*. Berger and Le Mens (2009) explore whether identity-relevant cultural tastes that have been adopted faster are more likely to be abandoned faster also. They analyze the adoption velocity and the abandonment of first-names in France and United States. Prins et al. (2009) study the effects of adoption timing on post-adoption usage and discontinuance of a new telecom service. They show that the rate of discontinuance is higher among later adopters.

Although further research about the relations between disposal, dispossession and discontinuance is required, the focus of this article is on discontinuance. In the following sections, a classification of discontinuers based on the relative time of discontinuance is presented.

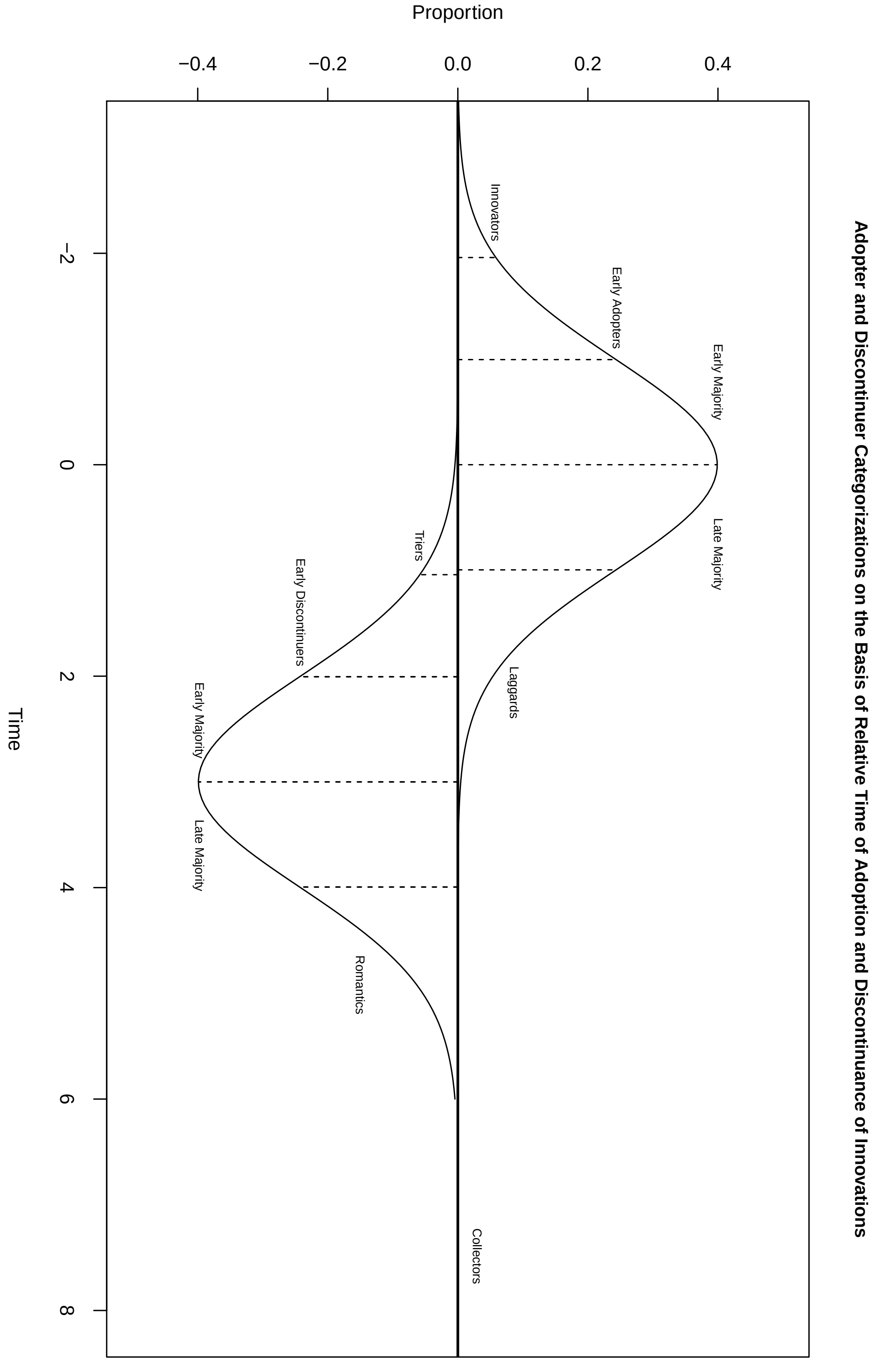
To study more deeply how a product is discontinued on a global scale, black-and-white television sets are analyzed. Diffusion models are used to describe discontinuance of black-and-white television sets of 41 countries in which the peak in adoption is observed between 1977 and 2008. Also, the level of penetration of black-and-white television sets in 70 countries is analyzed and how it is affected by household members' characteristics of each country. Six household variables are observed to affect the level of penetration of black-and-white television sets for 2008: age of the head, economic status, income, household size, tenure, and type of house.

2.1.3 The Discontinuance Process: Discontinuers and Collectors

The key concepts related to adoption and discontinuance are summarized here. *Adoption* is a decision to make full use of an innovation (Rogers 2004, page 21). In this article, data containing information about whether households have black-and-white television sets or not is analyzed. Even if a household is indicated to possess a product it does not mean that it currently makes full use of it. *Rejection* is a decision not to adopt an innovation and *discontinuance* is a decision to reject an innovation after it has previously been adopted (Rogers 2004, page 190). Diffusion of innovations is the process by which information about an *innovation* is *communicated* through certain *channels* over *time* among the members of a *social system* (Rogers 2004). When the diffusion process ends, innovations have reached their maximum level of penetration and they often enter a flat stage in which the proportion of individuals using the innovation remains more or less constant. The rate of discontinuance is used to describe *the speed of the decrease on the level of penetration* that occurs when a technology is being discontinued. Discontinuance can be observed in the change of the level of penetration of a good at the stage when the proportion of individuals who stop using a product is greater than the proportion of individuals who adopt it.

It might be useful to integrate the concept of product life cycle (PLC) (Day 1981, Harrell and Taylor 1981, Midgley 1981, Schultz and Rao 1986) and the concept of diffusion of innovations. PLC depends on two elements, sales and time, and has commonly four stages: introduction, growth, maturity and decline (Kotler 2003, page 328). The *rate of adoption* refers to the speed of how an innovation is adopted by members of a social system (Rogers 2004, page 23) and the *rate of penetration* refers to the speed of the change in the proportion of members of a social system who possess a product. Here it is assumed that a positive rate of penetration is the same as the rate of adoption, and a negative rate of penetration is the same as the rate of discontinuance. Note that a form of disposal of a durable good might be storing it (Jacoby et al. 1977) and that even though the good may still be possessed by the household, the technology has been already discontinued, because the members of the household do not make full use of the good. A *rate* is a measure of change between time periods, and *levels* refer to measures of adoption of a product compared to the total market in a specific time period. Also, adoption and diffusion of innovations are two different points of view to study the same process. Diffusion of innovations focuses on the rate of adoption of an innovation in a social system and adoption focuses on the individual decision making to understand the behavioral change of a particular member of the social unit.

Figure 2.1: Adoption and Discontinuance.



Note: This is an example of a short term rate of discontinuance.

In the adoption process proposed by Rogers (2004) there are five categories of adopters separated by one standard deviation based on the time when they adopt a given innovation, that is, their degree of innovativeness. These categories are: *Innovators (2.5%), Early Adopters (13.5%), Early Majority (34%), Late Majority (34%), and Laggards (16%).* Discontinuance categories are based on adoption categories proposed by Rogers (2004). For this categorization, the noncumulative adoption process is described with a normal curve.

The five categories of the adoption process are defined to comply with three factors: 1) number of adopter categories, 2) proportion of the members of a social system to be included in each category, and 3) the statistical method to define these categories. The criterion to divide the categories is *innovativeness*, that is, the degree to which members of a group adopt an innovation earlier than other members of the group. The categorization has to be *exhaustive*, including all units of the system, *mutually exclusive*, preventing that units belong to more than one category, and based on a single *classificatory principle*, in this case, the mean and the standard deviation (see for details Rogers (2004)).

Here, Rogers (2004) is followed, but the meaning of its categories is reversed to classify discontinuers. Five categories of discontinuers are defined: *Triers (2.5%), Early discontinuers (13.5%), Early Majority (34%), Late Majority (34%), and Romantics (16%).* Once the last romantics appear, a new category of adopters appears: *Collectors (0.1%)* (see **figure 2.1**). With collectors, the mutually exclusive assumption for adopters is broken because any of the members inside the system might become collectors. It is hard to define a classificatory principle for collectors, but for practical reasons they are classified as the last 0.1% calculated from the discontinuance curve. Collectors are a privileged part of romantics, and of adopters (0.1%) at the same time who never discontinue (**figure 2.1**).

Triers are the first to discontinue a product. Once they find a substitute, or even earlier, they discontinue the product. They can also be the first to find that a product adopted is actually not useful for them, and therefore, be the first to discontinue its use. They are the most efficient type of discontinuers and they do not accumulate a lot of products, which could be seen as stock burdened with a storage cost, to satisfy their needs. Triers are followed by early discontinuers. While early adopters have a high degree of opinion leadership, it is not possible to know if early discontinuers will have this type of contagion effect on the rest of discontinuers. With a bad innovation they may be the reference of the social system and if they discontinue a product, or an idea, it will affect the other members of the system. For a consumer durable good, for instance, their influence remains an open question. The early majority discontinues the product just before the mean noncumulative number of discontinuers, and it is the largest group along with the late majority. These two groups take longer to decide to discontinue, maybe because of social pressure, emotional attachment to the product or not being satisfied with another technology that others adopt. Finally, romantics are the last to discontinue a product. They may attach an emotional value to a given product and be reluctant to discontinue it (Lambert-Pandraud and Laurent 2010). They differ from laggards because they have an influence on collectors and laggards have almost no opinion leadership. The main characteristic of collectors is that the value of their product starts increasing until the last collector has a unique piece of history: the last product everyone once had.

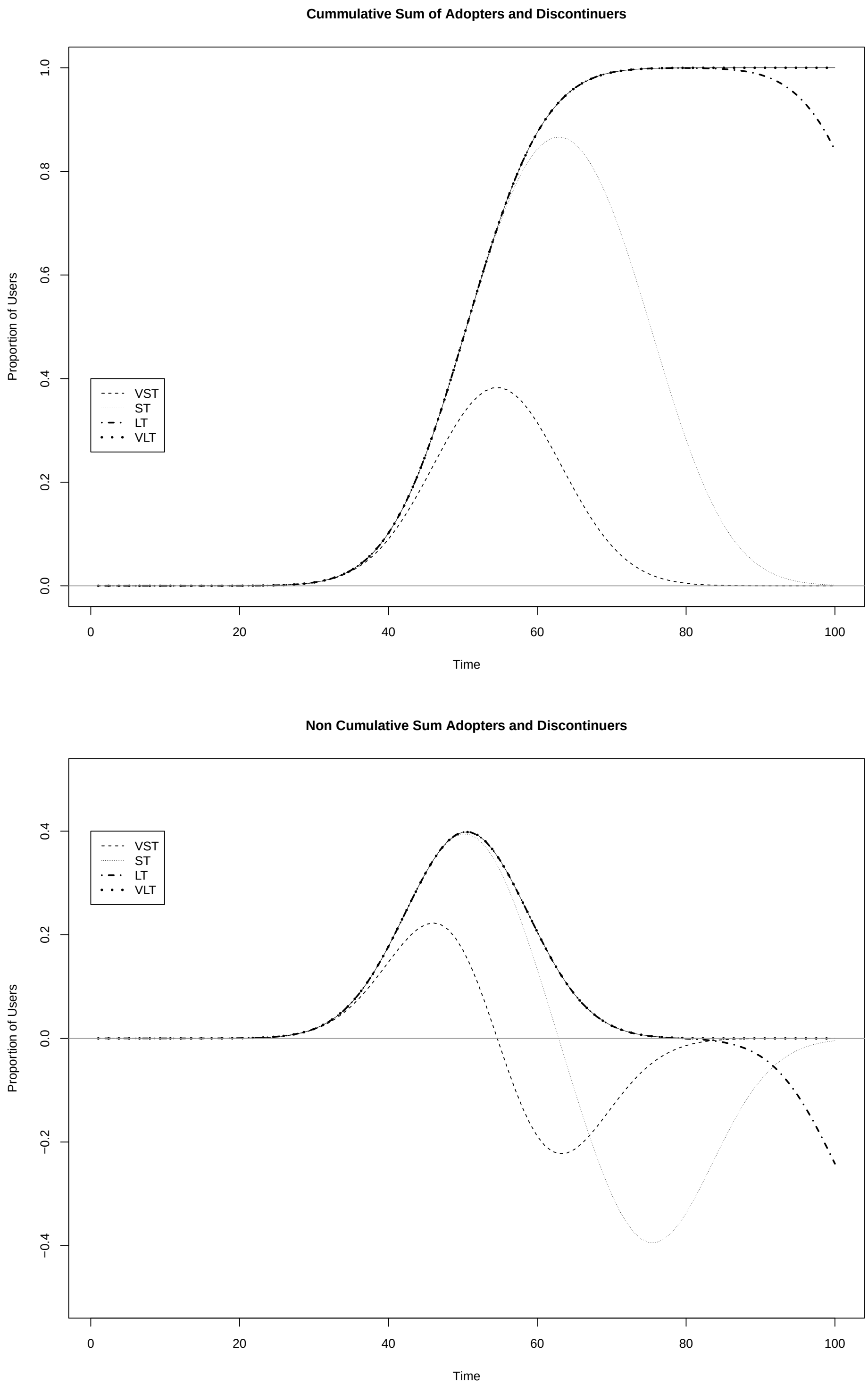
These types of discontinuers are only *ideal*, just as the original adopters classification described by Rogers (2004). In the next section, four relations of the discontinuance process with the adoption process are described.

The Interaction between Discontinuance and Adoption

For practical purposes, to explain graphically the relation of the discontinuance process with the adoption process of a product, the only difference assumed is in the mean. In reality, their variance can be an additional factor. For instance, if a given product is discovered to be very bad then the product may suffer of a sudden wave of discontinuance. On the other hand, for a product that is being substituted by another technology, but still has a practical use, the variance might by very high. The distribution of the discontinuance process might not be normal, and a social system might be a mixture of social sub-systems with distributions that have different locations and shapes that form at the end a distribution.

Locations for the mean are chosen for each of the four types of discontinuance in **figure 2.2**: Very Short Term (VST), Short Term (see **figure 2.1**; ST), Long Term (LT) and Very Long Term (VLT). The mean of the discontinuance process is assumed at a certain number of standard deviations away from the mean of the adoption process. For a very short term discontinuance process, the mean is situated one standard deviation above the mean of the adoption process. In this case, the discontinuance process starts very early. When early adopters are acquiring, innovators already start discontinuing their products and these might be the type of discontinuance where it interacts more with the adoption process. These types of products can create second-hand markets if the useful life of the product is not fully exploited in one period time, represented by one standard deviation. For short term discontinuance process, the mean of the frequency distribution of discontinuers over time starts at three standard deviations of the mean of the of the frequency distribution of adopters over time as in **figure 2.1**.

Figure 2.2: Adoption and Discontinuance Interactions.



Note: VST: Very Short Term μ=1, ST:Short Term μ=3, LT: Long Term μ=7, VLT: Very Long Term μ=10.

For a long term discontinuance process, the mean is situated seven standard deviations above the mean of the adoption process. It is where the adoption and discontinuance curves merge at their respective right-hand and left-hand tails. That is, a trier appears only when virtually every member has a specific innovation. Finally, to visualize what could be a starting point of a very long term discontinuance process,[3] the mean is situated ten standard deviations after the mean of the adoption process. In this case, before the start of the discontinuance process of a product, some time passes after every member of the social system has already adopted the product.

To show the effect of the overall process, the two distributions might be combined to form a single summary of their interaction. In **figure 2.2**, two graphs show the interaction between adoption and the different types of discontinuance, and how these affect the adoption process. One of them describes the noncumulative effect and the other the cumulative effect of their interaction. The moment at which discontinuers exceed adopters is when the lines cross the horizontal axis represents time in the graph of noncumulative sum of adopters and discontinuers. In the very long term and in the long term, discontinuance does not affect the adoption process, but in the short term and very short term it does.

2.1.4 The Bass Model and the Rate of Discontinuance

There are three types of diffusion models: contagion models, in which *"people adopt an innovation when they come in contact with those who already have adopted"*, social threshold models, in which *"people adopt when enough people in their group have adopted"* and social learning models, in which *"people adopt once they see enough evidence among prior adopters to convince them that the innovation is worth adopting"* (Young 2009). The most commonly used model of innovation diffusion is the Bass model, which is a contagion model. In the context of diffusion of innovations, it is common to use a model that allows contagion from both within the group and outside the group. Several models use these two types of contagion (Mahajan and Peterson 1985) and (Van den Bulte and Yogesh 2007). Mahajan et al. (1990) explains that the mean of the distribution represents the time of inflection, the point of time when a change in sign occurs in the diffusion curve, and that the analytical approach of the categories of innovators proposed by Rogers (2004) can also be explained by the Bass model (Bass 1969).

Bass (1969) states that the probability of adopting by those who have not yet adopted is a linear function of those who had previously adopted. The Bass model principle is

$$\frac{f(t)}{1-F(t)} = p + \frac{q}{N}A(t) \tag{2.1.1}$$

[3]The mean could start at hundred standard deviations of the mean of the adoption process if a new replacement technology only appeared hundred units of time later.

where $f(t)$ is the proportion of the potential market that adopts at time t; $F(t)$ is the proportion of the potential market that has adopted by time t; the parameter p represents adopters who have been influenced by external means, and is called *coefficient of innovation* and could be interpreted as advertising; the parameter q represents adopters who have been influenced internally, and is called *coefficient of imitation* and could be interpreted as word of mouth communication; N is an *index of market potential* that represents the ultimate number of adopters; $A(t)$ is the cumulative adoption of those that have adopted by time t. The three parameters are assumed to be non-negative, N has to be positive, and either p or q must be positive.

From equation 2.1.1, $f(t)$ can can be expressed as follows:

$$f(t) = \left\{p + \frac{q}{N}A(t)\right\}\{1 - F(t)\} \tag{2.1.2}$$

In the discrete version of the Bass model, the number of adopters at time t, $a(t)$, can be modeled as (see (Lilien et al. 2007) for a detailed description of this approach):

$$a(t) = \left\{p + \frac{q}{N}A(t-1)\right\}\{N - A(t-1)\} \tag{2.1.3}$$

In fact, if $p = 0$ the process of diffusion is converted into a logistic function which is S-shaped.

$$a(t) = \frac{q}{N}A(t-1)\{N - A(t-1)\} \tag{2.1.4}$$

If $p = 0$, the proportion of market already having the product $\frac{q}{N}A(t-1)$ is multiplied $N - A(t-1)$, which is the rest of the potential market or residual market. This is called *internal model*. And when $q = 0$ it becomes a concave curve.

$$a(t) = p\{N - A(t-1)\} \tag{2.1.5}$$

If $q = 0$, the parameter p is the proportion of people who are influenced from an external source of contagion. This is called *external model*. In the following equation, noncumulative adoption, $a(t)$, and cumulative adoption, $A(t)$ combine for a cumulative solution, where it is necessary to add the result of the diffusion model to the cumulative adoption of the last period:

$$A(t) = a(t) + A(t-1) \tag{2.1.6}$$

Bass model informs about the innovation specificity by explicitly assuming the presence of innovators at the start of the diffusion process. A brief comment of the strong assumptions that underlie the Bass model is necessary at this point (Lilien et al. 2007):

1. The diffusion process is binary, that is, members of the social system either adopt or not. This means that the adoption process of each member is not taken into account by this model.

2. The Bass model assumes a constant ceiling that represents the market potential (*N*). This means that the social system is assumed to be fixed during the diffusion process.

3. It only permits one adoption per adopting unit. It does not allow to differentiate if discontinuance occurs from the total adopted units in every period. It implies that some effects of discontinuance on the rate of adoption are not taken into account, and therefore, not visible in the model.

4. The coefficient of imitation q assumes a complete mixing of social system members. The effect between prior and potential adopters is assumed to be identical, temporally independent.

5. It is assumed that the characteristics of the innovation do not change over time and the innovation is independent from other innovations.

6. The spatial diffusion is assumed to be static along the diffusion process.

7. The model is assumed to capture all relevant information about the marketing environment.

For studying the rate of discontinuance, N that is the *"index of market potential"*, becomes the *"maximum level of adoption"* in the social system, which we call M. Therefore, the equation representing the Bass model for the rate of discontinuance becomes equation (2.1.3). The only difference is that we know that the index of market potential is the maximum level of adoption, and therefore, it is only necessary to estimate two coefficients, p and q. A direct application of the Bass model applied to the rate of discontinuance of smoking is found in (Redmond 1996) who interprets the parameters of the Bass model as the rate of quitting smoking influenced by both internal and external sources of contagion. In the next section, diffusion models for the rate of discontinuance of black-and-white television sets and the rate of adoption of color television sets are estimated. It seems likely that the influences of the rate of adoption of color television sets affect the rate of discontinuance of black-and-white television sets.

2.2 The International Rate of Discontinuance: The Case of Black-and-White Television Sets

From the point of view of the product's end of life, the literature on international diffusion is absent. However, thanks to the abundance of studies of the diffusion of innovations it is easy to set a benchmark for the study of the rate of discontinuance (Krishnan and Thomas 2009, Peres et al. 2010). In this part, the Bass model is used to understand the diffusion process of the rate of discontinuance of black-and-white television sets in an international context.

One of the objectives of international diffusion analysis has been to understand what factors affect the introduction of innovations in different countries. The Bass model has been applied widely to understand how a new product experiences different diffusion patterns based on the innovation and imitation coefficients. The relations between these coefficients and socioeconomic and cultural characteristics of countries to explain the diffusion process have been covered in the previous literature (Krishnan and Thomas 2009, Peres et al. 2010). Two approaches have been used in diffusion literature: first, a diffusion model is fitted to several countries separately and then the estimates are compared across countries and with socioeconomic and cultural characteristics of each country (Takada and Jain 1991, Helsen et al. 1993, Sundqvist et al. 2005, Dwyer et al. 2005). In the second approach, country characteristics are included in the diffusion model and therefore, the role of country characteristics is estimated at the same time as diffusion internal and external coefficients (Gatignon et al. 1989, Dekimpe et al. 1998, Talukdar et al. 2002, Stremersch and Tellis 2004, Desiraju et al. 2004, Kauffman and Techatassanasoontorn 2005). The main findings of these two approaches are summarized in Krishnan and Thomas (2009), Peres et al. (2010).

The two key concepts that affect diffusion are explained in Takada and Jain (1991): *country effects* and *time effects*. Diffusion processes are affected by factors under the control of the firm (e.g., marketing tactics) and by factors that cannot be controlled (e.g., culture, economy, law, geography, or politics) that comprise the macro-environment of each country. The life-cycle of a product should be similar in countries that are in the same macro-level segment (Helsen et al. 1993). This effect is referred as country effect. Cultural effects are sometimes separated from country effects (Sundqvist et al. 2005). Time passing since an innovation is introduced in a lead country and a lag country is one of the main elements that affects diffusion processes. Changes in the product and its usage and communication across these countries occur during this time. The effect created by the time that passes between the introduction of a product in a lead country and a lag country is known as time effect (or demonstration effect). In this section, these effects, that until now have been applied to the rate of adoption, are studied on the rate of discontinuance. Potential benefits of this approach are of three types: first, diffusion models may serve to forecast the behavior of the innovation and imitation coefficients for other countries and/or products that are going to be discontinued. In this case, most countries that are analyzed are developing countries. Most diffusion research has been applied to developed economies and this part provides the first analysis of the rate of discontinuance of a durable good in developing economies. Second, from a normative point of view, it is as important to know when to introduce a product in the global market as to know when to remove it. Sprinkler and waterfall strategies[4] are related to the international introduction of a product. Diffusion models applied to the rate of discontinuance may be help define optimal withdrawal strategies depending on the characteristics of the market. Finally, a descriptive use of these models is to analyze differences in their parameters and test whether their variation is due to specific dimensions of each country (Mahajan et al. 1990, 2000).

2.2.1 Methodology

Two types of methodologies are used to study the diffusion process across countries. First, Bass, external and internal models (see equations (2.1.3) – (2.1.5)) are fitted using nonlinear least squares (NLS) for each country separately (Srinivasan and Mason 1986, Lilien et al. 2007). Then, estimates obtained are later compared to country and time effects. This approach is called *two-stage analysis*.

Second, the Akaike information Criterion (AIC) assesses whether a variable should be included in the model or not and it is applied to decide which variables to retain in a final discontinuance model. The Bass model is used to estimate diffusion parameters and country effects simultaneously. To fit the Bass model simultaneously in all countries, the data set is prepared in a matrix containing the following columns: the decreasing levels of penetration of black-and-white television sets, time dependent and time independent country variables. First, a fit of I Bass models is prepared, in which the external coefficient $p = p_0 + p_1 X_i$ with one covariate on its own is compared separately with the fit of the Bass model without explanatory variables. As a matter of convention, the "best" five explanatory variables by AIC criterion are selected. Then, the fit of $5 \times (I - 1)$ models pairing each of these five variables with every other covariate is performed. That is, the results of a second model adding the rest of variables as a second explanatory variable, in which $p = p_0 + p_1 X_i + p_2 X_j$ where $i = 1, .., 5$ and $i \neq j$, are compared with the results of each of the models containing one of the "best" five explanatory variables previously selected. A χ^2 test is applied to test differences between the models. The same procedure is used with the internal coefficient. We call this approach *simultaneous analysis*.

[4] In a waterfall strategy an innovation is introduced at the same time in every region while in a sprinkler strategy the innovation is introduced sequentially.

2.2.2 Data set

A data set from Euromonitor that includes the annual percentage of penetration of black-and-white television sets from 1977 until 2008 in 70 countries is used. 41 countries whose peak level of penetration of black-and-white television sets occurred in this time range are selected. For these countries, it is possible to estimate the Bass model from the initial discontinuance period. These countries with their respective acronyms, are displayed in **table 2.1**. The 70 countries in the table are divided into five categories according to their gross domestic product per capita (GDP) at purchasing power parity (PPP) in 2008. All countries in the fifth category, and most countries in the fourth and third category, reached a peak level of penetration of black-and-white television sets between 1977 and 2008.

Table 2.1: Categories of Countries

Categories									
1		2		3		4		5	
Norway	NOR	Finland	FIN	Estonia	**EST**	Mexico	**MEX**	Colombia	**COL**
Kuwait	KWT	United Kingdom	GBR	Portugal	**PRT**	Bulgaria	**BGR**	Ecuador	**ECU**
Singapore	SGP	Germany	DEU	Saudi Arabia	**SAU**	Kazakhstan	**KAZ**	Ukraine	**UKR**
United States	USA	Japan	JPN	Slovakia	**SVK**	Romania	**ROU**	Egypt	**EGY**
Ireland	IRL	France	FRA	Hungary	**HUN**	South Africa	**ZAF**	China	**CHN**
Hong Kong	HKG	Spain	ESP	Latvia	**LVA**	Belarus	**BLR**	Jordan	**JOR**
Switzerland	CHE	Italy	ITA	Lithuania	**LTU**	Brazil	BRA	Bolivia	**BOL**
Austria	AUT	Greece	GRC	Poland	**POL**	Turkey	**TUR**	Morocco	**MAR**
Netherlands	NLD	Taiwan	TWN	Croatia	**HRV**	Turkmenistan	**TKM**	Indonesia	**IDN**
Canada	CAN	Israel	ISR	Russia	**RUS**	Azerbaijan	**AZE**	Philippines	**PHL**
Australia	AUS	New Zealand	NZL	Malaysia	**MYS**	Algeria	**DZA**	India	**IND**
Denmark	DNK	Slovenia	SVN	Chile	CHL	Thailand	**THA**	Pakistan	**PAK**
Sweden	SWE	South Korea	**KOR**	Argentina	ARG	Peru	**PER**	Vietnam	**VNM**
Belgium	BEL	Czech Republic	**CZE**	Venezuela	**VEN**	Tunisia	**TUN**	Nigeria	**NGA**

Note: Categories of countries based on gross domestic product per capita(GDP) at purchasing power parity (PPP) in 2008. Acronyms based on ISO 3166-1 alpha-3: Three-letter country codes. 41 countries with bold-face acronyms have a peak of adoption between 1977 and 2008. The initial values of their rate of discontinuance is available.

The year of initial discontinuance for estimating the Bass model is measured as the last year at which the maximum level of penetration of black-and-white television sets is achieved. Summary statistics about the adoption of color and black-and-white television sets from the 41 countries of the analysis are included in **table 2.2**. The first two columns represent the maximum and minimum level of penetration of black-and-white television sets, the following column represents the year with the maximum level of penetration of black-and-white television sets, and the last two columns represent the minimum and maximum level of penetration of color television sets, which coincide to happen in 1977 and in 2008 in every case.

For the two-stage analysis, Hofstede's four cultural dimensions and wealth as country effects are used. Hofstede's cultural dimensions represent each country's culture. These dimensions are: power distance (PDI), individualism (IDV), masculinity (MAS) and uncertainty avoidance (UAI) (Hofstede 2001). Cultural distance (CD) from the discontinuance center is calculated using Morosini et al. (1998) measure:

$$CD_j = \sqrt{\sum_{i=1}^{4}(I_{ij} - I_{iS})^2}, \tag{2.2.1}$$

where CD_j is the cultural distance for the jth country from the country that represents the discontinuance center, I_{ij} is the ith Hofstede' cultural score for the jth country and S represents the discontinuance center of our sample of countries. The discontinuance center selected is the last country to start the discontinuance process: India in 1996. From the 41 countries analyzed, only 29 countries have a Hofstede description available for the four cultural indexes used. GDP per capita at PPP of the year 2008 is used to represent wealth.

For the simultaneous analysis, a matrix containing 1312 rows (41 $countries \times 32$ $years$) and 23 columns, (black-and-white television sets diffusion rates, seven time dependent variables + fifteen time independent variables). From this matrix, only 953 rows are used because the Bass model is fitted only from the start of the discontinuance process. Country variables selected for the analysis are divided into time dependent variables, whose values differ over time, and time independent variables, whose values do not. The data set was obtained from different sources: Euromonitor, Datamonitor, International Monetary Fund, World Bank and the World Resource Institute.

Time dependent variables for 41 countries used in the analysis are: *satellite television sets* and *telephone*, which represent the percentage of population that possess these durable goods and are available between 1977 and 2008, *Carbon dioxide* emissions per capita between 1990 and 2008, which represent the total carbon dioxide emissions in millions of tonnes released from the burning of all fossil fuels, *total energy* consumption per capita in years 1990, 2000 and 2005 which measures the average annual amount of primary energy consumed per capita in a particular country, percentage of *rural population* in a particular country between 1977 and 2008, *death rate* per 1000 people between 1977 and 2008 and *wealth* per capita between 1977 and 2008, represented by GDP at PPP. Time independent variables are: *Gini index* of countries based on country surveys conducted between 2000 and 2007 as a measure of inequality; the higher the Gini index score, the higher the inequality (1 – 100), *Logistics performance index* of 2008, which is the ability to track and trace consignments (1 – 5), *Ease of doing business index* where lower scores are related to business friendly environments, *average annual temperature* and *average annual hours of sunshine* in the capital city of each country in 2008, *adult*, *female* and *young literacy*

Table 2.2: Minimum and Maximum Level of Penetration of Television Sets.

	Black-and-White Television Sets			Color Television Sets	
Countries	Min.	Max.	Peak	Min.	Max.
EST	2.5	74.2	1978	5.5	96.9
HUN	1.8	69.1	1978	8.7	98.1
POL	0.6	66.4	1978	4.9	98.8
BLR	6.4	63.3	1979	3.8	95.5
BGR	8.0	63.8	1979	4.2	92.7
TUR	7.9	63.0	1979	3.3	92.8
AZE	17.8	76.7	1980	0.2	92.7
HRV	3.2	65.5	1980	5.6	96.7
CZE	3.1	77.0	1980	8.7	98.2
RUS	8.4	62.0	1980	3.8	96.1
UKR	8.4	63.8	1980	3.3	97.4
COL	2.0	42.4	1980	2.0	80.7
JOR	14.6	59.6	1980	1.1	84.1
SAU	0.4	57.0	1980	29.3	97.9
PRT	3.3	58.5	1980	5.3	99.1
KOR	0.7	64.0	1981	33.1	99.4
LVA	3.6	68.4	1981	5.3	95.8
ROU	1.6	61.3	1981	1.6	90.0
SVK	2.4	71.4	1981	5.1	98.6
LTU	4.0	76.1	1982	5.7	97.4
VEN	5.3	57.8	1982	2.0	91.7
KAZ	22.7	60.0	1983	1.0	94.7
MYS	0.4	48.2	1983	1.1	96.0
MEX	6.8	60.9	1983	2.8	94.6
EGY	17.2	55.8	1984	0.2	85.3
TUN	16.1	54.9	1984	0.2	82.9
THA	0.9	30.6	1985	1.1	96.1
TKM	18.1	69.6	1985	0.3	75.2
BOL	13.4	42.5	1988	7.5	51.6
DZA	10.8	41.3	1988	0.3	90.6
ECU	12.1	55.2	1989	0.3	80.7
MAR	16.4	43.1	1990	0.2	80.7
PER	16.0	50.5	1992	1.7	54.7
ZAF	2.8	32.8	1993	0.5	66.0
CHN	5.0	51.4	1995	1.2	96.1
VNM	7.4	42.7	1995	0.1	79.0
IDN	4.8	46.0	1996	0.1	84.6
PHL	2.3	44.1	1996	0.3	88.4
PAK	1.0	22.7	1997	0.0	35.4
NGA	2.5	21.0	1997	0.0	32.0
IND	0.6	32.9	2000	0.0	51.7

In this table are presented the minimum and maximum levels of penetration of television sets. In the third column, the year at which black-and-white television sets achieved their last peak level are listed.

levels in 2007 measured as a percentage of countries' population and the six Hofstede's cultural dimensions (*Power Distance*, *Uncertainty Avoidance*, *Individualism*, *Masculinity*, *Long Term Orientation* (LTO) and *Indulgence versus Restrain* (IVR) indexes). Most of these variables have been previously used to analyze the rate of adoption from an international perspective: wealth and Gini index have been used by Dekimpe et al. (2000b,a), Kauffman and Techatassanasoontorn (2005), Stremersch and Tellis (2004), Sundqvist et al. (2005), Tellis et al. (2003), Desiraju et al. (2004), Talukdar et al. (2002), Van den Bulte and Stremersh (2004), illiteracy by Talukdar et al. (2002), Tellis et al. (2003), urbanization compared to rural areas by Talukdar et al. (2002), Albuquerque et al. (2007), telephone by Kauffman and Techatassanasoontorn (2005), cultural factors by Tellis et al. (2003), Van den Bulte and Stremersh (2004), Dwyer et al. (2005), Sundqvist et al. (2005) and death rate by Dekimpe et al. (1998).

Other variables that are not included in previous literature are diffusion used. Carbon dioxide emissions and total energy consumed are used because they can be related to the rate of discontinuance of black-and-white television sets because color television sets consume more energy. Temperature and sunshine hours can also affect the amount of energy required in a household. Channels of distribution are shared between satellite television sets and black-and-white television sets. Logistics performance and ease of doing business indices affect international trade and therefore, the diffusion of goods.

2.2.3 Two-Stage Analysis

Building on the methodology of Sundqvist et al. (2005), the rate of discontinuance of 41 countries is studied. In Sundqvist et al. (2005), country (wealth and cultural characteristics) and time effects on the diffusion of wireless communications are examined. According to diffusion literature, wealthier countries adopt products earlier (Dekimpe et al. 2000b) and at a faster rate (Desiraju et al. 2004, Sundqvist et al. 2005). Sundqvist et al. (2005) relate international diffusion of innovations to country and time effects. Similar effects on the rate of discontinuance are assumed and we base on their hypothesis to develop an analogous analysis on the rate of discontinuance. Three models are used to explore the dynamics of the discontinuance process: an external-influence model, in which no interpersonal communication among citizens is assumed to affect the rate of discontinuance; an internal-influence model, in which only a contagion process affects the rate of discontinuance and the internal-external model, and Bass model, in which influences that affect the rate of discontinuance are mixed.

Based on previous studies of international diffusion of innovations, it is hypothesized that:

- **Hypothesis 1:** Culturally different countries have a different discontinuance behavior.

- **Hypothesis 2:** Wealthier countries start discontinuing black-and-white television sets earlier.
- **Hypothesis 3:** The rate of discontinuance of black-and-white television sets is faster in countries that start discontinuing later.

Sundqvist et al. (2005) find a relation of the diffusion of products in countries with higher UAI with an imitation coefficient of the Bass model. They show that the cultural distance from the country that starts the adoption process first is related to the time of initial adoption year. IDV, MAS and PDI are also tested but no relations are found. Here, the relation of Hofstede's cultural dimensions to the parameter results of the models estimated is tested. A hypothesis for a specific cultural dimension is not set, but it is hypothesized that countries whose cultural distance is closer to the last country of the analysis that discontinues black-and-white television sets will discontinue later.

- **Hypothesis 4:** Countries whose cultural distance from the discontinuance center (India, 1996) is small, start discontinuing later black-and-white television sets.

The discontinuance process of a product may be caused by the appearance of an innovation in the market that covers the same needs. In our context, black-and-white television sets are replaced by color television sets. While research on replacement of innovations and substitution of a technology is extensive, the focus of that research is on the innovation, with very few exceptions, Prins et al. (2009). It is arguable whether the rate of adoption and the rate of discontinuance should be related and, therefore, it is hypothesized the following:

- **Hypothesis 5:** Countries with a faster rate of adoption of color television sets, have a faster rate of discontinuance of black-and-white television sets.

Results

Countries are clustered by the Ward method (Ward 1963) into four groups based on their cultural dimensions. **Table 2.3** shows the mean and the standard deviations of variables for each cluster. An analysis of variance F-test is performed to compare variable means between clusters based on cultural dimensions. The test rejects the hypothesis that the means are all the same at a 5 per cent significance level in initial discontinuance, wealth, diffusion coefficients of the internal model of both black-and-white television sets and color television sets and diffusion coefficients of the external model of black-and-white television sets. Differences between clusters are only significant for the internal coefficient of the Bass model applied to color television sets. Market potential (M=

93.7%, SD= 16.4%) for color television sets is not included in **table 2.3** and does not significantly differ among clusters. For black-and-white television sets, the hypothesis that mean coefficients of the Bass model are equal after deleting two non-significant and outlier coefficients (Rumania and Poland) cannot be rejected. For the external model the hypothesis that means are all the same cannot be rejected neither. Hypothesis 1 is supported by these results. The first cluster includes six Asian countries. PDI is high and IDV and UAI are low. They are late discontinuers (1994) and have a smaller discontinuance coefficients which indicates a faster rate of discontinuance. Their internal coefficients of the Bass model and the internal model are high which indicates a faster rate of adoption. They are also the least wealthy countries. The second cluster includes 14 countries: three Asian, five South American and six European. They are high in UAI and PDI and low in IDV. The third cluster, including four European countries and two African countries, have a higher MAS score. The first and the second cluster have similar adoption timings and model coefficients. The fourth cluster includes three European countries which have a high score of IDV and a low score MAS. They are wealthier countries and early discontinuers (1980).

Tables 2.4 – **2.9** include the internal, external and Bass model results for black-and-white and color television sets. Four external coefficients of the Bass model applied to color television sets were negative, and 15 applied to black-and-white television sets were positive. This result creates problems in the interpretation of their theoretical meaning because parameter p in the Bass model is related to external sources of information. They are normally assumed to increase sales, and therefore, affect positively the rate of adoption. Therefore, only negative values of this parameter can have a good interpretation for the rate of discontinuance. Furthermore, in only 13 cases p and q are significant at the same time for color television sets: in 15 countries p is significant and in 39 countries q is significant. And only 22 times for black-and-white television sets: in 23 countries p is significant, and in 39 countries q is significant. This implies that the interpretation for the Bass model parameters is unreliable. Estimating the internal and external models produces better results, with coherent signs and significant results for all estimates and both products. Market potential for the external model applied to color television sets is set to 100 % for the model to converge.

Hypotheses 2, 3 are supported by these results and simple regressions, visible in equations (2.2.2) and (2.2.3), confirm these hypotheses. Hypothesis 4 is also confirmed (equation (2.2.4)), but hypothesis 5 is only confirmed by regressing the coefficients of the external models (equation (2.2.5)), not by the coefficients of the internal models and neither by coefficients of the Bass models. Against to what is proposed in hypothesis 5, countries with faster rates of adoption of color television sets have slower rates of discontinuance of black-and-white television sets.

$$\begin{aligned} Year &= 16.1 - 0.0006\,Wealth \\ &\quad (1.5)\ (0.0001) \end{aligned} \tag{2.2.2}$$

$$\begin{aligned} q\text{-}internal\ (BW) &= -0.2 - 0.006\,Year \\ &\quad (0.01)\ (0.001) \end{aligned} \tag{2.2.3}$$

$$\begin{aligned} Year &= 24.4 - 0.3\,CD \\ &\quad (3.3)\ (0.07) \end{aligned} \tag{2.2.4}$$

$$\begin{aligned} p\text{-}external\ (BW) &= -0.1 + 0.54\,p\text{-}external\ (COL) \\ &\quad (0.01)\ (0.13) \end{aligned} \tag{2.2.5}$$

Finally, two multiple regressions are fitted to study the relation of the rate of discontinuance with Hofstede' cultural dimensions. The dependent variables for these regressions are the coefficients p and q from the internal and the external models. Wealth, initial year of discontinuance and cultural distance are also included in the model. A stepwise model selection by AIC confirmed the presence of UAI in both the internal and the external model, as well as initial year of discontinuance. Wealth, IDV and MAS are kept in the internal model and CD are kept in the external model.

$$\begin{aligned} p &= -0.03 - 0.0006\,UAI + 0.0007\,CD - 0.004\,Year \\ &\quad (0.02)\ (0.0002)\qquad (0.0006)\qquad (0.0003) \end{aligned} \tag{2.2.6}$$

$$\begin{aligned} q &= -0.2 + 0.0005\,IDV - 0.0004\,MAS - 0.002\,UAI - 0.00001\,Wealth - 0.008\,Year \\ &\quad (0.04)\ (0.0003)\qquad (0.0003)\qquad (0.0004)\qquad (0.000002)\qquad (0.002) \end{aligned} \tag{2.2.7}$$

In the next section, both variables effects and diffusion parameters are estimated simultaneously. Applying the AIC, a model is selected that includes variables that best[5] explain the rate of discontinuance from a global perspective. Subsequently, a discussion about the implications of these results is presented.

[5]Comparison of models based on AIC

Table 2.3: Description of Clusters Based on Hofstede's Cultural Differences.

Clusters		1	2	3	4
GDP	Mean	5145.31	12110.98	15246.06	16641.06
	S.D	4052.00	5967.19	7256.67	2133.38
Year	Mean	1994.00	1983.29	1983.33	1980.33
	S.D	5.59	5.48	6.50	2.08
p-Bass (BW)	Mean	0.12	0.01	0.01	–0.01
	S.D	0.19	0.06	0.02	0.00
q-Bass (BW)	Mean	–0.57	–0.25	–0.29	–0.21
	S.D	0.29	0.15	0.09	0.03
p-external(BW)	Mean	–0.11	–0.07	–0.06	–0.05
	S.D	0.04	0.03	0.02	0.01
q-internal (BW)	Mean	–0.34	–0.23	–0.27	–0.23
	S.D	0.05	0.04	0.07	0.03
p-Bass (COL)	Mean	0.00	0.00	0.00	0.01
	S.D	0.00	0.02	0.01	0.00
q-Bass (COL)	Mean	0.26	0.23	0.21	0.15
	S.D	0.06	0.07	0.06	0.01
p-external(COL)	Mean	0.03	0.05	0.05	0.05
	S.D	0.01	0.04	0.02	0.00
q-internal (COL)	Mean	0.27	0.23	0.22	0.17
	S.D	0.05	0.05	0.05	0.01
PDI	Mean	83.83	71.79	65.67	42.00
	S.D	12.62	11.34	21.13	2.00
IDV	Mean	26.67	23.36	60.17	63.33
	S.D	12.11	10.09	11.74	5.77
MAS	Mean	53.67	47.71	75.83	19.33
	S.D	10.23	13.78	21.83	10.50
UAI	Mean	38.00	82.14	69.50	62.67
	S.D	7.38	10.76	17.28	2.52

1: CHN, IND, IDN, MYS, PHL, VNM. **2:** PAK, KOR, THA, BGR, HRV, ROU, RUS, COL, ECU, MEX, PER, VEN, PRT, TUR. **3:** CZE, HUN, POL, SVK, MAR, ZAF. **4:** EST, LVA, LTU.

Table 2.4: Results of Bass Model Applied to Black-and-White Television Sets.

	Coefficients		Standard error		t–statistic		p–value	
Countries	p	q	p	q	p	q	p	q
AZE	0.04	–0.38	0.02	0.04	2.31	–10.15	0.03	0.00
CHN	–0.01	–0.39	0.03	0.09	–0.41	–4.47	0.69	0.00
IND	0.49	–1.11	0.09	0.15	5.50	–7.56	0.00	0.00
IDN	0.08	–0.52	0.04	0.09	2.29	–6.05	0.04	0.00
KAZ	0.05	–0.25	0.01	0.01	6.42	–17.41	0.00	0.00
MYS	0.00	–0.28	0.00	0.02	–0.61	–13.38	0.55	0.00
PAK	0.21	–0.72	0.05	0.11	4.33	–6.74	0.00	0.00
PHL	0.11	–0.58	0.02	0.04	6.13	–13.36	0.00	0.00
KOR	0.00	–0.29	0.00	0.02	0.85	–14.19	0.40	0.00
THA	–0.01	–0.28	0.00	0.02	–1.11	–14.51	0.28	0.00
TKM	0.03	–0.29	0.01	0.01	4.69	–19.67	0.00	0.00
VNM	0.06	–0.51	0.01	0.04	4.35	–12.90	0.00	0.00
BLR	–0.01	–0.16	0.00	0.01	–4.16	–17.14	0.00	0.00
BGR	0.00	–0.17	0.00	0.01	–1.29	–15.93	0.21	0.00
HRV	–0.02	–0.17	0.00	0.01	–6.66	–16.89	0.00	0.00
CZE	0.00	–0.29	0.01	0.06	–0.33	–5.24	0.75	0.00
EST	–0.01	–0.18	0.00	0.01	–4.85	–21.60	0.00	0.00
HUN	–0.01	–0.19	0.00	0.01	–2.68	–18.21	0.01	0.00
LVA	–0.01	–0.20	0.00	0.01	–2.05	–16.49	0.05	0.00
LTU	–0.01	–0.24	0.02	0.06	–0.64	–3.87	0.53	0.00
POL	–0.01	–0.23	0.00	0.01	–2.62	–23.01	0.01	0.00
ROU	–0.07	–0.04	0.02	0.04	–4.86	–0.96	0.00	0.34
RUS	–0.01	–0.17	0.00	0.01	–2.10	–14.31	0.05	0.00
SVK	0.01	–0.34	0.00	0.01	4.10	–40.85	0.00	0.00
UKR	–0.01	–0.18	0.00	0.01	–2.22	–18.45	0.04	0.00
BOL	0.08	–0.32	0.02	0.04	4.43	–8.76	0.00	0.00
COL	–0.01	–0.17	0.00	0.01	–2.53	–12.08	0.02	0.00
ECU	0.03	–0.29	0.02	0.04	1.62	–7.53	0.12	0.00
MEX	–0.01	–0.24	0.01	0.02	–1.95	–13.83	0.06	0.00
PER	0.01	–0.29	0.10	0.18	0.05	–1.60	0.96	0.13
VEN	–0.01	–0.22	0.01	0.02	–1.56	–12.86	0.13	0.00
DZA	0.06	–0.33	0.01	0.03	4.25	–9.67	0.00	0.00
EGY	0.03	–0.22	0.01	0.02	3.29	–10.06	0.00	0.00
JOR	0.00	–0.15	0.01	0.02	0.55	–8.37	0.59	0.00
MAR	0.03	–0.23	0.03	0.05	0.93	–4.39	0.37	0.00
NGA	0.07	–0.50	0.03	0.08	2.11	–6.59	0.06	0.00
SAU	0.00	–0.26	0.00	0.01	–0.54	–18.26	0.60	0.00
ZAF	0.03	–0.44	0.01	0.05	2.22	–9.53	0.04	0.00
TUN	0.02	–0.21	0.01	0.03	2.05	–8.03	0.05	0.00
PRT	0.01	–0.26	0.00	0.02	2.83	–17.19	0.01	0.00
TUR	0.00	–0.15	0.01	0.01	–0.43	–10.24	0.67	0.00

Table 2.5: Results of External Model Applied to Black-and-White Television Sets.

Countries	Coefficient p	Standard error	t–statistic	p–value
AZE	–0.11	0.01	–8.18	0.00
CHN	–0.13	0.02	–5.01	0.00
IND	–0.18	0.04	–4.30	0.00
IDN	–0.12	0.03	–4.75	0.00
KAZ	–0.08	0.01	–11.40	0.00
MYS	–0.04	0.01	–3.91	0.00
PAK	–0.10	0.03	–3.44	0.01
PHL	–0.11	0.02	–4.58	0.00
KOR	–0.03	0.01	–3.75	0.00
THA	–0.05	0.01	–4.98	0.00
TKM	–0.09	0.01	–9.11	0.00
VNM	–0.10	0.02	–4.34	0.00
BLR	–0.06	0.01	–10.42	0.00
BGR	–0.06	0.01	–9.32	0.00
HRV	–0.06	0.01	–9.17	0.00
CZE	–0.05	0.01	–3.95	0.00
EST	–0.05	0.01	–7.48	0.00
HUN	–0.04	0.01	–6.57	0.00
LVA	–0.05	0.01	–6.79	0.00
LTU	–0.06	0.01	–4.67	0.00
POL	–0.04	0.01	–4.92	0.00
ROU	–0.09	0.01	–9.26	0.00
RUS	–0.06	0.01	–10.01	0.00
SVK	–0.04	0.01	–4.14	0.00
UKR	–0.06	0.01	–9.99	0.00
BOL	–0.07	0.01	–6.65	0.00
COL	–0.05	0.01	–7.50	0.00
ECU	–0.09	0.01	–7.07	0.00
MEX	–0.08	0.01	–8.22	0.00
PER	–0.14	0.03	–5.37	0.00
VEN	–0.06	0.01	–7.42	0.00
DZA	–0.07	0.01	–6.28	0.00
EGY	–0.07	0.01	–9.29	0.00
JOR	–0.06	0.01	–10.85	0.00
MAR	–0.09	0.01	–9.69	0.00
NGA	–0.14	0.03	–5.43	0.00
SAU	–0.04	0.01	–4.33	0.00
ZAF	–0.07	0.02	–3.68	0.00
TUN	–0.07	0.01	–9.12	0.00
PRT	–0.04	0.01	–4.90	0.00
TUR	–0.05	0.01	–8.93	0.00

Table 2.6: Results of Internal Model Applied to Black-and-White Television Sets.

Countries	Coefficient q	Standard error	t–statistic	p–value
AZE	–0.30	0.02	–18.96	0.00
CHN	–0.42	0.04	–9.54	0.00
IND	–0.31	0.05	–6.12	0.00
IDN	–0.34	0.04	–9.56	0.00
KAZ	–0.16	0.01	–27.54	0.00
MYS	–0.29	0.02	–17.77	0.00
PAK	–0.28	0.05	–5.73	0.00
PHL	–0.33	0.03	–10.75	0.00
KOR	–0.28	0.02	–18.06	0.00
THA	–0.29	0.01	–21.57	0.00
TKM	–0.23	0.01	–31.23	0.00
VNM	–0.36	0.03	–13.08	0.00
BLR	–0.19	0.01	–30.99	0.00
BGR	–0.19	0.01	–33.13	0.00
HRV	–0.22	0.01	–21.55	0.00
CZE	–0.30	0.04	–7.76	0.00
EST	–0.21	0.01	–28.05	0.00
HUN	–0.21	0.01	–26.63	0.00
LVA	–0.22	0.01	–26.58	0.00
LTU	–0.27	0.04	–7.05	0.00
POL	–0.25	0.01	–28.69	0.00
ROU	–0.20	0.03	–5.79	0.00
RUS	–0.19	0.01	–30.62	0.00
SVK	–0.31	0.01	–41.48	0.00
UKR	–0.20	0.01	–38.41	0.00
BOL	–0.16	0.01	–11.83	0.00
COL	–0.20	0.01	–20.38	0.00
ECU	–0.24	0.02	–15.41	0.00
MEX	–0.27	0.01	–26.63	0.00
PER	–0.28	0.05	–6.06	0.00
VEN	–0.24	0.01	–23.43	0.00
DZA	–0.20	0.02	–12.72	0.00
EGY	–0.15	0.01	–19.68	0.00
JOR	–0.14	0.01	–22.39	0.00
MAR	–0.18	0.01	–14.66	0.00
NGA	–0.35	0.03	–12.01	0.00
SAU	–0.27	0.01	–24.45	0.00
ZAF	–0.36	0.03	–12.06	0.00
TUN	–0.16	0.01	–18.11	0.00
PRT	–0.23	0.01	–21.35	0.00
TUR	–0.16	0.01	–21.92	0.00

Table 2.7: Results of Bass Model Applied to Color Television Sets.

	Coefficients			Standard error			t–statistic			p–value		
Countries	p	q	M	p	q	M	p	q	M	p	q	M
AZE	0.00	0.30	1.10	0.01	0.04	0.07	–0.87	7.14	16.43	0.39	0.00	0.00
CHN	0.00	0.16	1.17	0.00	0.01	0.04	0.98	10.92	25.97	0.33	0.00	0.00
IND	0.00	0.29	0.66	0.00	0.02	0.03	1.39	12.70	20.38	0.18	0.00	0.00
IDN	0.00	0.28	0.93	0.00	0.01	0.01	0.32	39.10	112.03	0.75	0.00	0.00
KAZ	0.00	0.29	0.97	0.00	0.01	0.01	–2.26	33.83	155.14	0.03	0.00	0.00
MYS	0.00	0.23	0.99	0.00	0.01	0.01	2.52	33.38	164.14	0.02	0.00	0.00
PAK	0.00	0.32	0.39	0.00	0.01	0.00	–1.09	29.40	85.52	0.29	0.00	0.00
PHL	0.00	0.31	0.97	0.00	0.01	0.01	–2.35	39.73	115.55	0.03	0.00	0.00
KOR	0.08	0.19	0.99	0.01	0.03	0.00	5.29	7.37	314.06	0.00	0.00	0.00
THA	0.00	0.25	0.99	0.00	0.01	0.01	0.52	39.24	193.45	0.61	0.00	0.00
TKM	0.00	0.29	0.77	0.00	0.01	0.00	0.79	50.16	226.92	0.44	0.00	0.00
VNM	0.00	0.32	0.86	0.00	0.01	0.01	–1.41	36.58	106.42	0.17	0.00	0.00
BLR	0.01	0.15	1.08	0.00	0.01	0.03	1.73	10.63	38.44	0.09	0.00	0.00
BGR	0.01	0.12	1.06	0.00	0.01	0.02	5.66	12.65	46.88	0.00	0.00	0.00
HRV	0.00	0.24	0.98	0.01	0.02	0.01	–0.49	11.66	77.93	0.63	0.00	0.00
CZE	–0.01	0.24	1.00	0.00	0.01	0.01	–1.52	16.82	126.57	0.14	0.00	0.00
EST	0.01	0.17	1.04	0.01	0.03	0.03	0.82	6.04	31.96	0.42	0.00	0.00
HUN	0.00	0.16	1.06	0.01	0.02	0.03	0.01	8.03	40.96	0.99	0.00	0.00
LVA	0.01	0.14	1.05	0.00	0.01	0.02	2.83	10.71	49.73	0.01	0.00	0.00
LTU	0.01	0.14	1.07	0.01	0.03	0.06	1.09	4.21	18.70	0.28	0.00	0.00
POL	–0.01	0.29	1.00	0.00	0.01	0.01	–2.59	22.01	158.47	0.02	0.00	0.00
ROU	0.00	0.15	1.15	0.00	0.01	0.05	1.39	10.49	21.51	0.17	0.00	0.00
RUS	0.01	0.14	1.06	0.00	0.01	0.02	4.32	18.05	70.26	0.00	0.00	0.00
SVK	0.01	0.18	1.02	0.00	0.01	0.01	2.69	16.15	90.82	0.01	0.00	0.00
UKR	0.01	0.06	1.61	0.00	0.03	0.54	2.99	1.85	3.01	0.01	0.07	0.01
BOL	0.04	0.01	0.64	0.00	0.01	0.02	26.85	1.68	27.24	0.00	0.10	0.00
COL	–0.01	0.29	0.81	0.00	0.02	0.01	–1.55	16.02	93.48	0.13	0.00	0.00
ECU	0.00	0.26	0.84	0.00	0.01	0.01	–0.78	26.14	105.48	0.44	0.00	0.00
MEX	0.00	0.23	0.97	0.00	0.01	0.01	–0.17	30.83	155.11	0.87	0.00	0.00
PER	0.01	0.14	0.63	0.01	0.04	0.06	0.89	3.15	9.80	0.38	0.00	0.00
VEN	0.00	0.24	0.93	0.00	0.01	0.01	–0.47	18.77	92.13	0.64	0.00	0.00
DZA	0.00	0.28	0.97	0.00	0.01	0.01	0.21	37.53	122.07	0.83	0.00	0.00
EGY	0.00	0.28	0.93	0.00	0.00	0.00	–0.07	70.50	209.84	0.94	0.00	0.00
JOR	0.00	0.23	0.88	0.00	0.01	0.01	0.87	31.03	132.71	0.39	0.00	0.00
MAR	0.00	0.27	0.88	0.00	0.00	0.01	0.42	60.13	171.45	0.68	0.00	0.00
NGA	0.00	0.22	0.39	0.00	0.01	0.01	3.17	30.55	58.62	0.00	0.00	0.00
SAU	0.24	–0.08	0.98	0.02	0.04	0.01	13.03	–2.41	110.68	0.00	0.02	0.00
ZAF	0.01	0.13	0.75	0.00	0.01	0.02	6.80	15.82	48.14	0.00	0.00	0.00
TUN	0.00	0.27	0.91	0.00	0.00	0.01	0.45	61.08	174.04	0.66	0.00	0.00
PRT	–0.03	0.36	1.00	0.01	0.03	0.01	–3.73	13.08	95.52	0.00	0.00	0.00
TUR	0.00	0.29	0.93	0.00	0.02	0.01	–1.03	15.92	110.92	0.31	0.00	0.00

Table 2.8: Results of External Model Applied to Color Television Sets.

Countries	Coefficient p	Standard error	t–statistic	p–value
AZE	0.02	0.01	2.41	0.02
CHN	0.03	0.01	4.72	0.00
IND	0.01	0.00	3.37	0.00
IDN	0.02	0.01	3.47	0.00
KAZ	0.04	0.01	4.27	0.00
MYS	0.04	0.01	5.58	0.00
PAK	0.01	0.00	4.76	0.00
PHL	0.02	0.01	3.15	0.00
KOR	0.18	0.01	33.96	0.00
THA	0.04	0.01	5.24	0.00
TKM	0.03	0.01	5.00	0.00
VNM	0.02	0.01	3.37	0.00
BLR	0.04	0.01	6.85	0.00
BGR	0.04	0.01	8.96	0.00
HRV	0.06	0.01	7.09	0.00
CZE	0.06	0.01	8.00	0.00
EST	0.05	0.01	6.95	0.00
HUN	0.05	0.01	7.20	0.00
LVA	0.05	0.01	8.34	0.00
LTU	0.05	0.01	6.49	0.00
POL	0.06	0.01	6.01	0.00
ROU	0.03	0.01	5.15	0.00
RUS	0.05	0.01	7.57	0.00
SVK	0.05	0.01	7.87	0.00
UKR	0.04	0.01	6.03	0.00
BOL	0.02	0.00	29.61	0.00
COL	0.04	0.01	6.19	0.00
ECU	0.03	0.01	5.13	0.00
MEX	0.04	0.01	6.11	0.00
PER	0.02	0.00	7.02	0.00
VEN	0.04	0.01	5.69	0.00
DZA	0.03	0.01	3.57	0.00
EGY	0.03	0.01	3.55	0.00
JOR	0.04	0.01	6.03	0.00
MAR	0.02	0.01	3.75	0.00
NGA	0.01	0.00	5.50	0.00
SAU	0.17	0.01	29.17	0.00
ZAF	0.03	0.00	10.10	0.00
TUN	0.02	0.01	3.67	0.00
PRT	0.05	0.01	4.67	0.00
TUR	0.05	0.01	6.48	0.00

Table 2.9: Results of Internal Model Applied to Color Television Sets.

	Coefficients		Standard error		t–statistic		p–value	
Countries	q	M	q	M	q	M	q	M
AZE	0.28	1.12	0.03	0.07	8.16	15.66	0.00	0.00
CHN	0.17	1.15	0.01	0.04	17.12	31.21	0.00	0.00
IND	0.30	0.65	0.02	0.03	14.16	21.64	0.00	0.00
IDN	0.28	0.93	0.01	0.01	46.67	117.64	0.00	0.00
KAZ	0.27	0.98	0.01	0.01	40.16	143.79	0.00	0.00
MYS	0.24	0.99	0.01	0.01	44.67	163.83	0.00	0.00
PAK	0.31	0.39	0.01	0.00	33.60	85.86	0.00	0.00
PHL	0.30	0.97	0.01	0.01	42.57	106.84	0.00	0.00
KOR	0.32	0.99	0.01	0.00	38.30	299.64	0.00	0.00
THA	0.25	0.99	0.00	0.00	55.92	205.42	0.00	0.00
TKM	0.29	0.77	0.00	0.00	62.79	235.51	0.00	0.00
VNM	0.31	0.86	0.01	0.01	41.22	105.32	0.00	0.00
BLR	0.17	1.06	0.01	0.02	20.09	48.07	0.00	0.00
BGR	0.16	1.01	0.01	0.02	22.19	53.37	0.00	0.00
HRV	0.23	0.98	0.01	0.01	20.40	82.04	0.00	0.00
CZE	0.22	1.00	0.01	0.01	30.70	124.83	0.00	0.00
EST	0.18	1.03	0.01	0.03	12.31	38.95	0.00	0.00
HUN	0.16	1.06	0.01	0.02	16.59	47.19	0.00	0.00
LVA	0.17	1.02	0.01	0.02	21.27	60.27	0.00	0.00
LTU	0.17	1.05	0.02	0.04	9.25	25.50	0.00	0.00
POL	0.26	1.01	0.01	0.01	30.59	138.92	0.00	0.00
ROU	0.16	1.12	0.01	0.04	17.03	27.10	0.00	0.00
RUS	0.17	1.04	0.01	0.01	29.43	75.45	0.00	0.00
SVK	0.20	1.01	0.01	0.01	28.42	99.66	0.00	0.00
UKR	0.12	1.25	0.02	0.13	6.74	9.69	0.00	0.00
BOL	0.15	0.53	0.01	0.01	14.66	44.07	0.00	0.00
COL	0.27	0.81	0.01	0.01	21.80	89.21	0.00	0.00
ECU	0.25	0.85	0.01	0.01	34.36	108.62	0.00	0.00
MEX	0.23	0.97	0.00	0.01	47.55	166.56	0.00	0.00
PER	0.16	0.61	0.03	0.04	6.32	14.19	0.00	0.00
VEN	0.24	0.93	0.01	0.01	27.26	96.75	0.00	0.00
DZA	0.28	0.97	0.01	0.01	45.75	128.07	0.00	0.00
EGY	0.28	0.93	0.00	0.00	84.75	219.84	0.00	0.00
JOR	0.23	0.87	0.01	0.01	44.39	142.81	0.00	0.00
MAR	0.28	0.88	0.00	0.00	72.47	180.33	0.00	0.00
NGA	0.24	0.39	0.01	0.01	32.86	57.01	0.00	0.00
SAU	0.32	0.95	0.02	0.01	14.90	114.03	0.00	0.00
ZAF	0.17	0.72	0.01	0.02	19.56	45.38	0.00	0.00
TUN	0.27	0.91	0.00	0.00	73.60	183.02	0.00	0.00
PRT	0.27	1.02	0.02	0.02	14.41	65.10	0.00	0.00
TUR	0.27	0.93	0.01	0.01	24.23	110.73	0.00	0.00

2.2.4 Simultaneous Analysis

If in the previous approach every country's rate of discontinuance is modeled separately and then estimates are related to country and time effects, a second option is to estimate diffusion parameters and country effects simultaneously in a single model. This approach was used to explore which country effects are related to the rate of adoption (Gatignon et al. 1989, Dekimpe et al. 1998, Talukdar et al. 2002, Stremersch and Tellis 2004, Desiraju et al. 2004, Kauffman and Techatassanasoontorn 2005). Here, AIC is applied to decide which variables to retain in the final model that explains the rate of discontinuance.

Results

The Bass model for estimating country effects on external coefficients with the highest log-likelihood is as follows:

$$a(t) \quad = \quad \left\{p - \frac{0.23}{M}A(t-1)\right\}\{M - A(t-1)\} \tag{2.2.8}$$

where

$$p \quad = \quad 0.07 - 0.02\,Logistics - 0.0002\,Rural$$

The external coefficients have the highest log-likelihood with logistics, UAI, adult literacy, rural population and satellite television sets. Rural population appears as the second best external coefficient with logistics, UAI and adult literacy and logistics appears as the second best external coefficient with rural population. The model with the highest log-likelihood with external influence explanatory variables includes logistics *(Logistics)* and rural population *(Rural)* (loglik=25.24, AIC=23.45) compared to a Bass model with a single explanatory variable. A higher ability to track and trace consignments a higher percentage of rural population in a country are negatively related to the external influence affecting the rate of discontinuance. Other explanatory variables often included as good couples to the first five external influence coefficients are rural population and women literacy.

The Bass model estimating country effects on internal coefficients with the highest log-likelihood is as follows:

$$a(t) \quad = \quad \left\{-0.006+\frac{q}{M}A(t-1)\right\}\{M-A(t-1)\} \tag{2.2.9}$$

where

$$q \quad = \quad -0.36+0.0001\,Ease-0.002\,UAI$$

The internal coefficients have the highest log-likelihood with logistics, UAI, rural population, ease of doing business and LTO. UAI appears four times as the second best internal coefficient with logistics, rural population, ease of doing business and LTO and logistics appears as the second best external coefficient with UAI. The model with the highest log-likelihood with internal influence explanatory variables includes ease of doing business *(Ease)* and *(UAI)* (loglik=63.07, AIC=61.07) compared to a discontinuance model with a single explanatory variable. Ease of doing business is positively associated with the internal coefficient and UAI is negatively related to the external influence affecting the rate of discontinuance. Other explanatory variables often included as good couples to the first five internal influence coefficients are rural population, MAS, PDI, logistics and telephone.

2.2.5 Conclusion

The two-stage analysis has several implications: discontinuance of black-and-white television sets is faster in countries whose discontinuance starts later. Poorer countries have faster rates of discontinuance. This time effect combined with the country effect that discontinuance starts earlier in wealthier countries shows how important it is to understand the phenomena of the rate of discontinuance (e.g., waste generated by the disposal of useless durable goods in poorer countries can increase at faster in poorer countries). The relation between coefficients of the external model of rates of adoption of color television sets and black-and-white television is found to be negative, meaning that countries with higher rates of adoption of color television sets tend to have lower rates of discontinuance of black-and-white television sets. This result might be very specific to developing countries where black-and-white television sets are still a useful device while color television sets has had time to become easier to trade. The results obtained in this analysis are descriptive but normative conclusions based on these results help establish strategies to manage the discontinuance process. For instance, since the relation between the rate of adoption and the rate of discontinuance is negative, obtaining a big growth in sales of an innovation in a given market does not imply having to retire the technology being substituted. In fact certain parts of the market might become reluctant to adopt a new technology because they prefer or can only afford the older technology. Cultural dimensions of a country are found to affect the rate of discontinuance. Countries culturally closer to the discontinuance center are found to start discontinuing later and close cultural countries have a similar discontinuance start. The rates of discontinuance are found to be different when measured with an internal model as posed to the external model and the cultural dimension that seems to be related differently with internal and external sources of contagion is UAI.

The simultaneous analysis is conditioned by the variables that can improve the Bass model. Many variables could possibly be related to the sources of contagion that affect the discontinuance of a durable good. Variable selection performed on 22 variables by AIC shows that the external coefficient of the Bass model is mainly related to logistics, the ability to track and trace consignments, and the percentage of rural population in a country. The internal coefficient of the Bass model is mainly related to business friendly environments and UAI in a country. A counter-intuitive result is that ease of doing business index has a negative relation with the rate of discontinuance. A linear regression of initial year of discontinuance and ease of doing business business shows a positive relation. The negative relation of ease of doing business and the rate of dicontinuance can be explained by this second relation.

In the following section, household characteristics and level of discontinuance are examined. Next, a discussion with the implications and the limitations of this article is presented.

2.3 Household Characteristics and the Level of Discontinuance

In this section, a cross-sectional data set of 70 countries and six household characteristics to study the level of discontinuance in 2008 is analyzed and household characteristics of countries with different levels of wealth are compared. Household characteristics have been previously used to study drivers of consumer innovativeness (Steenkamp et al. 1999, Gielens and Steenkamp 2007). Here, the focus is on the probability that a household will discontinue a black-and-white television set given certain household characteristics. A data set from Euromonitor that includes the percentage level of penetration of black-and-white television sets in 2008 for six types of household characteristics is used: age, economic status, income, household size, tenure of household and the type of household.

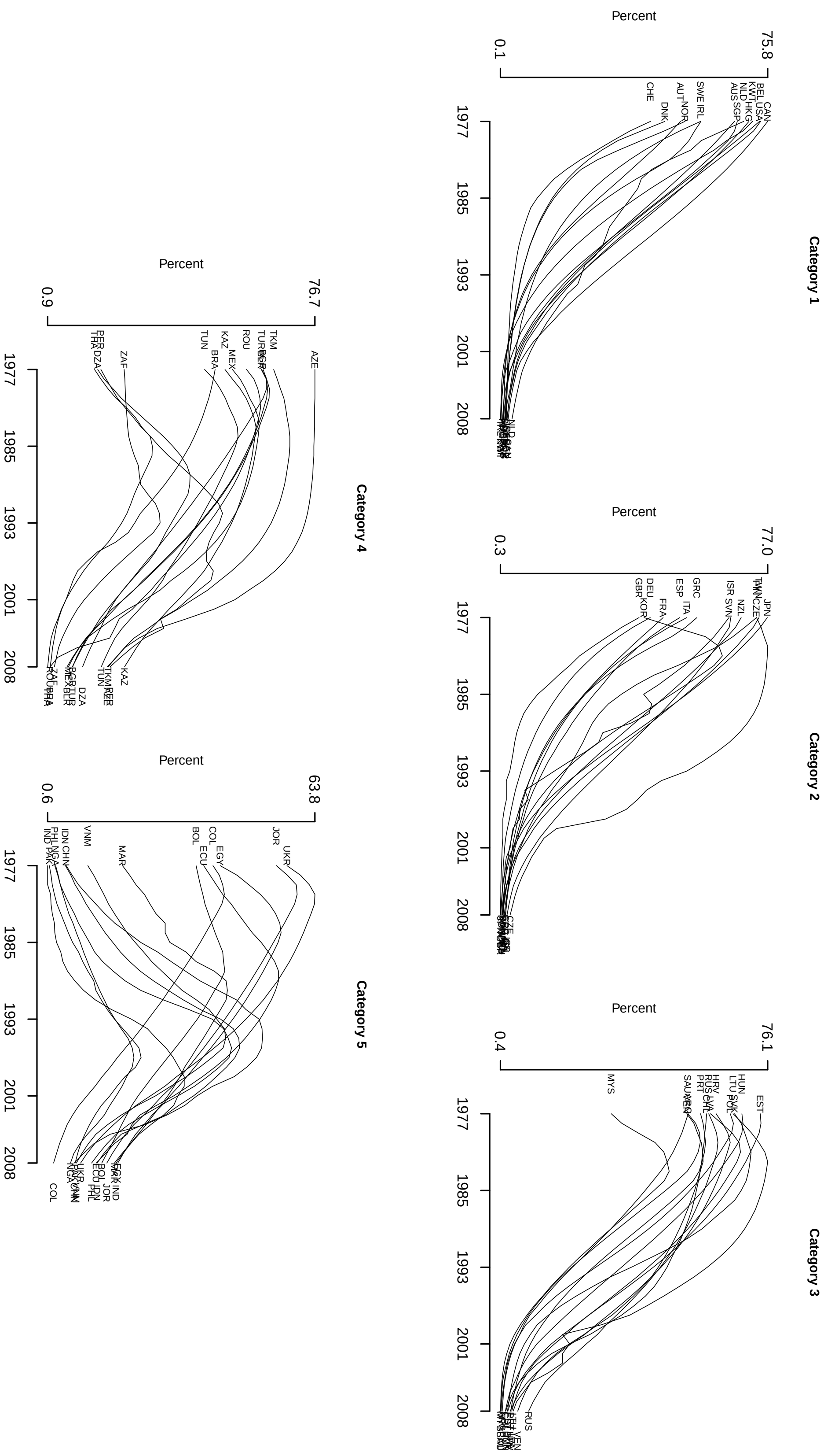
Age represents the age of the head of the household and it ranges from below twenty years old to above sixty years old. The economic status of the head of the household is divided into three categories: employee, either employer or self-employed and unemployed. Income is divided into ten deciles which represent the yearly income of the household. Household size is divided into six categories, from one person to six or more members. Tenure is divided into two categories, whether the house is owned or rented. Type of house is divided into six categories that represent the composition of the household: either a couple with children, a couple, a single member with children, a single or another composition.

2.3.1 The Levels of Discontinuance of Black-and-White Television Sets

Before analyzing the level of discontinuance of black-and-white television sets it is helpful to visualize the pattern of their diffusion process. **Figure 2.3** shows the diffusion process of black-and-white television sets of 70 countries and **figure 2.4** shows the diffusion process of color television sets in these 70 countries. Countries are separated by categories according to GDP per capita at PPP. For black-and-white television sets, countries in 1977 have more or less the same percentage of households of black-and-white television sets in all categories. In 2008, though, richer countries have fewer black-and-white television sets than poorer countries. Countries in category 1 follow a similar pattern[6]. They were already in a clear discontinuance stage, where households are discontinuing black-and-white television sets. In category 2, though, two countries do not follow the pattern of the rest of countries' rates of discontinuance. They are South Korea and Czech Republic. In these countries, diffusion rates are still positive in 1977 like in most countries of category 3. South Korea shows a pattern that reaches the maximum level of adoption faster than countries of category 3, and enters directly into a fast rate of discontinuance. In category 4 and 5, countries have mainly two types of shape. For some countries the level of penetration reaches a peak between 1977 and 1993, and for others, it reaches a peak between 1993 and 2008. In category 4, Turkmenistan and Azerbaijan follow a very different pattern because they have constant level of penetration. The mean level of penetration of black-and-white television sets for all countries in 2008 is 6.05% and the standard deviation is 6.42%. Kazakhstan has the highest level of penetration with 22.4% of households, and Kuwait has the lowest level of penetration with 0.1% of households.

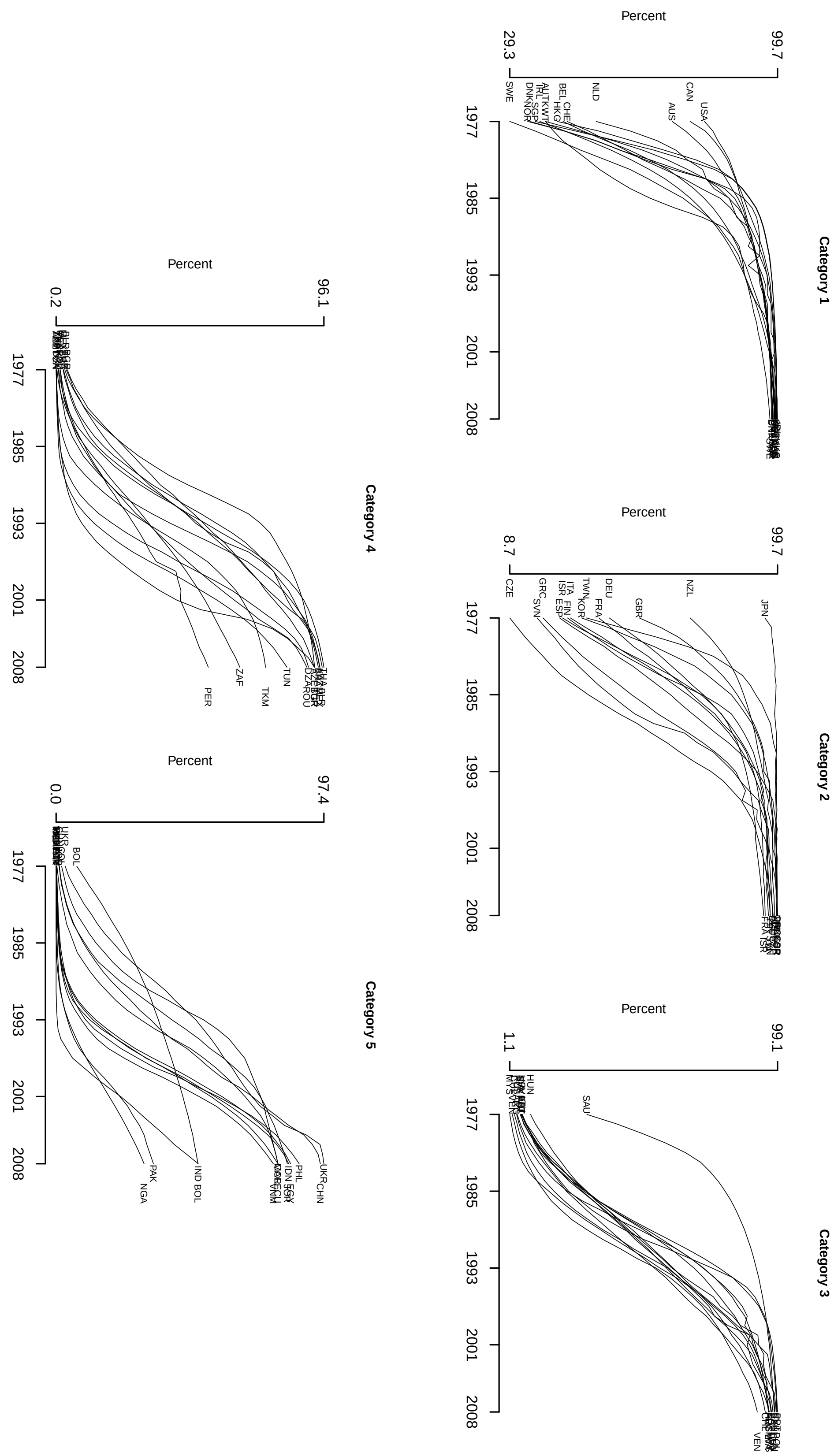
[6]See **figure 2.7** in Appendix 1 to observe global diffusion and discontinuance of color and black-and-white television sets in a World map.

Figure 2.3: Rate of Discontinuance of Black-and-White Television Sets.



Note: The vertical axis represents the percentage of households that possess a black-and-white television set for each country and the horizontal axis represent time.

Figure 2.4: Rate of Adoption of Color Television Sets.



Note: The vertical axis represents the percentage of households that possess a color television set for each country and the horizontal axis represent time.

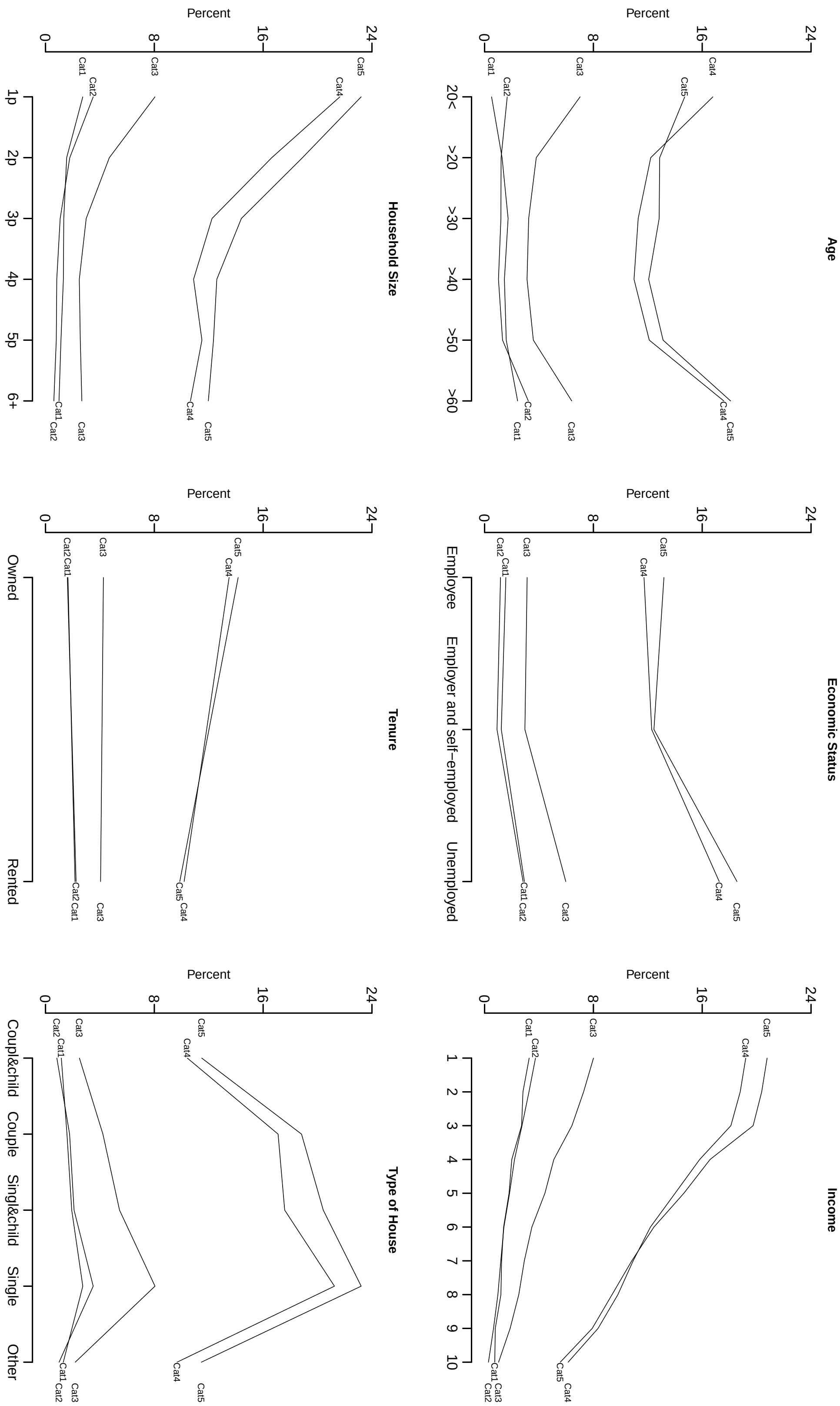
Figures 2.5 – **2.6** display for every category of countries how age, economic status, income, household size, tenure of household and the type of household affect the level of penetration of black-and-white television sets in 2008. **Figure 2.5** shows the mean of each category and **figure 2.6** show each country by categories.

An analysis of variance F-test was performed to assess whether the hypothesis that their means are all the same at a 5 per cent significance level for every category of country and for every type of household can be rejected. All the tests are significant except for category 1 and income ($p>0.10$). In richer countries income matters less for having or not a black-and-white television sets.

Consumers who still possess a black-and-white television set in 2008 are late majority, romantics and collectors since they will fall below the mean of the normal distribution of discontinuers in their countries. The richer a country is, the higher the probability of classifying a household as a collector, the last 0.1% of discontinuers, if it possesses a black-and-white television set.

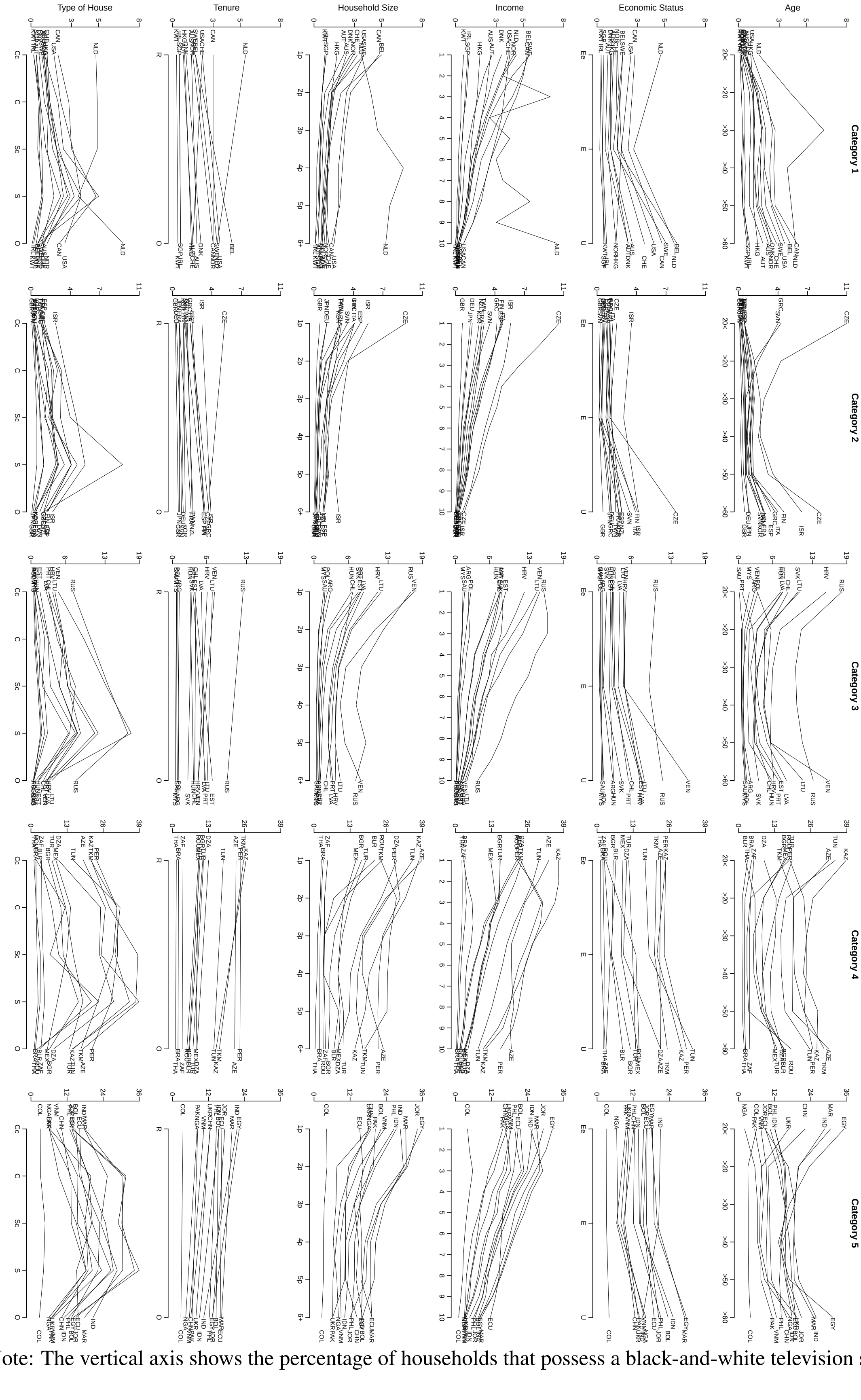
Figure 2.5 shows the level penetration of black-and-white television sets in 2008 based on the characteristics of the household and by categories based on GDP. Households of countries in categories 4 and 5 are very close to each other and have more black-and-white television sets than households in countries in the other categories. Category 3 always lies in between the extreme categories and, categories 1 and 2 are more or less together and have far fewer black-and-white television sets than households in countries of category 3. In the plot for age, households in poorer countries with the head of household below twenty and above fifty have more black-and-white television sets than those household in which the head is between 20 and 50 years old. This occurs in all categories except category 1, in which families with the head of the household below 20 do not have a black-and-white television sets, while older people may still have them. Economic status affects similarly every category. Families in which the head of household is unemployed are more likely to have black-and-white television sets and when the head of household is an employer or is self-employed they have fewer black-and-white television sets. The effect of income on the penetration of black-and-white television sets is consistent in every category of countries. Households that are in a lower decile of income are more likely to have black-and-white television sets and the poorer the country the more pronounced is this difference. If the household size is large, the probability that this household has a black-and-white television set is lower. The effect of the tenure is different for each category. For category 1, 2 and 3 if the house is rented, they have more black-and-white television sets and for category 4 and 5 the contrary is the case; if a house is owned there are more black-and-white television sets. The composition of a household has also an effect on the number of black-and-white television sets. Couples with children and other compositions do not have as many black-and-white television sets as couples, or single parents with children. Single people are most likely to possess black-and-white television sets.

Figure 2.5: Level of Penetration of Black-and-White Television Sets and Household Characteristics by Categories of Countries.



Note: The vertical axis represents the percentage of households that possess a black-and-white television set for each category and the horizontal axis represent the characteristics of the household.

Figure 2.6: Level of Penetration of Black-and-White Television Sets and Household Characteristics.



Note: The vertical axis shows the percentage of households that possess a black-and-white television set.

In **figure 2.6**[7], for the first column of graphs, the range of the level of penetration of black-and-white television sets for countries in category 1 is from 0% until 7.5%. A full description would be too lengthy, so only some exceptional cases are noted. A clear outlier in the data is The Netherlands. It has more black-and-white television sets than the rest, but some of the household characteristics have a different effect: the effect of income is not clear, being a household head between 20 and 30, owning a house, living in households of six or more people leads to having more black-and-white television sets while living single leads to having fewer black-and-white television sets. This could be due to a problem in the data set, or an exception in the habits of possession of black-and-white television sets. For the rest of countries in category 1 the level of penetration of black-and-white television sets has more or less the same explanation according to the characteristics of a household. When the head of the household is older, unemployed, poorer or single, the house is rented and occupied by only one person, the odds of having a black-and-white television set in countries of category 1 is higher.

In the second column of **figure 2.6**, the percentage level of penetration of black-and-white television sets in households of countries of category 2 and their characteristics are represented. The graph that represents the age of the head of the household shows how in Slovenia, Czech Republic and Greece, being below 30 increases the probability of having a black-and-white television set. For the rest of countries, like for households in countries of category 1, when the head of the household is older, unemployed, poorer, single, the house is rented and occupied by only one person, the odds of having a black-and-white television set is higher.

For countries in category 3, the graph that represents age shows that except for Saudi Arabia, Portugal and Poland, being below 30 increases the probability of having a black-and-white television set. Household size has also different effects on the level of penetration of black-and-white television sets. For some, larger households lower the chances of having a black-and-white television set at home, and for others, like Venezuela, the line follows a U-shape, and the chances for having a black-and-white television set are higher in very large households. The effect of the tenure of the household is less clear than for richer categories. The general trend for this category of countries is the following: when the household head is older than 40 or younger than 30, unemployed, poorer, single, household size is large and the house is rented, the odds of having a black-and-white television set is higher.

For countries in category 4, the effect of being below 30 is not clear. Households in six countries are less likely to have a black-and-white television set. For the rest of countries, being below 30 increases the probabilities of having a black-and-white television set. Household size has also disparate effects, like in category 3. The effect of tenure of a house for category 4 is the

[7] Economic Status: Employee (Ee), Employer or self-employed (E), Unemployed (U). Tenure: Rented (R), Owned (O). Type of House: Couple with children (Cc), Couple (C), Single with children (Sc), Single (S), Other (O).

complete opposite of the effect for categories 1 and 2. For category 4, when the head of the household is unemployed, poorer, single and the house is owned, the odds of having a black-and-white television set is higher. A smaller household size increases the odds of having a black-and-white television set. Also, being above 40 increases the odds of having a black-and white television.

For countries in category 5, the level of penetration of black-and-white television sets ranges from 0.4% to 38.9%. Households in ten countries are more likely to have a black-and-white television sets if their head is below 30. Household size has disparate effects, like in category 3 and 4. When the head of the household is unemployed, poorer, single and the house is owned the odds of having a black-and-white television set are higher. The effect of household size, age and tenure of a house are similar to category 4. Also, smaller households and being above 40 increases the odds of having a black-and-white television set too. **Table 2.10** summarizes the main results.

Table 2.10: Household Characteristics and Level of Penetration

Household Members	Wealthier Countries	Poorer Countries
Young	(–)*	(+ and –)
Old	(+)	(+)
Mature	(–)	(–)
Unemployed	(+)	(+)
Higher Income	(–)	(–)
More People	(–)	(–)
Owned House	(–)	(+)
Single	(+)	(+)

* With a few exceptions. Inhabitants of wealthier countries who possess a black-and-white television set are in the romantic and collector categories. Inhabitants of poorer countries that possess a black-and-white television set are in the late majority, romantic and collector categories.

2.4 Implications

The focus of this article is on discontinuance and it relation to disposal and dispossession is explained. The categories of the discontinuance process presented here are based on a normal distribution, as proposed by Rogers (2004). The definition of the categories of discontinuance process are a point of departure to investigate how it is related to consumer behavior. For instance, a new invention may affect the discontinuance of a product in different ways. In Black (1983), ten propositions to relate innovativeness and discontinuousness are provided. *Ideal types* of discontinuers can be related to the types of adopters described in Rogers (2004) but these assumptions might be too simplistic and should be treated with care. For instance, maybe an *innovator* in the adoption process can be a *romantic*, a *trier*, or, even a *collector* in the discontinuance process, especially, for the same product (Lambert-Pandraud and Laurent 2010). From a consumer behavior point of view, it is necessary to understand how the discontinuance of a product may affect its satisfaction and its propensity to adopt a new product. This classification provides the opportunity to extend what DeFleur (1966) proposes: *obsolescence should show a kind of "reverse" diffusion curve. Its form should be opposite to the familiar S-shaped curve describing adoption. There should be a "curve of abandonment" for once institutionalized behavior forms that are dropping out of the social or cultural system of a given group or society.*

It is especially interesting to understand how the rates of adoption are affected by the rate of discontinuance and vice versa. Diffusion models represent helpful devices for managers and public policy administrators to study the rate of discontinuance. The two-stage methodology is appropriate to study the discontinuance process country by country and the simultaneous methodology allows to explicitly model country effects that affect the rate of discontinuance. Noteworthy, is that a time effect is found in poorer countries and they deal with faster rates of discontinuance. Relations between the rate of adoption of color television sets and the rate of discontinuance of black-and-white television sets are counterintuitive. Only a negative relation between the external coefficients is found. On the other hand, several country effects are found: countries with higher UAI tend to have faster rates of discontinuance. Wealth and cultural distance from the discontinuance center (India) are related to the rate of discontinuance. Logistics and rural proportion of a country are related country characteristics to the external coefficient and ease of doing business index and UAI to the internal coefficient. By controlling the discontinuance process, may apply diffusion models to create strategies that increase their market profitability by the use of better addressed promotions (Hogan et al. 2003) and create more sustainable marketing actions, such as more efficient reverse logistic activities. Public policy administrators might apply diffusion models to the rate of discontinuance to help them decide which mechanisms are better to manage WEEE. For instance, they may compare country and time effects across countries and enforce solutions that companies might need to provide to reduce WEEE.

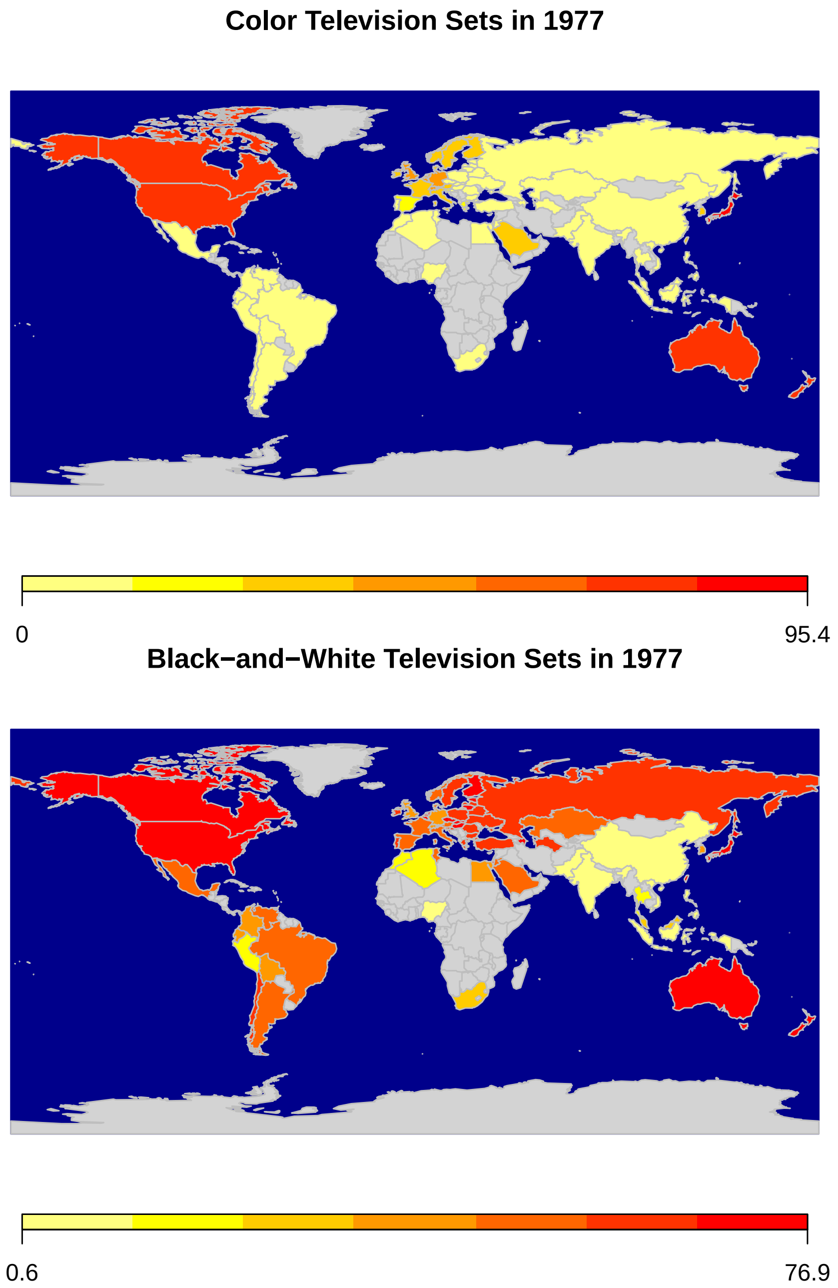
It is the first time that the level of discontinuance of black-and-white television sets has been analyzed on a global scale. While the difference in GDP per capita between countries is one of the main moderators of the rate of discontinuance for black-and-white television sets, individual household characteristics provide useful explanation of the discontinuance of black-and-white television sets. A country that belongs to a rich category has higher odds of having a black-and-white television set for a household if the head of the household is older, unemployed, poorer, single, the house is rented and occupied by only one person. In poorer countries, when the head of the household is older than 40 or younger than 30, unemployed, poorer, single and the house is rented and has fewer members, a household has higher odds of having a black-and-white television set. Categories based of discontinuance are useful to describe members of the market (**See table 2.10**).

2.4.1 Limitations

Three types of analysis are provided to help understand the dynamics of the rate of discontinuance of black-and-white television sets and several limitations are noted. First, other technologies have different discontinuance processes. It would be necessary to analyze new data sets including other types of products. Second, a new model including the rate of adoption and the rate of discontinuance at the same time for the same product can be used to analyze product and services in fast changing environments (e.g., hi-tech markets). The development of this model could be related to country and time characterizes. Third, a closer analysis of the initial years of the rate of discontinuance should help determine if a process similar to the takeoff, which is a sudden increase of penetration levels, exists, and in which cases it does not. Fourth, relations between disposal, dispossession and discontinuance could be a fruitful area of research for future studies. Despite these limitations, the main purpose of this article, which is to show the importance and attractiveness of taking into account the dynamics of the rate of discontinuance as a key element for the evolution of technology in global markets, is hopefully achieved.

Appendix 1: Animation

Figure 2.7: Global Diffusion and Discontinuance of Black-and-White and Color Television Sets.



Note: Only available in the electronic version of the document.

Chapter 3

Time to Dive

Dive is a sudden increase in the rate of discontinuance of durable goods, that is, a negative takeoff. Socio-economic and cultural characteristics of countries are related to time-to-dive in the analysis of three durable goods that are discontinued globally. A Cox proportional hazard model and a regression tree are used to evaluate the relation of country characteristics with time-to-dive. Relations between time-to-dive and time-to-takeoff of several products are also studied. A hidden incubation period, which affects time-to-dive and may cause an over-prediction, is found for every type of product category. The applications of these findings to products entering the decline stage of their life-cycle are discussed.

Key phrases: Dive, Takeoff, Rate of Discontinuance, Rate of Adoption, International Diffusion of Innovations.

Introduction

In the aeronautical terminology, dive is a steep descending flight path, and takeoff the portion of an aircraft flight immediately after the airplane leaves the ground (Crane and Crane 2006). In marketing, takeoff is a term used to describe a sudden increase in sales after the launch of a new product or service, usually measured by levels of penetration. In this article, dive describes the sudden and substantial decrease of penetration of a technology.

How does a social system react to an old technology when a new one appears? Do dive and takeoff share similar dynamics? Investigations on diffusion of innovations address how a new technology is diffused among members in a social system. Much less attention has been devoted to the process of discontinuance. This phenomenon has been referred as "pro-innovation bias" (Rogers 2004). While this article is written, Twitter appears to be capturing the market of the SMS technology. How can we know whether SMS is starting to disappear or will just be partially substituted by a competing technology? Nearly every successful innovation has a dramatic increase of adoption in its early life. This pattern is called takeoff (Golder and Tellis 1997). Following the same rationale, a marketer could ask the following questions: does the rate of discontinuance experience a similar phenomenon, or does it have a slow rate of discontinuance? That is, does the rate of discontinuance experience a dive? And, if this happens, what kind of time or country effects are present in an international context?

Dive represents a theoretical challenge for marketing researchers. Recycling and reusing is becoming an obligation for companies to reduce the environmental impact of e-waste (CEC 2003)[1]. Companies all of a sudden need to plan for dealing with a product once it is no longer in demand. As new technologies are developed in a fast and changing environment, dive becomes even more relevant. The strategic aspects of dive affect several areas of a company, from after-sales service to R&D+i investments. Companies must decide whether or not to continue investing in their key strategic business units. Dive might help understand the takeoff of a new technology and vice versa. The dynamics of an innovation will depend on the characteristics of the product being substituted and the satisfaction of its users (Black 1983). Public policy actors may be also interested, because the discontinuance of a technology might involve a new perspective on infrastructure investment. The introduction of a new technology may require a gradual change of the support for its development, and it will depend on both its rate of adoption and the discontinuance of the pre-

[1] Waste Electrical and Electronic Equipment (WEEE)

vious technology. Understanding the influences that affect the different stages of discontinuance of a given technology is crucial to managers who dwell on strategic decision making of company's resource allocation. For instance, whether a market has a fast dive or not is crucial to establishing exit strategies to ameliorate the effects of a disruptive innovation.

This article analyzes the time and country characteristics of the dive processes with data from 67 countries. Using previous work on diffusion of innovations in an international context as a framework, this article studies time-to-dive with three technologies that are being or have been discontinued: black-and-white television sets, cassette-radio players and CD players.

This empirical investigation uses three factors that may have an effect on time-to-dive: country effects, time effects, and substitution effects. The country effects are derived from economic characteristics and cultural factors. Time effects, such as the time elapsed between a prior dive of an innovation in a country and the remaining countries are also investigated. In the marketing literature, this effect is called *demonstration effect*. Finally, substitution effects, such as the relation between the level of adoption of a new product and time-to-dive of the previous technology, are also analyzed.

Theoretical background is presented in the next section, followed by research hypotheses. Section 3.2 describes the data set used in the analysis, section 3.3 explains the methodology, and section 3.4 presents the results. A discussion including marketing implications, future research and limitations is presented in the concluding section.

3.1 Theoretical Background

This article builds on two lines of research: the rate of adoption, and especially time-to-takeoff, and the rate of discontinuance. Both phenomena have been investigated in the field of diffusion of innovations. Research on this field studies how an innovation is adopted and spread in a social system. For instance, internal and external influences that affect the life-cycle of a given product or service in a social system are addressed. The Bass model has been the most commonly used device to understand this phenomenon (Bass 1969). However, recently a strong interest of marketers has been shown in modeling time-to-takeoff (Golder and Tellis 1997). Most successful product innovations have a dramatic increase in sales. This pattern, called takeoff, reflects a sudden increase in demand for the product. In contrast, literature addressing the rate of discontinuance of products is extremely scarce compared to research done on the rate of adoption (see below). This might be the reason why no empirical research has addressed the questions related to dive. Dive is a process similar to takeoff but it refers to the rate of discontinuance; that is, a dramatic increase in the rate of discontinuance.

Black (1983) examines the relation between the rates of adoption and discontinuance and proposes a conceptual model of the post-adoption process. Redmond (1996) investigates smoking cessation as an adoption/diffusion process. Hogan et al. (2003) develop a model to determine the effect of discontinuance on the value of a lost customer. Athiyaman (2008) explores the discontinuance of tiger parts consumption in China. And Prins et al. (2009) analyzes the effect of adoption timing on discontinuance.

Time-to-takeoff is receiving a lot of attention as a new stream of diffusion research (Chandrasekaran and Tellis 2007, Krishnan and Thomas 2009, Peres et al. 2010). Takeoff is generally followed by a steady increase of adoption until a *slowdown* close to the peak of growth[2]. This makes it strategically important to understand the processes that are related to it. A manager needs to know whether to invest in limited resources or not, such as manufacturing, inventory, or distribution. The introductory stage can be seen as an *incubation period*, the time between the end of product development and the start of substantial sales (Kohli et al. 1999). As mentioned above, takeoff is the time at which a dramatic increase in sales occurs in the early stages of the diffusion of a new product (Golder and Tellis 1997), and can be seen as a point of transition from the introduction stage to the growth stage of the product life cycle. There is no unique measure for time-to-takeoff. Golder and Tellis (1997) develop a method based on the base level of sales relative to the percentage sales growth. When the base level of sales is low, a large increase in sales is required to signal takeoff and vice versa. Based on this logic, a threshold of takeoff is developed and used as a heuristic measure. The authors compare this rule with two alternatives: a logistic curve rule and a maximum growth rule. Agarwal and Bayus (2002) develop a statistical procedure based on a generalized version of discriminant analysis to distinguish between two consecutive intervals by examining the data on annual percentage change in sales and annual net entry of firms for each good. In Garber et al. (2004) and Goldenberg et al. (2001) takeoff occurs when 16% of the population adopts. Wiorkowski and Gylys (2006) develop two alternative measures to identify the location of takeoff that allow for a real-time test. Another method based on Golder and Tellis (1997) specifies a threshold function that plots the growth rate of sales against market penetration. Takeoff is identified at the time point when the product growth in sales exceeds this threshold (Tellis et al. 2003, Stremersch and Tellis 2004, van Everdingen et al. 2009).

Several authors model new product takeoff from an international perspective. Tellis et al. (2003) find that the average time-to-takeoff in Scandinavian countries is shorter than in other European countries; brown goods (entertainment and information products) take off faster than white goods (kitchen and laundry appliances); and venturesome culture explains the variation in time-to-takeoff while GDP per capita does not. On the other hand, Stremersch and Tellis (2004), Chandrasekaran and Tellis (2008) and van Everdingen et al. (2009) find the opposite relation of GDP per capita

[2]In some markets an initial rise is followed by a decrease in sales. This phenomenon is called *saddle*.

to time-to-takeoff. Chandrasekaran and Tellis (2008) finds that two cultural factors are related to time-to-takeoff: collectivism and uncertainty avoidance. The relation of uncertainty avoidance is confirmed by van Everdingen et al. (2009). The authors also find cross-country spill-over effects.

Research on time-to-takeoff, and the rate of adoption in general, has obtained relevant results in an international context (Krishnan and Thomas 2009), but possible relations to time-to-dive, such as time, country and substitution effects remain unaddressed. Previous findings though, provide an excellent framework for studying time-to-dive. Two main types of country differences have been found to affect the rate of adoption: cultural and economic. Economic differences can be subdivided into economic wealth of countries, usually measured by gross domestic product (GDP) per capita, and income inequality, usually measured with the Gini index (Salverda et al. 2009). Economic measures, such as lifestyle, health status, or urbanization, have been found to affect diffusion (Helsen et al. 1993, Dekimpe et al. 1998, 2000a, Talukdar et al. 2002, Van den Bulte and Stremersh 2004, Desiraju et al. 2004, Stremersch and Tellis 2004, Kauffman and Techatassanasoontorn 2005, Sundqvist et al. 2005, Dwyer et al. 2005, Chandrasekaran and Tellis 2008, van Everdingen et al. 2009). Indeed, it is a common finding that high-income consumers adopt new products earlier (Rogers 2004). Therefore, earlier adoption of an innovation, expected in wealthier countries, implies that the older technology is discontinued earlier. We formulate this as:

Hypothesis 1: Products are discontinued earlier in richer countries than in poorer countries.

A wealthier portion of the population who can afford the cost of adopting a new technology accelerates time-to-takeoff (Golder and Tellis 1997, 2004). Therefore, it is expected to be negatively related to GDP per capita (Stremersch and Tellis 2004). Time-to-dive might have a similar relationship. Besides, since the value of an adopted technology is relatively higher in poorer countries, products might also have a longer useful life and be more resistant to discontinuance. Based on the above, wealthier countries are expected to have a shorter time-to-dive.

Hypothesis 2: Products have a shorter time-to-dive in richer countries than in poorer countries.

In a country with a high level of income inequality, only a few people will be able to afford an innovation (Talukdar et al. 2002, Tellis et al. 2003, Van den Bulte and Stremersh 2004). In line with this argument, time-to-dive is expected to be longer if the level of income inequality is higher.

Hypothesis 3: Products have a longer time-to-dive in countries with a higher level of income inequality than in countries with a lower one.

The level of urbanization of a country is an indicator of the level of penetration of a potential new product in a country (Talukdar et al. 2002). Countries with a higher percentage of rural population are expected to have a longer time-to-dive, as a new product will reach a lower percentage of the population.

Hypothesis 4: Products have a longer time-to-dive in countries with a higher level of rural population than in countries with a lower level.

Time effects refer to the reaction of lagged countries to prior dives on lead countries (also called lead-lag countries effect). Lead countries adopt a technology before a lagged country, which is a country that adopts a technology once it has been introduced in other countries. A negative effect is found on time-to-takeoff of products, which implies a learning effect among countries (Chandrasekaran and Tellis 2007, van Everdingen et al. 2009). A takeoff of an innovation in a country might increase company efforts to enter new markets (Tellis et al. 2003), which may cause a sudden increase of the replaced technology's rate of discontinuance. Therefore, time-to-dive might also be affected by prior dives in other countries, and the same lead-lag countries effects can be assumed. A dive in a country can stimulate a dive in another country. Based on these results, it is expected that the greater the amount of prior dives in foreign countries, the shorter the time-to-dive.

Hypothesis 5: The greater the amount of prior dives in foreign countries, the shorter the time-to-dive.

Previous research suggests that cultural factors of countries are associated with different patterns of adoption of innovations. Nonetheless, results about their effects are inconclusive (Krishnan and Thomas 2009). In this article, Hofstede's four cultural indices are hypothesized to have a potential impact on time-to-dive: uncertainty avoidance (UAI), masculinity (MAS), power distance (PDI) and individualism (IND).

Hypothesis 6: Cultural dimensions of countries affect time-to-dive.

For a technology to be discontinued, consumers must be able to replace its benefit by adopting a new substituting technology: a new product or service. In the case of sewing machines, a decrease of the level of adoption has been caused by a decrease in the price and a new form of selling and consuming cloth (Godley 2001, Morgan and Birtwistle 2009). In the case of professions (e.g., shoe repairs), new technologies might replace the benefits of their service. In a dynamic market, innovations cause the discontinuance of products and services and both the new and old products are present in the market while the change is taking place (Sterman 2000). Therefore, the *substitution effect* captures the impact of an innovation being introduced on the discontinuance of the previous technology (Andonova and Ladrón-De-Guevara 2011). It is expected that the higher the level of penetration of an innovation in a market, the shorter the time-to-dive for the older product. Similarly, the shorter the time-to-takeoff, the shorter time-to-dive for a substituted technology.

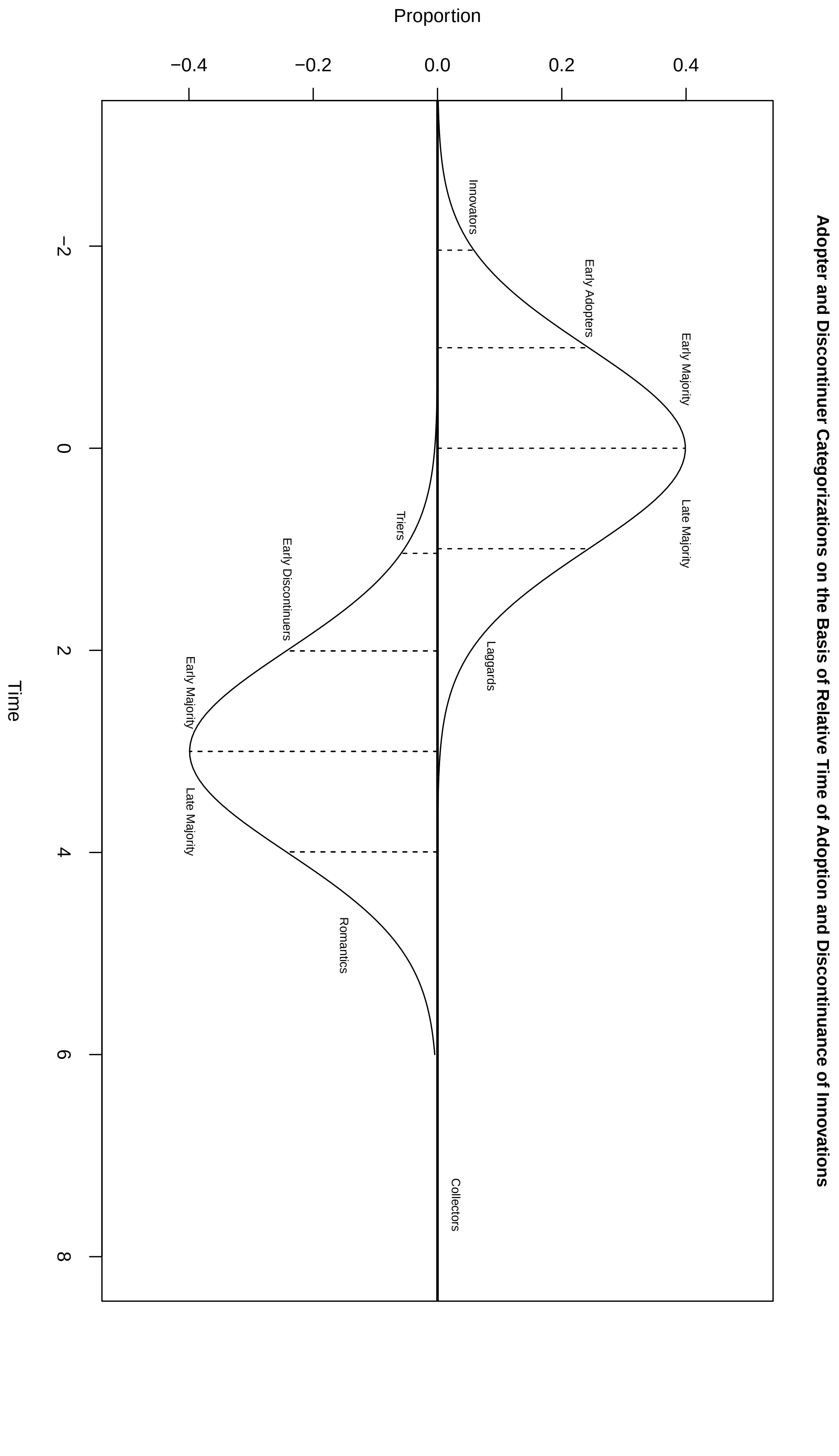
Hypothesis 7: Countries with a higher level of penetration of an innovation at the start of the discontinuance process will have a shorter time-to-dive.

Hypothesis 8: Countries with a shorter time-to-takeoff of an innovation will present a shorter time-to-dive.

Diffusion is defined as the adoption of innovations over time among members of a social system (Rogers 2004). In our case, social systems are operationalized as countries. Consumers of a country can be classified using five adopter-and-discontinuer categories based on their degree of innovativeness and discontinuousness. The five adopter categories are innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%), and laggards (16%) as defined by Rogers (2004). The five discontinuer categories are triers (2.5%), early discontinuers (13.4%), early majority (34%), late majority (34%), and romantics (16%) (Palacios Fenech 2008, Athiyaman 2008) (see **figure 3.1**). Countries with a shorter time-to-takeoff are expected to achieve these levels of innovativeness faster than countries with a longer time-to-takeoff. Based on this, countries with a shorter time-to-dive will reach these levels of discontinuance faster than countries with a longer time-to-dive.

Hypothesis 9: Countries with a shorter time-to-dive of a discontinuance will reach newer levels of discontinuance earlier.

Figure 3.1: Adoption and Discontinuance.

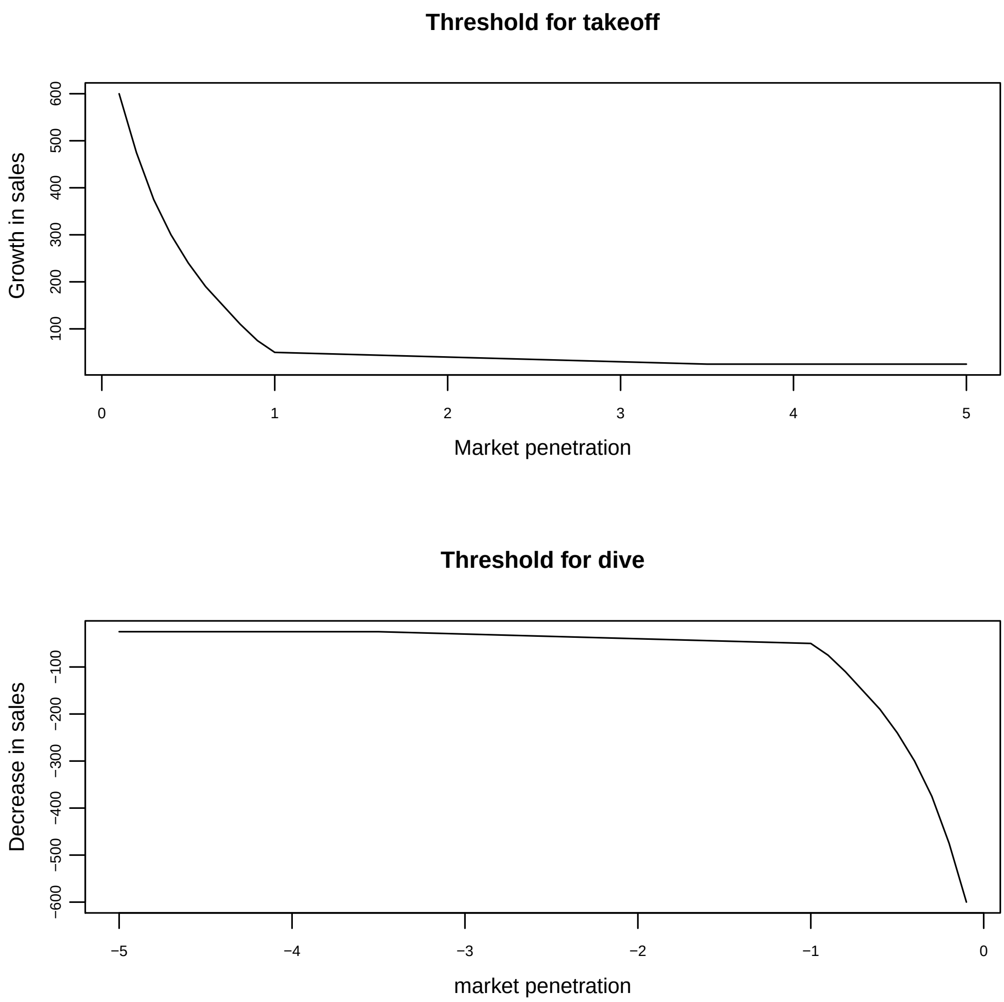


3.2 Data

This study uses a database composed of several sources: Euromonitor, World Bank, World Resource Institute, and Hofstede's data base (Hofstede 2001). The data set contains the annual levels of penetration of three products being discontinued between 1977 and 2008: black-and-white television sets, cassette-radio players, and CD players. Other variables in the data set include socio-economic and cultural characteristics of each country, as well as adoption levels for innovations entering the markets.

The start of discontinuance is identified as the last year in which the level of penetration reaches a local maximum, since there may be several maximums. The starting year to calculate time-to-dive is the initial year of discontinuance. Time-to-dive is identified by similar criteria as the threshold rule for time-to-takeoff developed by Tellis et al. (2003). A threshold for dive is defined as a standard plot of a required decrease in sales for various levels of market penetration (**figure 3.2**). Time-to-dive is calculated using an inverted version of the threshold rule for time-to-takeoff. Both events, takeoff and dive, occur during the first year a product diffusion crosses this threshold. The two thresholds are compared in **figure 3.2**. The threshold for takeoff was inferred to give the best prediction if visually identified (Golder and Tellis 1997, Tellis et al. 2003). The threshold rule has been slightly modified for calculating both time-to-dive and time-to-takeoff. The original threshold rule takes into account only the possibility that takeoff occurs until a 3.5% market penetration. In this analysis, the percentage of market penetration is increased to 5%. From 3.5% to 5%, the required change to cross the threshold in sales is 25%. For the three studied technologies, a sudden increase in the rate of discontinuance occurs many times in the first year after the local maximum. When this happens, change in sales cannot be calculated. Therefore, as an addition to the threshold rule, when 2% of the market discontinues the good in the first period or over 5% of the market discontinues the good in the second period, the threshold is assumed to be crossed. In contrast to the analysis of time-to-takeoff, for time-to-dive the maximum adoption level has already been achieved. Now we can obtain the exact percentage of the market that has discontinued the product and calculate both market penetration and decrease in sales.

Figure 3.2: Thresholds for Takeoff and Dive.



Note: The level of penetration in percentages is used instead of the number of sales.

A summary of the statistics for the three products are included in **tables 3.1** – **3.3**. This summary is complemented with **figures 3.3** – **3.5**[3]. In these figures, the first plot (Discontinuance/GDP) represents the initial time in which discontinuance takes place in the horizontal axis and is compared to GDP. The horizontal axis of the rest of the plots represents time-to-dive, and the vertical axis a related covariate. Time-to-dive often occurs in two years for the three products. **Table 3.4** presents the acronyms of countries included in the analysis. In this table, countries are displayed in five categories based on gross domestic product (GDP) per capita at purchasing power parity (PPP).

[3] To avoid extreme overprinting, the acronyms of the countries are printed to the left or right of their value.

Table 3.1: Black-and-White Television Sets

	Disc	Dive	T.Dive	E.D	E.M	L.M	Romantic	T.E.D
Mean	1985	1987	2	1988	1992	1999	2003	3
S.D.	7	6	1	6	5	4	3	2
Max	2000	2001	9	2001	2004	2006	2008	12
Median	1982	1984	2	1986	1991	1999	2004	2
Min	1978	1980	1	1980	1984	1990	1997	1
Missing	0	0	0	0	0	1	17	0

	T.E.M	T.L.M	T.Roma	TV Disc	TV Dive	T.E.A.TV	T.E.M.TV	T.L.M.TV
Mean	7	15	22	14	19	-4	2	10
S.D.	3	4	5	14	16	4	5	5
Max	19	24	28	65	72	7	16	22
Median	7	16	23	11	14	-3	3	11
Min	2	6	12	1	1	-15	-7	-1
Missing	0	1	17	0	0	0	0	2

	T.L.TV	PDI	IDV	MAS	UAI	Gini	GDP	RURAL
Mean	18	70	36	52	68	39	10669	38
S.D.	6	17	20	21	20	9	6411	15
Max	28	104	80	110	104	59	25498	72
Median	18	70	30	50	70	38	9343	34
Min	4	40	8	9	30	26	1939	7
Missing	12	12	12	12	12	1	0	0

41 Countries: AZE, CHN, IND, IDN, KAZ, MYS, PAK, PHL, KOR, THA, TKM, VNM, BLR, BGR, HRV, CZE, EST, HUN, LVA, LTU, POL, ROU, RUS, SVK, UKR, BOL, COL, ECU, MEX, PER, VEN, DZA, EGY, JOR, MAR, NGA, SAU, ZAF, TUN, PRT, TUR.

Disc: Year of discontinuance. Dive: Year of dive. T.Dive: Time-to-dive. E.D: Year of early discontinuance. E.M: Year of early majority. L.M: Year of late majority. Romantic: Year of romantic. T.E.D: Time to early discontinuance. T.E.M: Time to early majority. T.L.M: Time to late majority. T.Roma: Time to romantic. TV Disc: Level of possession of color TV at year of discontinuance. TV Dive: Level of possession of color TV at year of dive. T.E.A TV: Time to early adopters of color TV from discontinuance. T.E.M TV: Time to early majority of color TV from discontinuance. T.E.A TV: Time to late majority of color TV from discontinuance. T.L. TV: Time to laggards of color TV from discontinuance. PDI: Power Distance. IDV: Individualism. MAS: Masculinity. UAI: Uncertainty Avoidance. Gini: Gini index. GDP: GDP at PPP in 2008. RURAL: Percentage of rural population in 2008.

Figure 3.3: Time-to-Dive of Black-and-White Television Sets

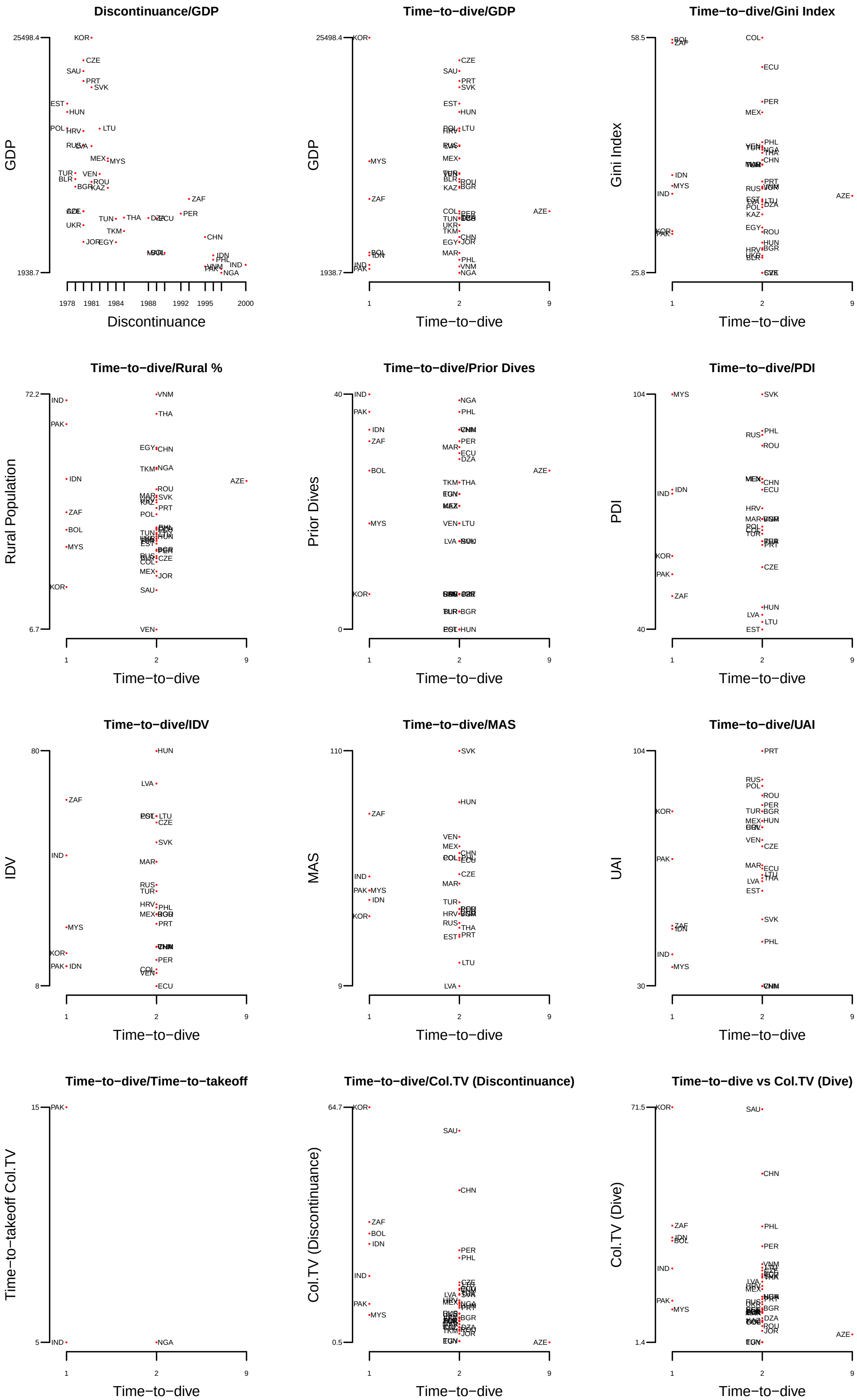


Table 3.2: Cassette-Radio Players

	Disc	Dive	T.Dive	E.D	E.M	L.M	Romantic	T.E.D
Mean	1998	2000	2	2002	2005	2005	NA	4
S.D.	2	2	0	3	3	3	NA	2
Max	2005	2006	3	2006	2008	2007	NA	7
Median	1998	2000	2	2002	2006	2007	NA	4
Min	1992	1994	1	1995	1997	2001	NA	1
Missing	0	3	3	3	28	54	57	3
	T.E.M	T.L.M	T.Roma	CD Disc	CD Dive	T.E.A.CD	T.E.M.CD	T.L.M.CD
Mean	7	11	NA	27	28	-9	-5	-3
S.D.	3	4	NA	27	28	6	6	2
Max	12	15	NA	85	88	8	10	1
Median	7	9	NA	15	15	-11	-6	-3
Min	2	8	NA	1	1	-16	-13	-6
Missing	28	54	57	0	3	4	24	40
	T.L.CD	PDI	IDV	MAS	UAI	Gini	GDP	RURAL
Mean	2	59	47	49	66	36	20645	29
S.D.	2	22	23	22	23	8	12836	16
Max	5	104	90	110	112	58	49415	70
Median	2	62	46	50	68	35	17651	29
Min	0	11	12	5	8	25	2344	0
Missing	49	7	7	7	7	2	1	1

57 Countries: AZE, CHN, HKG, IND, IDN, JPN, KAZ, MYS, PAK, PHL, SGP, KOR, TWN, THA, AUS, NZL, BLR, BGR, HRV, CZE, EST, LVA, LTU, POL, ROU, RUS, SVK, SVN, UKR, ARG, BOL, BRA, CHL, COL, MEX, PER, VEN, JOR, MAR, SAU, CAN, AUT, BEL, DNK, FIN, FRA, DEU, GRC, IRL, ITA, NLD, NOR, PRT, ESP, SWE, CHE, GBR.

Disc: Year of discontinuance. Dive: Year of dive. T.Dive: Time-to-dive. E.D: Year of early discontinuance. E.M: Year of early majority. L.M: Year of late majority. Romantic: Year of romantic. T.E.D: Time to early discontinuance. T.E.M: Time to early majority. T.L.M: Time to late majority. T.Roma: Time to romantic. CD Disc: Level of possession of CD players at year of discontinuance. CD Dive: Level of possession of CD players at year of dive. T.E.A CD: Time to early adopters of CD players from discontinuance. T.E.M CD: Time to early majority of CD players from discontinuance. T.E.A CD: Time to late majority of CD players from discontinuance. T.L. TV: Time to laggards of CD players from discontinuance. PDI: Power Distance. IDV: Individualism. MAS: Masculinity. UAI: Uncertainty Avoidance. Gini: Gini index. GDP: GDP at PPP in 2008. RURAL: Percentage of rural population in 2008.

Figure 3.4: Time-to-Dive of Cassette-Radio Player

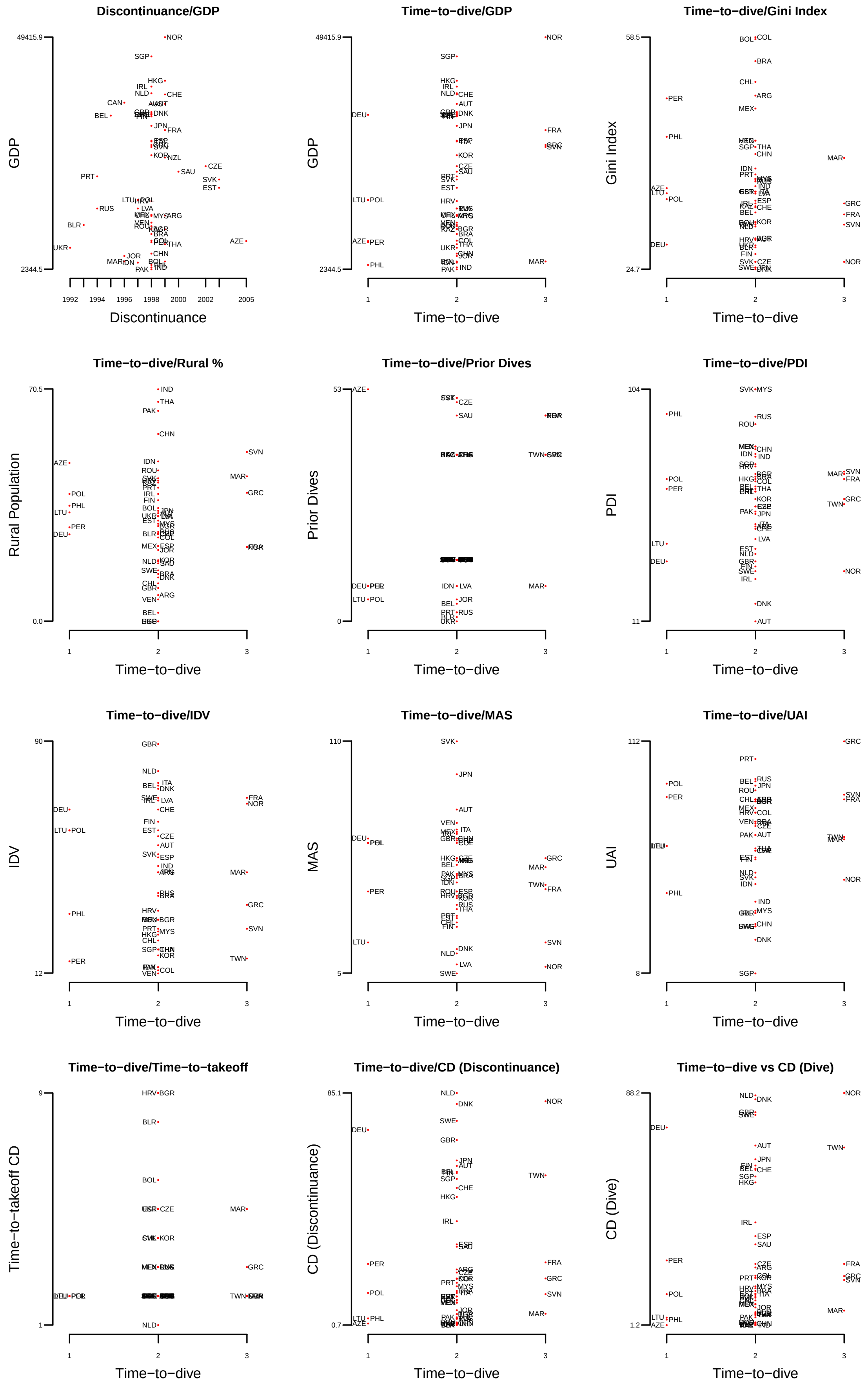


Table 3.3: CD Players

	Disc	Dive	T.Dive	E.D.	E.M	L.M	Romantic	T.E.D
Mean	2004	2006	2	2006	NA	NA	NA	2
S.D.	1	1	1	1	NA	NA	NA	1
Max	2006	2008	4	2008	NA	NA	NA	6
Median	2004	2005	2	2006	NA	NA	NA	2
Min	2000	2002	1	2004	NA	NA	NA	1
Missing	0	1	1	5	30	30	30	5
	T.E.M	T.L.M	T.Roma	NET Disc	NET Dive	CD Adopt	CD Takeoff	T.Takeoff CD
Mean	NA	NA	NA	32	39	1984	1987	3
S.D.	NA	NA	NA	22	25	2	4	2
Max	NA	NA	NA	70	82	1990	1995	11
Median	NA	NA	NA	34	44	1983	1985	2
Min	NA	NA	NA	1	2	1981	1984	1
Missing	30	30	30	0	1	0	1	1
	T.E.A.	PDI	IDV	MAS	UAI	Gini	GDP	RURAL
Mean	5	52	57	50	65	35	25594	27
S.D.	3	22	20	27	26	9	12902	13
Max	12	104	90	110	112	58	49416	46
Median	4	49	66	55	64	34	28342	28
Min	1	11	20	5	8	25	3950	0
Missing	0	4	4	4	4	0	0	0

30 Countries: HKG, SGP, AUS, BLR, BGR, HUN, LVA, ROU, SVK, ARG, BOL, MEX, DZA, ZAF, TUN, AUT, BEL, DNK, FIN, FRA, DEU, GRC, IRL, ITA, NLD, NOR, PRT, ESP, SWE, CHE.

Disc: Year of discontinuance. Dive: Year of dive. T.Dive: Time-to-dive. E.D: Year of early discontinuance. E.M: Year of early majority. L.M: Year of late majority. Romantic: Year of romantic. T.E.D: Time to early discontinuance. T.E.M: Time to early majority. T.L.M: Time to late majority. T.Roma: Time to romantic. NET Disc: Level of possession of internet personal computers at year of discontinuance. NET Dive: Level of possession of internet personal computers at year of dive. CD Adopt: Year of adoption of CD players. CD Takeoff: Year of takeoff of CD players. T.Takeoff CD: time-to-takeoff of CD players. T.E.A: Time to early adopters of CD players. PDI: Power Distance. IDV: Individualism. MAS: Masculinity. UAI: Uncertainty Avoidance. Gini: Gini index. GDP: GDP at PPP in 2008. RURAL: Percentage of rural population in 2008.

Figure 3.5: Time-to-Dive of CD Player

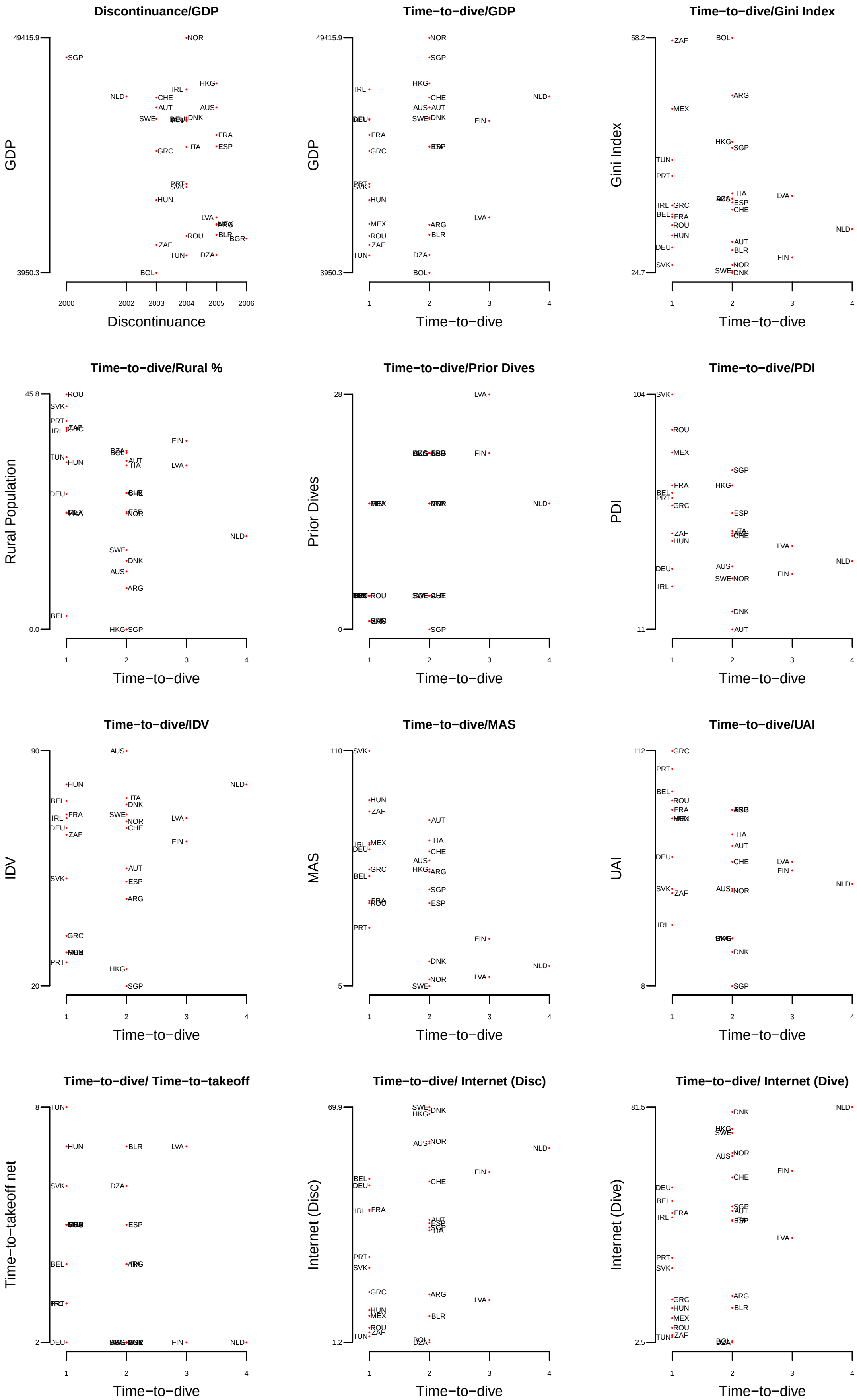


Table 3.4: Categories of Countries

Categories									
1		2		3		4		5	
Norway	NOR	Finland	FIN	Estonia	EST	Mexico	MEX	Colombia	COL
Kuwait	KWT	United Kingdom	GBR	Portugal	PRT	Bulgaria	BGR	Ecuador	ECU
Singapore	SGP	Germany	DEU	Saudi Arabia	SAU	Kazakhstan	KAZ	Ukraine	UKR
United States	USA	Japan	JPN	Slovakia	SVK	Romania	ROU	Egypt	EGY
Ireland	IRL	France	FRA	Hungary	HUN	South Africa	ZAF	China	CHN
Hong Kong	HKG	Spain	ESP	Latvia	LVA	Belarus	BLR	Jordan	JOR
Switzerland	CHE	Italy	ITA	Lithuania	LTU	Brazil	BRA	Bolivia	BOL
Austria	AUT	Greece	GRC	Poland	POL	Turkey	TUR	Morocco	MAR
Netherlands	NLD	Taiwan	TWN	Croatia	HRV	Turkmenistan	TKN	Indonesia	IDN
Canada	CAN	Israel	ISR	Russia	RUS	Azerbaijan	AZE	Philippines	PHL
Australia	AUS	New Zealand	NZL	Malaysia	MYS	Algeria	DZA	India	IND
Denmark	DNK	Slovenia	SVN	Chile	CHL	Thailand	THA	Pakistan	PAK
Sweden	SWE	South Korea	KOR	Argentina	ARG	Peru	PER	Vietnam	VNM
Belgium	BEL	Czech Republic	CZE	Venezuela	VEN	Tunisia	TUN	Nigeria	NGA

Note: Categories of countries based on gross domestic product per capita (GDP) at purchasing power parity (PPP). Acronyms based on ISO 3166-1 alpha-3: Three-letter country codes.

A summary of the data used to analyze time-to-dive of black-and-white television sets is presented in **table 3.1**. The analysis is based on 41 countries displayed in the footnote of the table. In these countries the discontinuance takes place after 1977. They belong to the poorest categories shown in **table 3.4**. The average starting year of discontinuance is 1985 and the average year in which dive occurs is 1987. So, the average time-to-dive is 2 years. The last country that discontinues black-and-white television sets does so in year 2000 and the last dive occurs in 2001. Times-to-dive are in the range of one to nine years. These tables also present the years in which the several levels of discontinuance are reached. On average, countries enter the early-discontinuers category in 1988, the early-majority in 1992, the late-majority in 1999, and the romantic stage in 2003; which correspond to 3, 7, 14, and 18 years, respectively. Only one country does not reach the late majority stage and 17 countries do not reach the romantics stage. The average level of possession of color television sets at the years of discontinuance and dive of black-and-white television sets are 14% and 19%, respectively. To provide intuition about the interaction between both technologies, the years that Rogers' categories are reached for color television relative to the start of the discontinuance of black-and-white television sets are also presented in **table 3.1**.

A summary of the data set used for the analysis of cassette-radio players is presented in **table 3.2**. The initial year of discontinuance is available for 57 countries. For these countries, discontinuance of cassette-radio players takes place in 1998 and dive in 2000 on average. In three countries dive does not take place: Australia, New Zealand and Canada. These countries never enter the early-discontinuers category. On average, it takes four years to reach the early-discontinuers level, seven years to reach the early majority level, and eleven years to reach the late majority level. Only three countries reach the late majority level and none of them reach the romantics level before 2008. The average level of penetration of CD players when discontinuance and dive of cassette-radio players occurs, is 27% and 28% respectively. The early adopter category of CD player is reached on average nine years before the start of the discontinuance of cassette-radio players and only six countries reach the laggards stage.

Table 3.3, shows that dive of CD players occurs in 30 out of the 31 countries in which discontinuance takes place before 2008. The average time-to-dive is two years, and it is absent only in Bulgaria. The average initial year of discontinuance is 2004. The average time required to reach the level of early discontinuers is two years, and five countries do not reach this level. None of the later levels of discontinuance are reached by any country. The possession of internet personal computers is used as a proxy of the innovation that is causing CD players to be discontinued. MPEG-1 or MPEG-2 Audio Layer III, commonly referred to as MP3, which is an audio format for consumer audio storage that allows to accumulate great amounts of information, could also be used. However, no data on penetration levels is available for these technologies. The average levels of possession of internet personal computers at the time of discontinuance and dive are 32% and 39%, respectively. Both key turning points for CD players, takeoff and dive, take place between 1977 and 2008. Only in Romania, takeoff never takes place. The average years of adoption and takeoff of CD players are 1984 and 1987, respectively. The average time-to-takeoff is three years for these countries and the average time to early adopters is five years.

The last seven variables included in **tables 3.1** – **3.3** are Hofstede's cultural indices, Gini index based on country surveys conducted between 2000 and 2007, GDP per capita at PPP, and the percentage of rural population in 2008. These variables are used in the models to estimate time-to-dive. Two of them are time dependent: GDP per capita at PPP and rural population. The rest are defined as fixed within the period studied.

Takeoff for color television sets is only for three countries: India and Nigeria in 1981 and Pakistan in 1991. In eight out of the 57 countries where discontinuance of cassette-radio player occurs, takeoff for CD players does not take place. The average time-to-takeoff is three years, and the standard deviation is approximately two years. The average time-to-takeoff of internet in countries where discontinuance of CD player has started is slightly above four years and the standard deviation also approaches two years. In four countries takeoff of internet has not occurred by year 2008.

The products included in this article allow us to compare three types of economic and historical environments. In the case of black-and-white television sets, the rate of discontinuance in richer countries started before 1977. Therefore, only less developed and emerging economies are included in the analysis of this product. Cassette-radio players have the widest sample with 57 countries, including different types of economies. Finally, for CD players only wealthier countries have already initiated discontinuance before 2008 except some exceptional developing countries (i.e. Bolivia). For each sample of countries, on average, dive occurs when the level of penetration for black-and-white television sets is 53.8% (*14.6%*), for cassette-radio players is 69.9% (*14.6%*), and for CD players is 41.4% (*30.8%*).

3.3 Methodology

Phases of adoption were first studied by duration models by Dekimpe et al. (2000a). Traditionally, time-to-takeoff has been modeled with a duration model (Tellis et al. 2003, Stremersch and Tellis 2004, Chandrasekaran and Tellis 2008, van Everdingen et al. 2009). The same methodology is used to model time-to-dive with the Cox proportional hazard model (Cox 1972), and a parametric hazard model, assuming a Weibull baseline distribution (Cox and Oakes 1984). Both models are applied to each product separately and pooling the three products together. Proportional hazard models applied to calculate time-to-dive can be written as

$$h(t) = h_0(t)\exp\sum_j \beta_j X_j \qquad (3.3.1)$$

where $X_1, X_2, ...$ represent the covariates included in the model. It can be interpreted as the product of a baseline hazard function $h_0(t)$, and a non-negative function of the covariates. This hazard function indicates the extent to which explanatory variables drive the time-to-dive in a country, given that it has still not occurred. The Cox model has no intercept and the effects of covariates are proportional to the baseline hazard, which is unspecified and fixed over time. The Cox model has a semi-parametric form that does not allow us to choose a particular distribution function. In this methodology we estimate the parameters, $\hat{\beta}_1, \hat{\beta}_2, ...$, and evaluate the effect of multiple time-dependent and time-independent variables. The estimated hazards are always non-negative and the information combined in the censored cases is not lost.

In a parametric model, $h_0(t)$ is assumed to be parametric and follow a particular distribution. The Weibull distribution is suitable for modeling data with monotone hazard rates that either increase or decrease exponentially over time. For the proportional hazard model, the function $h_0(t)$ takes a Weibull form, pt^{p-1}, where p is the shape parameter to be estimated from the data. To estimate the effect of covariates, we use an accelerated failure time (AFT) model assuming a Weibull baseline distribution, in which the natural logarithm of time-to-dive is expressed as a linear function of the covariates as follows:

$$\log(t) = \sum_j \alpha_j X_j + z \tag{3.3.2}$$

where z is the residual error term and follows a Weibull distribution (see Srinivasan et al. (2004) for a detailed description of this approach). The estimation of hazard models is fitted with the `eha` and the `survival` package of the `R` software and `streg` function of the STATA software.

A regression tree model for each product is also employed. Tree-based models are commonly used in several fields, including marketing science (Currim et al. 1988, Lemmens and Croux 2006). A regression tree model is a variable selection device. It is based on binary recursive partitioning: an iterative process of splitting the data into partitions, and then splitting them further. Each terminal node of a regression tree provides a predicted value for the subset of cases (in this case, countries) corresponding to the sequence of splits leading up that node. In this study, time-to-dive is the dependent variable, and countries that do not cross the threshold of dive are excluded from the analysis. Regression tree models are fitted with the `tree` package of the `R` software (Ripley 2008).

A linear regression is used to estimate the relation between the first year of discontinuance and GDP per capita. A one-way permutation test is used to test the relation between prior dives in leading countries and time-to-dive in lagged ones, in which dive occurs after a certain time. The permutation test is carried out with the `coin` package of the `R` software.

3.4 Results

The three technologies studied in this research present different timings for the discontinuance process. For richer countries, black-and-white television sets are discontinued before 1977. Therefore, only less-developed economies present the initial time of discontinuance within our sample period. For CD players, the initial time of discontinuance is available only for some richer countries. Most of the developing economies are lagged countries, which do not present a start of a discontinuance process before 2008. Finally, for cassette-radio players, the data set includes the initial time of discontinuance within the period studied for a wide range of countries.

Table 3.5 illustrates the relation between initial time of discontinuance and GDP per capita using a linear regression. For black-and-white television, GDP is strongly associated with the first year of discontinuance, and for CD players, GDP per capita is slightly associated at the 5% confidence level. However, looking at the top left-hand plot in each of figures **3.3–3.5**, the linearity of the relation can not be confirmed.

Table 3.5: Discontinuance and GDP

Black-and-white TV	Coeffficient	Standard error	t–statistic	p–value
Intercept	1991.76	1.63	1219.40	0.00
GDP	–1.24	0.36	–3.41	0.00
Cassette-radio player				
Intercept	1998.82	1.63	1219.40	0.00
GDP	0.01	0.03	0.48	0.64
CD player				
Intercept	2005.72	0.44	4603.32	0.00
GDP	–0.04	0.02	–2.05	0.05

Note: Black-and-white TV: 41 countries. Cassette-radio players: 57 countries. CD players: 30 countries. GDP per capita at PPP in thousands of $.

Each proportional hazard model includes six time-independent covariates: Gini index, uncertainty avoidance, masculinity, individualism, power distance, and level of penetration of the substituting technology; and two time-dependent covariates: percentage of rural population and GDP per capita at PPP. For cassette-radio players and CD players, time-to-takeoff of the substituting technologies are included in the model[4]. A pooled hazard model is applied to the data within which the effect of covariates of the three product categories are analyzed simultaneously. Two types of models are used to test the hypotheses related to time-to-dive: the Cox proportional hazard model and a parametric model with a Weibull distribution with an AFT specification. **Tables 3.6 and 3.7** include a summary of the key results.

Results with the Cox proportional hazard model can be interpreted when they are expressed as the percentage change in the hazard, which can be calculated from e^{β} by the formula $100 \times (e^{\beta} - 1)$. In AFT models, the effect of covariates is interpreted directly in the time-to-dive instead of the hazard. With a Weibull baseline distribution, if the shape parameter p is less than one, instantaneous hazard decreases with time, and if p is greater than one, instantaneous hazard increases with time. The acceleration factor $exp(\beta_k)$, can be estimated to read the results. If the acceleration factor is greater than one, time-to-dive increases, and if it is lower than one, time-to-dive decreases. The same transformation with the formula $100 \times (e^{\beta} - 1)$ can be used on the results, but the interpretation varies, as the effect of the resulting value is on time-to-dive (Mills 2010).

[4]For black-and-white television sets, time-to-takeoff of color televisions sets is not included in the model because only two cases are available (see **figure 3.3**).

Table 3.6: Hazard Model for Black-and-White Television Sets, Cassette-Radio Player and CD Player

	Cox model			AFT model		
	β	t–statistic	p–value	β	t–statistic	p–value
Black-and-white TV						
Gini	–0.011	–0.294	0.769	0.003	0.497	0.619
UAI	0.001	0.094	0.925	–0.001	–0.343	0.732
PDI	–0.002	–0.127	0.899	0.001	0.297	0.767
MAS	0.003	0.211	0.833	0.000	–0.230	0.818
IDV	0.000	0.024	0.981	0.000	0.119	0.905
TV	0.022	1.104	0.270	–0.005	–1.423	0.155
GDP	–0.013	–0.286	0.775	0.003	0.490	0.624
Rural	0.006	0.315	0.753	–0.001	–0.207	0.836
Intercept				0.599	1.048	0.295
log(shape)				1.867	10.151	0.000
R^2			*0.05*			*0.08*
Cassette-radio player						
Gini	–0.049	–1.419	0.156	0.036	2.280	0.023
UAI	–0.008	–0.852	0.394	0.003	0.640	0.522
PDI	–0.012	–0.927	0.354	0.005	0.762	0.446
MAS	0.003	0.409	0.683	0.000	0.030	0.976
IDV	–0.016	–1.488	0.137	0.013	2.580	0.010
CD player	–0.018	–1.100	0.271	0.016	1.948	0.051
GDP	–0.030	–0.983	0.326	0.011	0.762	0.446
Rural	–0.019	–1.274	0.203	0.010	1.459	0.144
Takeoff CD	–0.194	–1.443	0.149	0.154	2.550	0.011
Intercept				–2.881	–2.039	0.041
log(shape)				0.763	6.353	0.000
R^2			*0.06*			*0.23*
CD player						
Gini	–0.014	–0.264	0.792	0.016	1.033	0.302
UAI	0.009	0.654	0.513	–0.005	–1.311	0.190
PDI	0.009	0.549	0.583	–0.005	–1.121	0.262
MAS	0.022	2.065	0.039	–0.008	–3.295	0.001
IDV	–0.006	–0.319	0.750	0.003	0.568	0.570
Internet	–0.008	–0.215	0.829	0.005	0.538	0.591
GDP	0.063	0.869	0.385	–0.019	–0.972	0.331
Rural	–0.011	–0.357	0.721	0.008	0.945	0.345
Takeoff internet	0.134	0.436	0.663	–0.032	–0.397	0.692
Intercept				0.936	1.011	0.312
log(shape)				1.333	7.868	0.000
R^2			*0.19*			*0.33*

Note: Black-and-white TV: n=46 (36*), 23 countries. Cassette-radio players: n=111 (27*), 45 countries. CD players: n=42 (10*), 25 countries. *Observations deleted due to missingness. See Schemper and Stare (1996) for AFT model's R^2

In **table 3.6**, the first three columns display the results from the Cox proportional hazard model. Only the resulting model of time-to-dive for CD players shows some significant results. Holding all other covariates constant, each additional point of the level of masculinity in a country increases the hazard of dive of CD players by 2.2%. In other words, CD players dive earlier if the level of masculinity in a country is higher. This result is consistent with the result obtained with the AFT model. Holding all other covariates constant, each additional unit increase of the level of masculinity decreases expected time-to-dive by 0.8%. Three country characteristics display significant results for the AFT model of cassette-radio players: Gini index, individualism and time-to-takeoff of CD players. As hypothesized, countries with a shorter time-to-takeoff of the substituting technology present a shorter time-to-dive, and countries with higher levels of inequality present a longer time-to-dive. Each additional year of time-to-takeoff of CD players is associated with a 16.6% increase in the expected time-to-dive of cassette-radio players. And for each additional point of the Gini index, an increase of 3% on time-to-dive of cassette-radio players is expected. A higher level of individualism in a country is also associated with a longer time-to-dive of cassette-radio players (1.3% for every unit increase.). The level of penetration of CD players at the initial time of the discontinuance process is significant with a 10% confidence level. The shape parameter for the three products is greater than one, which reflects that the hazard of a dive increases with time.

Results from the pooled models are presented in **table 3.7**. A Cox proportional hazard model and an AFT model with a Weibull baseline distribution are fitted for the three products at the same time. Two types of regressions are fitted: including and excluding time-to-takeoff of the substituting technology. This decision is taken because time-to-takeoff of color television is only available for two countries. Using the Cox proportional hazard model, the estimate for masculinity remains positive and significant in both models, including and excluding time-to-takeoff. Using the AFT model, individualism and time-to-takeoff of the substituting technology are significant. Based on the model including time-to-takeoff, an additional unit increase of individualism, increases 0.7% expected time-to-dive of a product. Each additional year of time-to-takeoff of the substituting technology is associated with a 9.6% increase on the expected time-to-dive. Gini index is significant with a 10% confidence level, and each additional point on this index is associated with an increase of 2% of the expected time-to-dive.

A model fitted on every covariate on its own is presented in Appendix 1. Using a Cox proportional hazard model (see **table 3.8**), none of the covariates presents significant results for black-and-white television sets except for the level of penetration of color television sets with a 10% confidence level. For cassette-radio players, an increase on individualism, GDP per capita and the level of penetration of CD players is associated with an decrease of the hazard of a dive, significantly. Masculinity is positively associated with the hazard of a dive of CD players.

For black-and-white television sets, using an AFT model, an increase on the level of penetration of color television sets is strongly associated with a decrease of expected time-to-dive (see **table 3.9**). For cassette-radio players, uncertainty avoidance (–)[5], power distance (–), individualism (+), the level of penetration of CD players (+), GDP per capita (+) and percentage of rural population (–) present significant results (see **table 3.10**). For CD players, power distance and masculinity are negatively associated with expected time-to-dive, and the level of penetration of internet personal computers is positively associated with a 10% confidence level (see **table 3.11**).

A model fitted on every covariate is also applied to the pooled data sets with both methods. Gini index, masculinity, and percentage of rural population are significantly associated with an increased hazard of a dive using the Cox proportional hazard model. An increase on the level of penetration of a substituting technology and GDP per capita reduce the hazard of a dive. Individualism is positively associated with a 10% confidence level (see **table 3.12**).

By applying the AFT model to the pooled data set, an increase of Gini index, uncertainty avoidance and percentage of rural population are significantly associated with a decrease in the expected time-to-dive. On the other hand, higher levels of individualism, penetration level of the substituting technology and GDP per capita are significantly associated with an increase in the expected time-to-dive (see **table 3.13**).

For each product, a one-way permutation test is performed to test the relation between prior dives in leading countries and time-to-dive in lagged ones Hollander and Wolfe (1999). The difference of their means is found to have a 5% significance level for every product. However, for CD players the more prior dives in lead countries, the lower the hazard of a dive in a lagged country.

Figure 3.6 shows the relation between time-to-dive and time to reach categories of adopters and discontinuers. A weak relation is present between time-to-dive and the time needed to achieve levels of discontinuance and the relation between time-to-dive and levels of adoption of entrant technologies is not visible in **figure 3.6**. Time-to-dive has only three or four values because of rounding to years. That is why any association is difficult to discern.

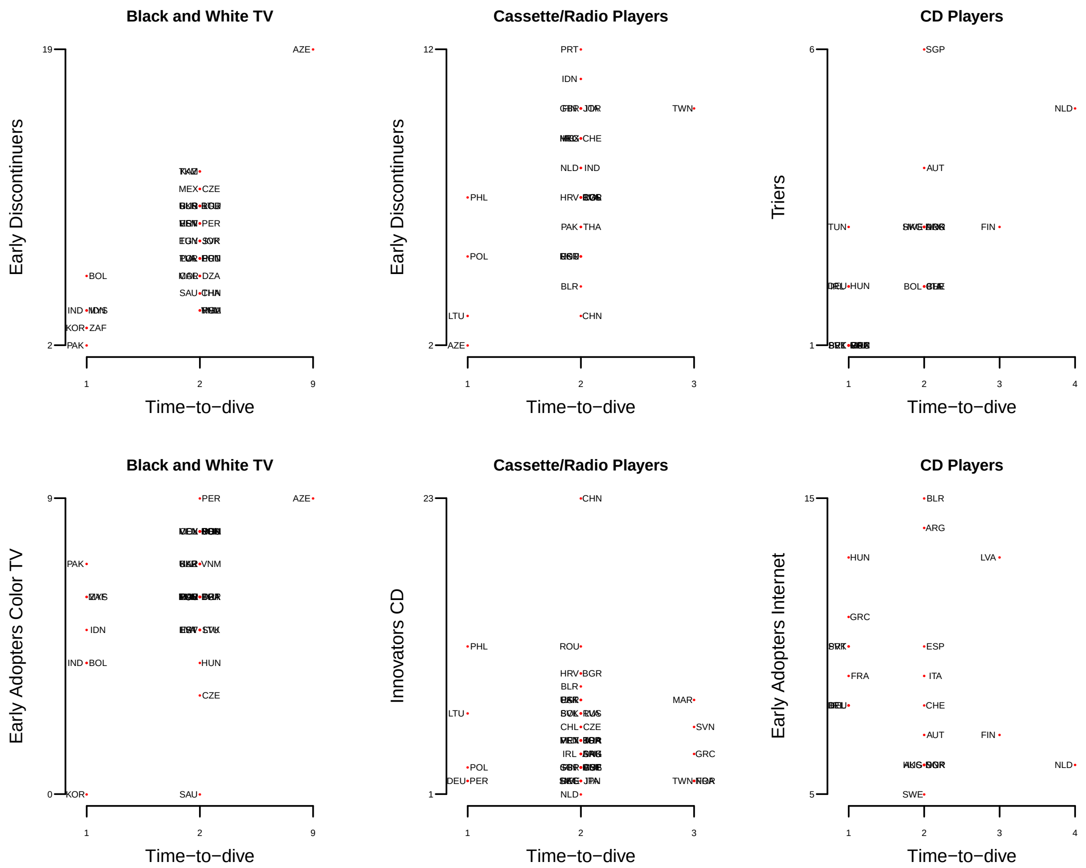
[5]The signs in the parentheses indicate the signs of the estimated coefficients.

Table 3.7: Pooled Hazard Model

	With takeoff			Without takeoff		
	β	t–statistic	p–value	β	t–statistic	p–value
Cox model						
Gini	–0.006	–0.276	0.782	0.001	0.087	0.931
UAI	0.001	0.262	0.793	–0.001	–0.214	0.830
PDI	0.002	0.312	0.755	0.003	0.635	0.525
MAS	0.010	2.728	0.006	0.010	3.431	0.001
IDV	–0.007	–1.454	0.146	–0.005	–0.926	0.355
Substitute	–0.009	–0.837	0.403	–0.003	–0.325	0.745
GDP	0.006	0.250	0.803	–0.002	–0.132	0.895
RURAL	–0.002	–0.214	0.830	0.005	0.860	0.390
Takeoff subst.	–0.045	–0.635	0.525			
R^2			*0.09*			*0.07*
AFT model						
Gini	0.020	1.933	0.053	0.007	0.940	0.347
UAI	–0.003	–0.739	0.460	–0.002	–0.690	0.490
PDI	–0.001	–0.406	0.684	–0.002	–0.790	0.429
MAS	–0.003	–1.159	0.246	–0.003	–1.480	0.139
IDV	0.007	2.656	0.008	0.007	2.484	0.013
Substitute	0.009	1.331	0.183	0.003	0.571	0.568
GDP	0.009	0.567	0.571	0.011	0.810	0.418
RURAL	0.004	0.744	0.457	–0.002	–0.548	0.584
Takeoff subst.	0.091	2.164	0.030			
Intercept	–1.787	–1.951	0.051	0.477	0.737	0.461
log(shape)	0.827	9.571	0.000	0 .894	9.900	0.000
R^2			*0.25*			*0.24*

Note: With takeoff: n=157 (115*), 47 countries. Without takeoff: n=213 (59*), 54 countries. *Observations deleted due to missingness.

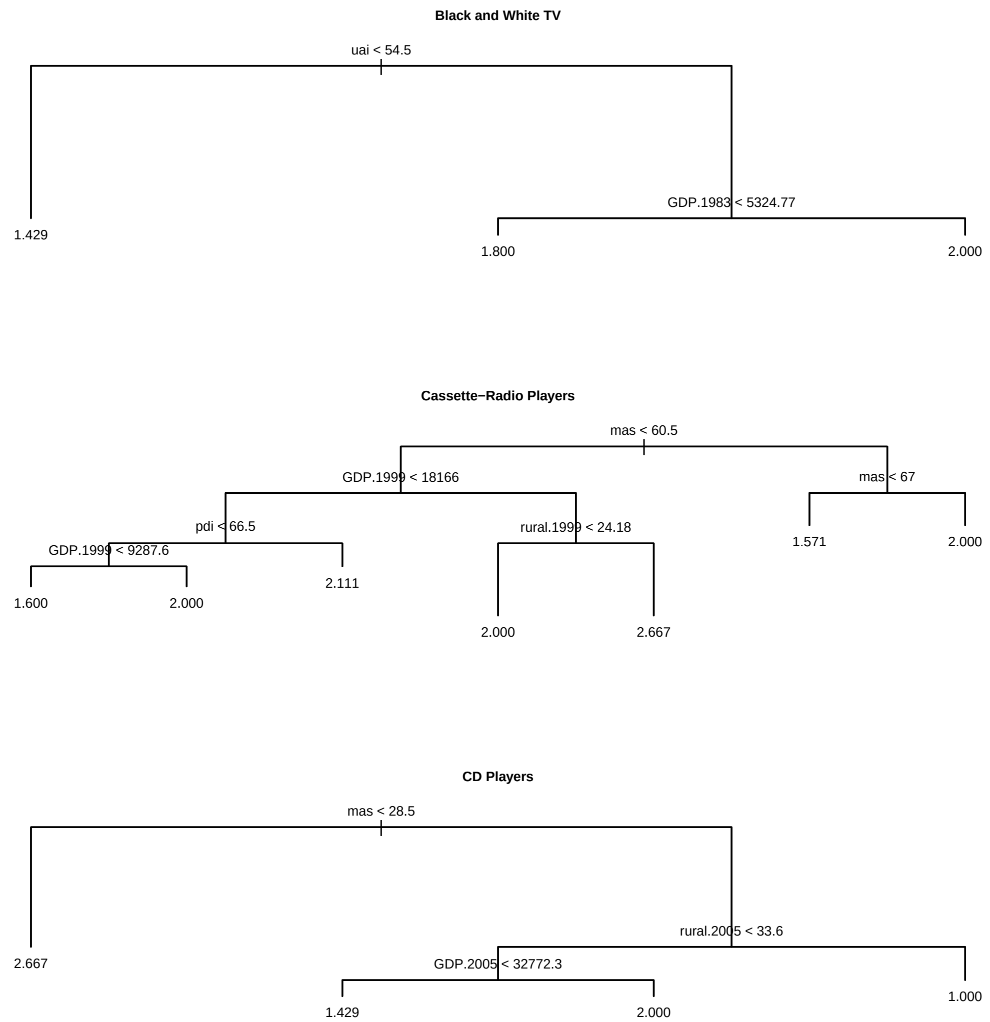
Figure 3.6: Time-to-Dive and Adopter and Discontinuer Categories.



Note: To avoid extreme overprinting, the acronyms of the countries are printed to the left or right of their value.

The previous analysis of time-to-dive is complemented with regression-tree analysis. **Figure 3.7** plots the results for the three products. The final model for black-and-white television contains 23 countries and the R^2 is 59.7%. For cassette-radio player, 46 countries are used and the R^2 is 68.7%. For CD players, 25 countries are used and the R^2 is 81.7%. The prediction shows that for a level of uncertainty avoidance lower than 54.5, time-to-dive of black-and-white television sets is expected to be faster (in only one year and a half). With a higher level of uncertainty avoidance, a new split based on GDP is found: for countries with GDP lower than \$5324.77, the prediction is 1.8 years, and for countries with a higher GDP the prediction is 2.0 years. For the cassette-radio players, masculinity is the covariate that splits the data better. Additional explanatory variables affecting time-to-dive are GDP, the percentage of rural population, and power distance. For CD players, masculinity is also found to be the best split. For a low masculinity level (<28.5), the predicted time-to-dive is slightly above two and a half years (2.67 years). However, with higher levels of masculinity, the average time-to-dive is significantly lower and further splits are found based on GDP and rural population (see **figure 3.7**).

Figure 3.7: Regression Trees



Note: GDP per capita at PPP is calculated at the median of the time period studied for every product.

Regarding incoming technologies, the average time-to-takeoff is 3.02, 8.33, and 4.14 years for CD players, color television sets, and internet, respectively. In contrast, the average time-to-dive for discontinuing technologies is significantly lower, approaching two years for the three products

(Black-and-white television sets: 2.00 years; Cassette-radio player: 2.00 years; CD players: 1.72 years). These values show that dive of discontinuing technologies occurs faster than takeoff of the corresponding innovations. This is a robust result present in all the three processes studied. Several managerial implications derived from these technological substitution patterns are explained in the next section.

3.5 Discussion

Time-to-dive has been a neglected topic in the marketing literature. Marketing managers could make bad decisions if findings related to time-to-takeoff were uncritically adapted to time-to-dive. Our results show that time-to-dive and time-to-takeoff present different dynamics but also share some characteristics. Time-to-dive is an event on its own, and special care needs to be taken when confronted with an early discontinuance process. The *hidden incubation period* enables us to understand this asymmetry between these two turning points: dive for the old technology and takeoff for the new one.

Kohli et al. (1999) defines the incubation period as the time between the completion of product development and introduction in the market and the beginning of substantial sales of the product. The incubation period of most radical innovations is several years, characterized by small penetration levels. The introduction of a substitute technology often overlaps with the diffusion of the older technology (Norton and Bass 1987). When this happens, both technologies have increasing adoption levels during the first years of the substitution process, *hiding* the incubation period until penetration rates become negative. During the hidden incubation period the older technology may still have a high number of adoptions even though adopters of a new technology are already discontinuing it. If companies are not aware of this early discontinuance process, their exit strategies may fail (Harrigan 1980). Dive appears more suddenly than takeoff. Knowing how old technologies will be discontinued is paramount to fully understand how the market will react to a new technology (Shocker et al. 2004). For instance, resistance to adopt innovations might be created by the discontinuance process of a particular product (Garcia et al. 2007). Related literature on strategies for the declining stage of a product shows that managers have a *pro-innovation bias* and focus more on product development strategies than on exit strategies (Kotler 1965, Carlotti et al. 2004, Varadarajan et al. 2006).

During the period of overlapping technologies, in which some consumers migrate from one technology to another, firms should provide the market with alternative options (John et al. 1999). For instance, a large quantity of products may suddenly be disposed by households which do not find them useful anymore and after-sales services may require new plans to deal with demand. This event can generate opportunities, such as second-hand markets for segments that still find these products useful. Since dive occurs faster than takeoff, public policy makers and companies should react faster after a new product is introduced in the market. Firms that react only when the discontinuance process reduces the levels of penetration may be missing out on new opportunities. The dynamics of dive illustrate the relevance of monitoring both processes. For color television sets, the early adopters stage, 16% of the market, is reached on average four years before dive of black-and-white television occurs, and for cassette-radio players the early adopters stage is reached on average nine years earlier.

Part of the hypothesis based on previous research of diffusion of innovations are confirmed by our results. Cultural dimensions of countries are associated with time-to-dive which confirms hypothesis 6 (see **tables 3.6–3.13**). Uncertainty avoidance, power distance and masculinity are associated with a decrease of time-to-dive, and individualism is associated with an increase of time-to-dive. And as hypothesized, time-to-takeoff is positively related to time-to-dive (see **tables 3.6** and **3.7**).

Nonetheless, many limitations have been encountered that affect the validity of these results. The three analyzed products belong to different stages of discontinuance. This causes covariates to have a distinct relation to dive. In the period studied, only data for countries that are late discontinuers is available for black-and-white television sets, and they tend to have low GDP levels. The largest sample of countries is for cassette-radio players, which includes countries at all the stages of the global rate of discontinuance. Early discontinuers compose the sample of countries for CD players. Also, time-to-dive may require a totally new theoretical framework. That is, time-to-dive and time-to-takeoff may not share the same assumptions. For instance, the discontinuance and the adoption process share the characteristic of adopting and discontinuing innovations earlier or later depending on their wealth (see **table 3.5**). In contrast, time-to-takeoff is shorter in richer countries but a reduced hazard of a dive is associated to GDP per capita for cassette-radio players in **table 3.8** and **3.12**, and a longer time-to-dive in **tables 3.10** and **3.13**. An increase on the percentage of rural population, hypothesized to be related to longer time-to-dive periods (see hypothesis 3), is positively associated with a hazard of a dive and negatively associated with the expected time-to-dive (see **tables 3.10, 3.12** and **3.13**). Gini index is positively associated to time-to-dive in **tables 3.6** and **3.7**, and negatively associated in **tables 3.12** and **3.13**. The level of penetration of a substituting technology is hypothesized to reduce time-to-dive. This is the case for color television sets and time-to-dive of black-and-white television sets (see **table 3.9**). However, in the model fitted on a single covariate for cassette-radio players (see **table 3.8** and **3.10**) and the pooled regressions presented in **tables 3.12** and **3.13**, an increase in the level of penetrations of a substitute technology is significantly associated with a decrease in the hazard of a dive and an increase in the expected time-to-dive. This is a counterintuitive result and contradicts hypothesis 7, but a substituting technology could act as a complementary technology in the early phases of its introduction in the market. For instance, CD players and cassette-radio players were sold in one single product and CDs can be used to store information downloaded from a personal computer, such as music, that can later be listened in a CD player.

The relation of time-to-dive with the amount of prior dives in foreign countries is not clear, although in the case of CD players it is positively related (see **figure 3.5**), contrary to what was hypothesized based on the conclusion from previous time-to-takeoff research. Also, there is only a weak relation between countries with a shorter time-to-dive reaching newer levels of discontinuance earlier (see **figure 3.6**).

These results bring us directly to the conclusion that a greater effort is needed to fully understand the dynamics of time-to-dive and to the limitations of this study. A longer period of time, and a more detailed data set could be helpful to understand processes related to turning points of the life-cycle of a product. For instance, no information is available on current incentives to adopt a new product, like the price of the innovation compared to the old technology's maintenance costs. The data are too coarse, one year is too long a period of time for capturing fast-paced changes in the market. Therefore, a better data set with a larger sample of products and observations, without interval-censored values, would allow for a better interpretation of the model. Yearly data hides seasons of the years and monthly data could provide valuable information. Furthermore, in our sample time-to-dive occurs very often in two years, and possible relations with other covariates are more difficult to identify.

Another limitation is the type of measure used to calculate time-to-dive. Time-to-dive could have different characteristics than time-to-takeoff. A measure which is practically the same, except for being inverted, could be inappropriate and give unreliable estimates of time-to-dive. In this case, the conclusions about the relations with other covariates could be biased. Although we have visually inspected the rates of discontinuance, and compared the results of the estimation based on Tellis et al. (2003) with their own prediction, no formal visual inspection tests with independent subjects have been performed.

Several extensions of this article would provide fruitful avenues for future researches to overcome current limitations. To cite a few, investigating the effects of network externalities on the rate of discontinuance would allow to learn how time-to-dive and a hidden incubation period may be affected by social interactions. Second, an appropriate estimation method to predict when time-to-dive occurs combining information on different factors may be explored, such as internal and external influences in the market, or incorporating penetration levels of innovations. Third, time-to-dive processes for products characterized by different patterns of decline can also inform about this neglected event. Fourth, price of the products can create different patterns of disposal that affect the rate of discontinuance. Fifth, distinct life-cycle of products may offer interesting patterns of discontinuance.

Time-to-dive of a product and the dynamics of the rate of discontinuance are becoming more important for marketers because of a rapid rate of technological change (Sood and Tellis 2005). Limitations of this article can be overcome by new data sets that capture the full life-cycle of a product and relate pre-adoption, adoption and discontinuance of a technology, its costs and revenue strategies, its benefits and threats, and the study of the slowdown of a discontinuance, called *landing*, provides opportunities of research in the future. Marketers who overcome pro-innovation bias will be able to understand the full dynamics of the diffusion process.

Appendix 1: Separate Analysis for each Country Characteristic

Table 3.8: Cox Proportional Hazard Model

	β	e^{β}	S.E.(β)	t–statistic	p–value	R^2
Black-and-white TV						
Gini	0.017	1.017	0.022	0.759	0.448	0.016
UAI	–0.008	0.992	0.009	–0.873	0.383	0.025
PDI	0.000	1.000	0.011	0.042	0.967	0.000
MAS	0.001	1.001	0.008	0.121	0.904	0.001
IDV	–0.003	0.997	0.010	–0.308	0.758	0.003
TV	1.889	6.610	1.037	1.821	0.069	0.066
GDP	–0.004	0.996	0.024	–0.175	0.861	0.000
Rural	0.009	1.009	0.012	0.771	0.441	0.007
Cassette-radio player						
Gini	0.016	1.016	0.017	0.901	0.368	0.014
UAI	0.002	1.002	0.006	0.298	0.766	0.002
PDI	0.011	1.011	0.007	1.580	0.114	0.050
MAS	0.002	1.002	0.007	0.213	0.831	0.001
IDV	–0.013	0.987	0.006	–2.072	0.038	0.086
CD Players	–1.234	0.291	0.561	–2.200	0.028	0.089
GDP	–0.027	0.973	0.013	–2.118	0.034	0.034
Rural	0.008	1.008	0.008	0.986	0.324	0.007
Takeoff CD players	0.005	1.005	0.084	0.056	0.955	0.000
CD player						
Gini	0.021	1.022	0.021	1.015	0.310	0.032
UAI	0.010	1.010	0.010	1.070	0.284	0.045
PDI	0.017	1.017	0.011	1.520	0.129	0.084
MAS	0.025	1.025	0.009	2.745	0.006	0.262
IDV	–0.006	0.994	0.010	–0.609	0.542	0.014
Internet	–0.988	0.372	0.859	–1.151	0.250	0.044
GDP	–0.021	0.979	0.023	–0.936	0.349	0.017
Rural	0.013	1.013	0.015	0.863	0.388	0.015
Takeoff Internet	0.092	1.096	0.096	0.959	0.337	0.031

Note: Black-and-white TV: 41 countries. Cassette-radio players: 57 countries. CD players: 30 countries.

Table 3.9: AFT Model for Black-and-White Television Sets

	β	e^{β}	S.E.(β)	t–statistic	p–value	R^2
Gini	–0.016	0.984	0.013	–1.237	0.216	
Intercept	1.454	4.280	0.512	2.840	0.005	
log(shape)	0.606	1.833	0.105	5.781	0.000	0.040
UAI	0.001	1.001	0.001	0.982	0.326	
Intercept	0.570	1.768	0.100	5.713	0.000	
log(shape)	1.954	7.057	0.181	10.799	0.000	0.033
PDI	0.000	1.000	0.002	–0.048	0.962	
Intercept	0.666	1.946	0.114	5.856	0.000	
log(shape)	1.952	7.043	0.181	10.754	0.000	0.000
MAS	0.000	1.000	0.001	–0.125	0.900	
Intercept	0.668	1.950	0.066	10.111	0.000	
log(shape)	1.952	7.043	0.181	10.754	0.000	0.001
IDV	0.000	1.000	0.001	0.353	0.724	
Intercept	0.643	1.902	0.056	11.406	0.000	
log(shape)	1.952	7.043	0.181	10.761	0.000	0.004
Color TV	–1.480	0.228	0.420	–3.521	0.000	
Intercept	1.014	2.757	0.098	10.335	0.000	
log(shape)	0.734	2.083	0.096	7.608	0.000	0.175
GDP	–0.010	0.990	0.011	–0.877	0.381	
Intercept	0.885	2.423	0.123	7.213	0.000	
log(shape)	0.618	1.855	0.099	6.213	0.000	0.009
Rural	–0.003	0.997	0.008	–0.419	0.676	
Intercept	0.961	2.614	0.362	2.650	0.008	
log(shape)	0.622	1.863	0.092	6.736	0.000	0.002

Table 3.10: AFT Model for Cassette/Radio Players

	β	e^{β}	S.E.(β)	t–statistic	p–value	R^2
Gini	–0.014	0.986	0.013	–1.109	0.267	
Intercept	1.531	4.623	0.470	3.258	0.001	
log(shape)	0.396	1.486	0.091	4.325	0.000	0.020
UAI	–0.010	0.990	0.004	–2.310	0.021	
Intercept	1.729	5.635	0.308	5.619	0.000	
log(shape)	0.436	1.547	0.104	4.198	0.000	0.090
PDI	–0.016	0.984	0.004	–4.390	0.000	
Intercept	1.976	7.214	0.233	8.478	0.000	
log(shape)	0.557	1.745	0.107	5.200	0.000	0.244
MAS	0.005	1.005	0.006	0.938	0.348	
Intercept	0.803	2.232	0.283	2.833	0.005	
log(shape)	0.373	1.452	0.099	3.769	0.000	0.017
IDV	0.017	1.017	0.003	5.952	0.000	
Intercept	0.226	1.254	0.176	1.288	0.198	
log(shape)	0.684	1.982	0.113	6.054	0.000	0.368
CD players	1.584	4.874	0.280	5.647	0.000	
Intercept	0.573	1.774	0.111	5.180	0.000	
log(shape)	0.697	2.008	0.102	6.818	0.000	0.348
GDP	0.033	1.034	0.007	5.054	0.000	
Intercept	0.459	1.582	0.137	3.337	0.001	
log(shape)	0.629	1.876	0.101	6.203	0.000	0.129
Rural	–0.015	0.985	0.005	–3.290	0.001	
Intercept	1.498	4.473	0.171	8.734	0.000	
log(shape)	0.495	1.640	0.095	5.202	0.000	0.060
Takeoff CD players	0.027	1.027	0.060	0.458	0.647	
Intercept	0.987	2.683	0.208	4.734	0.000	
log(shape)	0.377	1.458	0.098	3.851	0.000	0.004

Table 3.11: AFT Model for CD Players

	β	e^{β}	S.E.(β)	t–statistic	p–value	R^2
Gini	–0.010	0.990	0.008	–1.267	0.205	
Intercept	1.041	2.832	0.295	3.532	0.000	
log(shape)	0.947	2.578	0.138	6.839	0.000	0.046
UAI	–0.007	0.993	0.004	–1.595	0.111	
Intercept	1.095	2.989	0.274	3.990	0.000	
log(shape)	0.921	2.512	0.148	6.221	0.000	0.091
PDI	–0.010	0.990	0.004	–2.510	0.012	
Intercept	1.178	3.248	0.217	5.437	0.000	
log(shape)	0.989	2.689	0.151	6.532	0.000	0.175
MAS	–0.010	0.990	0.002	–4.344	0.000	
Intercept	1.147	3.149	0.141	8.164	0.000	
log(shape)	1.172	3.228	0.158	7.427	0.000	0.395
IDV	0.006	1.006	0.004	1.455	0.146	
Intercept	0.359	1.432	0.238	1.509	0.131	
log(shape)	0.935	2.547	0.155	6.046	0.000	0.067
Internet	0.561	1.752	0.311	1.807	0.071	
Intercept	0.491	1.634	0.131	3.739	0.000	
log(shape)	0.977	2.656	0.139	7.045	0.000	0.097
GDP	0.011	1.011	0.009	1.236	0.217	
Intercept	0.502	1.652	0.165	3.040	0.002	
log(shape)	0.955	2.599	0.139	6.848	0.000	0.027
Rural	–0.004	0.996	0.006	–0.712	0.476	
Intercept	0.815	2.259	0.204	3.992	0.000	
log(shape)	0.917	2.502	0.135	6.778	0.000	0.010
Takeoff Internet	–0.049	0.952	0.035	–1.389	0.165	
Intercept	0.879	2.408	0.158	5.569	0.000	
log(shape)	0.942	2.565	0.142	6.651	0.000	0.062

Table 3.12: Cox Proportional Model for Pooled Data

	β	e^{β}	S.E.(β)	t–statistic	p–value	R^2
Gini	0.019	1.019	0.007	2.744	0.006	0.047
UAI	0.003	1.003	0.003	0.997	0.319	0.049
PDI	0.000	1.000	0.000	–0.381	0.703	0.033
MAS	0.010	1.010	0.003	3.612	0.000	0.084
IDV	–0.008	0.992	0.004	–1.807	0.071	0.053
Substitute	–0.816	0.442	0.376	–2.168	0.030	0.059
GDP	–0.020	0.980	0.008	–2.599	0.009	0.028
Rural	0.009	1.009	0.004	2.190	0.029	0.021
Takeoff subst.	0.057	1.059	0.048	1.202	0.229	0.068

Table 3.13: AFT Model for Pooled Data

	β	e^{β}	S.E.(β)	t–statistic	p–value	R^2
Gini	–0.013	0.987	0.005	–2.783	0.005	
Intercept	1.341	3.822	0.272	4.929	0.000	
log(shape)	–0.540	0.583	0.100	–5.379	0.000	0.106
UAI	–0.007	0.993	0.003	–2.699	0.007	
Intercept	0.887	2.428	0.120	7.392	0.000	
log(shape)	–0.652	0.521	0.093	–7.002	0.000	0.213
PDI	0.000	1.000	0.000	–0.923	0.356	
Intercept	0.864	2.373	0.212	4.072	0.000	
log(shape)	–0.522	0.593	0.099	–5.292	0.000	0.095
MAS	–0.002	0.998	0.002	–1.109	0.268	
Intercept	0.765	2.150	0.152	5.023	0.000	
log(shape)	–0.602	0.548	0.101	–5.964	0.000	0.163
IDV	0.011	1.011	0.003	3.820	0.000	
Intercept	0.308	1.361	0.192	1.604	0.109	
log(shape)	–0.640	0.527	0.106	–6.063	0.000	0.231
Substitute	0.946	2.576	0.324	2.924	0.003	
Intercept	0.739	2.093	0.161	4.598	0.000	
log(shape)	–0.620	0.538	0.113	–5.488	0.000	0.197
GDP	0.023	1.023	0.008	3.048	0.002	
Intercept	0.244	1.276	0.0146	1.674	0.094	
log(shape)	0.625	1.868	0.106	5.903	0.000	0.096
Rural	–0.012	0.988	0.004	–3.276	0.001	
Intercept	1.017	2.765	0.147	6.893	0.000	
log(shape)	0.595	1.813	0.148	5.773	0.000	0.075
Takeoff subst.	–0.013	0.987	0.046	–0.284	0.776	
Intercept	0.420	1.522	0.396	1.060	0.289	
log(shape)	–0.505	0.603	0.115	–4.388	0.000	0.128

Bibliography

Agarwal, R. and Bayus, B.: 2002, The market evolution and sales takeoff of product innovations, *Management Science* **48**(8), 1024–1041.

Albuquerque, P., Bronnenberg, B. J. and Corbett, C. J.: 2007, A spatiotemporal analysis of the global diffusion of ISO 9000 and ISO 14000 certification, *Management Science* **53**(3), 451–468.

Alexander, C., Smaje, C., Timlet, R. and Williams, I.: 2009, Improving social technologies for recycling, *Waste and Resource Management* **162**, 15–28.

Andonova, V.: 2006, Mobile phones, the internet and the institutional environment, *Telecommunications Policy* **30**(1), 29–45.

Andonova, V. and Ladrón-De-Guevara, A.: 2011, Internet interacted: 1991-2003, *Management Research: The Journal of the Iberoamerican Academy of Management (Forthcoming)* .

Antonides, G.: 1989, *The lifetime of a durable good: An economic psychological approach*, Kluwer Academics Publishers, Dordrecht, The Netherlands.

Antonides, G.: 1991, An economic psychologial model of scrapping behavior, *Journal of Economic Psychology* **12**(2), 357–379.

Arnold, D. and Quelch, J.: 1998, New strategies in emerging markets, *Sloan Management Review* **40**(1), 7–20.

Atasu, A., Sarvary, M. and Van Wassenhove, L. N.: 2008, Remanufacturing as a marketing strategy, *Management Science* **54**(10), 1731–1746.

Athiyaman, A.: 2008, An exploration into modeling sustainable consumption: The case of animal-based traditional medicines, *Australasian Journal of Business and Behavioural Sciences* **3**, 16–23.

Baker, S. M., Hunt, D. M. and Rittenburg, T. L.: 2007, Consumer vulnerability as a shared experience: Tornado recovery process in Wright, Wyoming, *Journal of Public Policy & Marketing* **26**(1), 6–19.

Baliamoune-Lutz, M.: 2003, An analysis of the determinants and effects of ICT diffusion in developing countries, *Information Technology for Development* **10**(3), 151–169.

Banerjee, A. and Ros, A.: 2004, Patterns in global fixed and mobile telecommunications development: a cluster analysis, *Telecommunications Policy* **28**(2), 107–132.

Barro, R. and Sala-i Martin, X.: 2004, *Economic Growth, 2nd ed*, MIT-Press.

Bass, F.: 1969, A new product growth for model consumer durables, *Management Science* **15**, 215–227.

Bayus, B. and Carlstrom, C.: 1990, Grouping durable goods, *Applied Economics* **22**(6), 759–774.

Bayus, B. L.: 1988, Accelerating the durable replacement cycle with marketing mix variables, *Journal of Product Innovation Management* **5**(3), 216–226.

Bayus, B. L.: 1991, The consumer durable replacement buyer, *Journal of Marketing* **55**(1), 42–51.

Beise, M.: 2004, Lead markets: Country-specific drivers of the global diffusion of innovations, *Research Policy* **33**(6-7), 997–1018.

Belk, R.: 2007, Why not share rather than own?, *Annals of The American Academy of Political And Social Science* **611**, 126–140.

Berger, J. and Le Mens, G.: 2009, How adoption speed affects the abandonment of cultural tastes, *Proceedings of the National Academy of Sciences* **106**(20), 8146–8150.

Black, W.: 1983, Discontinuance and diffusion: Examination of the post-adoption decision process, *Advances in Consumer Research* **10**, 356–361.

Box, J.: 1983, Extending product lifetime: Prospects and opportunities, *European Journal of Marketing* **17**(4), 34–49.

Boyd, T. C. and McConocha, D. M.: 1996, Consumer household materials and logistics management: Inventory ownership cycle, *Journal of Consumer Affairs* **30**(1), 218–249.

Bradford, T. W.: 2009, Intergenerationally gifted asset dispositions, *Journal of Consumer Research* **36**(1), 93–111.

Brown, B.: 2004, Thing theory, *Critical Inquiry* **28**(1), 1–22.

Burgess, S. and Steenkamp, J.: 2006, Marketing renaissance: How research in emerging markets advances marketing science and practice, *International Journal of Research in Marketing* **23**(4), 337–356.

Burke, M., Conn, W. and Lutz, R.: 1978, Using psychographic variables to investigate product disposition behaviors, *American Marketing Association Proceedings, Educators Conference* pp. 321–326.

Carlotti, S., Coe, M. and Perry, J.: 2004, Making brand portfolios work, *McKinsey Quarterly* **4**, 24–36.

Carrigan, M., Marinova, S. and Szmigin, I.: 2005, Ethics and international marketing: Research background and challenges, *International Marketing Review* **22**(5), 481–493.

CEC: 2003, Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on Waste Electrical and Electronic Equipment (WEEE)., *Official Journal* **37**, 24–38.

Chandrasekaran, D. and Tellis, G. J.: 2007, A critical review of marketing research on diffusion of new products, *Naresh K. Malhotra, Review of Marketing Research*, Vol. 3, Armonk: M.E. Sharpe, pp. 39–80.

Chandrasekaran, D. and Tellis, G. J.: 2008, Global takeoff of new products: Culture, wealth, or vanishing differences, *Marketing Science* **27**(5), 844–860.

Chircu, A. and Mahajan, V.: 2009, PERSPECTIVE: Revisiting the digital divide: An analysis of mobile technology depth and service breadth in the BRIC countries, *Journal of Product Innovation Management* **26**(4), 455–466.

Chu, H. and Liao, S.: 2007, Exploring consumer resale behavior in C2C online auctions, *Academy of Marketing Science Review* **11**(3), 1–25.

Conn, W. D. and Warren, E. C.: 1979, Developing a tentative model of disposal decisions, *Journal of Environmental Systems* **9**(2), 129–144.

Cooper, T.: 2000, WEEE, WEEE, WEEE, WEEE all the way home? An evaluation of proposed electrical and electronic waste legislation, *European Environment* **10**(3), 121–130.

Cooper, T.: 2003, Durable consumption: Reflections on product life cycles and the throwaway society, *Product Life and the Throwaway Society*, Centre for Sustainable Consumption, Sheffield Hallam University.

Cooper, T.: 2004, Inadequate life? Evidence of consumer attitudes to product obsolensce, *Journal of Consumer Policy* **27**(4), 421–449.

Cooper, T.: 2005, Slower consumption - Reflections on product life spans and the "throwaway society", *Journal of Industrial Ecology* **9**(1-2), 51–67.

Cooper, T. and Mayers, K.: 2000, *Prospects for houses appliances (E-Scope: Electronics Industry - Social Considerations of Product End-of-Life project)*.

Coulter, R. A. and Ligas, M.: 2003, To retain or to relinquish: Exploring the disposition practices of packrats and purgers, *Advances in Consumer Research, Vol 30* **30**, 38–43.

Cox, D.: 1972, Regression models and life-tables, *Journal of the Royal Statistical Society. Series B (Methodological)* **34**(2), 187–220.

Cox, D. and Oakes, D.: 1984, *Analysis of Survival Data*, New York: Chapman and Hall.

Crane, D. and Crane, D.: 2006, *Dictionary of aeronautical terms*, Aviation Supplies & Academics.

Curasi, C. F.: 1999, In hope of an enduring gift: The intergenerational transfer of cherished possessions; a special case of gift giving, *Advances in Consumer Research* **26**, 125–132.

Currim, I., Meyer, R. and Le, N.: 1988, Disaggregate tree-structured modeling of consumer choice data, *Journal of Marketing Research* **25**(3), 253–265.

Czinkota, M. R. and Ronkainen, I.: 2003, An international marketing manifesto, *Journal of International Marketing* **11**(1), 13–27.

Darby, L. and Obara, L.: 2005, Household recycling behaviour and attitudes towards the disposal of small electrical and electronic equipment, *Resources, Conservation and Recycling* **44**(1), 17–35.

Day, G.: 1981, The product life cycle: Analysis and alpplications issues, *Journal of Marketing* **45**(4), 60–67.

DeBell, M. and Dardis, R.: 1979, Extending product life cycle: Technlogy isn't the only issue, *Advances in Consumer Research* **6**, 381–385.

DeFleur, M.: 1966, Mass communication and social changes, *Social Forces* **44**(3), 314–326.

Dekimpe, M. G., Parker, P. M. and Sarvary, M.: 1998, Forecasting the diffusion pattern of cellular telecommunications on the country-level using a staged estimation approach, *Technological Forecasting and Social Change* **57**, 105–132.

Dekimpe, M. G., Parker, P. M. and Sarvary, M.: 2000a, Global diffusion of technological innovations: A coupled hazard approach, *Journal of Marketing Research* **37**(1), 47–59.

Dekimpe, M. G., Parker, P. M. and Sarvary, M.: 2000b, Globalization modelling technology adoption timing across countries, *Technological Forecasting and Social Change* **63**, 25–42.

DeLorme, D. E., Zinkhan, G. M. and Hagen, S. C.: 2005, The process of consumer reactions to possession threats and losses in a natural disaster, *Marketing Letters* **15**(4), 185–199.

Desiraju, R., Nair, H. and Chintagunta, P.: 2004, Diffusion of new pharmaceutical drugs in developing and developed nations., *Journal of Research in Marketing* **21**(4), 341–357.

Dholakia, N., Dholakia, R., Lehrer, M. and Kshetri, N.: 2004, *Wireless Communications and Mobile Commerce*, Igi Global, chapter Global heterogeneity in the emerging m-commerce landscape, pp. 1–22.

Dray, S.: 2011, Analyzing spatial multivariate structures, *Correspondence Analysis and Related Methods - CARME*, Agrocampus Ouest, Rennes FRANCE, p. 74.

Durning, A.: 1994, *How Much Is Enough?*, Worldwatch Institute.

Dwyer, S., Mesak, H. and Hsu, M.: 2005, An exploratory examination of the influence of national culture on cross-national product diffusion, *Journal of International Marketing* **13**(2), 1–27.

Ekerdt, D. J.: 2008, *Consumption and Generation Change*, Transaction Publishers, New Brunswick and London, chapter Dispossession: The tenacity of things, pp. 63–78.

Ekerdt, D. J. and Sergeant, J. F.: 2006, Family things: Attending the household disbandment of older adults, *Journal of Aging Studies* **20**(3), 193–205.

Elberse, A. and Eliashberg, J.: 2003, Demand and supply dynamics for sequentially released products in international markets: The case of motion pictures., *Marketing Science* **22**, 329–354.

Erlich, C.: 1990, *The Piano: A History*, Oxford University Press, USA; Revised edition.

Fernandez, K.: 2001, Observable and unobservable determinants of replacement of home appliances, *Energy Economics* **23**(3), 305–323.

Fleischmann, M., Bloemhof-Ruwaard, J. M., Dekker, R., van der Laan, E., Van Nunen, J. E. and Van Wassenhove, L.: 1997, Quantitative models for reverse logistics: A review, *European Journal of Operational Research* **103**(1), 1–7.

Ganesh, J. and Kumar, V.: 1996, Capturing the cross-national learning effect: An analysis of an industrial technology diffusion, *Journal of the Academy of Marketing Science* **24**(4), 328–337.

Ganesh, J., Kumar, V. and Subramanian, V.: 1997, Learning effect in multinational diffusion of cuonsumer durables: An exploratory investigation, *Journal of the Academy of Marketing Science* **25**(4), 214–228.

Garber, T., Goldenberg, J., Libai, B. and Muller, E.: 2004, From density to destiny: Using spatial dimension of sales data for early prediction of new product success, *Marketing Science* **23**, 419–428.

Garcia, R., Bardhi, F. and Friedrich, C.: 2007, Overcoming consumer resistance to innovation, *MIT Sloan management review* **48**(4), 82–88.

Gatignon, H., Eliasberg, J. and Robertson, T. S.: 1989, Modelling multinational diffusion patterns: An efficient methodology, *Marketing Science* **8**(3), 231–247.

Ghareeb, E.: 2000, New media and the information revolution in the arab world, *Middle East Journal* **54**(3), 402 – 409.

Gielens, K. and Steenkamp, J.-B. E.: 2007, Drivers of consumer acceptance of new packaged goods: An investigation across products and countries, *International Journal of Research in Marketing* **24**(2), 97–111.

Glassmeyer, S. I., Hinchey, E. K., Boehme, S. E., Daughton, C. G., Ruhoy, I. S., Conerly, O., Daniels, R. L., Lauer, L., McCarthy, M., Nettesheim, T. G., Sykes, K. and Thompson, V. G.: 2009, Disposal practices for unwanted residential medications in the united states, *Environment International* **35**(3), 566–572.

Godley, A.: 2001, The global diffusion of the sewing machine, 1850-1914, *Research in Economic History* **20**, 1–46.

Goldenberg, J., Libai, B. and Muller, E.: 2001, Using complex systems analysis to advance marketing theory development: Modeling heterogeneity effects on new product growth through stochastic cellular automata, *Academy of Marketing Science Review* **9**(3), 1–18.

Golder, P. N. and Tellis, G.: 1997, Will it ever fly? Modelling the takeoff of really new consumer durables., *Marketing Science* **16**(3), 256–270.

Golder, P. and Tellis, G.: 2004, Growing, growing, gone: Cascades, diffusion, and turning points in the product life cycle, *Marketing Science* **23**(2), 207–218.

Green, R., Mandhachitara, R. and Smith, T.: 2001, Macroeconomic shock and product disposition in an emerging market, *Journal of Macromarketing* **21**(1), 47–60.

Greenacre, M. .: 2010, *Biplots in Practice.*, Madrid: BBVA Foundation.

Gregson, N., Metcalfe, A. and Crewe, L.: 2007, Identity, mobility, and the throwaway society, *Environment and Planning D-Society & Space* **25**(4), 682–700.

Grewal, R., Mehta, R. and Kardes, F.: 2004, The timing of repeat purchases of consumer durable goods: The role of functional bases of consumer attitudes, *Journal of Marketing Research* **41**(1), 101–115.

Gunter, M.: 2007, Do economists reach a conclusion on household and municipal recycling., *Econ Journal Watch* **4**(1), 83–111.

Guo, L.: 2008, PERSPECTIVE: An analysis of 22 years of research in JPIM, *Journal of Product Innovation Management* **25**(3), 249–260.

Hanson, J. W.: 1980, A proposed paradigm for consumer product disposition processes, *Journal of Consumer Affairs* **14**(1), 49–67.

Harrell, G. D. and McConocha, D. M.: 1992, Personal factors related to consumer product disposal tendencies, *Journal of Consumer Affairs* **26**(2), 397–417.

Harrell, S. G. and Taylor, E.: 1981, Modelling the product life cycle for consumer durables, *Journal of Marketing* **45**, 68–75.

Harrigan, K.: 1980, The effect of exit barriers upon strategic flexibility, *Strategic Management Journal* **1**(2), 165–176.

Helsen, K., Jedidi, K. and DeSarbo, W. S.: 1993, A new approach to country segmentation utilizing multinational diffusion patterns, *Journal of Marketing* **57**(4), 50–71.

Herrmann, G.: 1996, Women's exchange in the U.S. garage sale: Giving gifts and creating community, *Gender and Society* **10**(6), 703–728.

Herrmann, G. and Soiffer, M.: 1984, For fun and profit: An analyisis of the American garage sale, *Urban Life* **12**(4), 397–421.

Hetherington, K.: 2004, Secondhandedness: Consumption, disposal, and absent presence, *Environment and Planning D-Society & Space* **22**(1), 157–173.

Hibbert, S. A., Horne, S. and Tagg, S.: 2005, Charity retailers in competition for merchandise: Examining how consumers dispose of used goods, *Journal of Business Research* **58**(6), 819–828.

Hicks, C., Dietmar, R. and Eugster, M.: 2005, The recycling and disposal of electrical and electronic waste in China - Legislative and market responses, *Environmental Impact Assessment Review* **25**(5), 459–471.

Hofstede, G.: 2001, *Culture's Consequences, Comparing Values, Behaviors, Institutions, and Organizations Across Nations*, Sage Publications.

Hogan, J. E., Lemon, K. N. and Libai, B.: 2003, What is the true value of a lost customer?, *Journal of Service Research* **5**(3), 196–208.

Hollander, M. and Wolfe, D.: 1999, *Nonparametric Statistical Methods*, Wiley-Interscience, New York, 2nd Ed.

Hotelling, H.: 1933, Analysis of a complex of statistical variables into principal components, *Journal of Educational Psychology* **24**, 417–441.

Huh, Y. and Kim, S.: 2008, Do early adopters upgrade early? Role of post-adoption behavior in the purchase of next-generation products., *Journal of Business Research* **61**(1), 40–46.

Iyengar, R., Koenigsberg, O. and Muller, E.: 2009, The effects of uncertainty on mobile phone package size and subscribers choice.

Jacoby, J., Berning, C. K. and Dietvorst, T. F.: 1977, What about disposition?, *Journal of Marketing* **41**(2), 22–28.

James, J. and Versteeg, M.: 2007, Mobile phones in Africa: How much do we really know?, *Social indicators research* **84**(1), 117–126.

John, G., Weiss, A. and Dutta, S.: 1999, Marketing in technology-intensive markets: Toward a conceptual framwork, *Journal of Marketing* **63**, 78–91.

Jolliffe, I.: 2002, *Principal Component Analysis. Second Edition*, Springer-Verlag, New York.

Kagawa, S., Nansai, K. and Kudoh, Y.: 2009, Does product lifetime extension increase our income at the expense of energy consumption?, *Energy Economics* **31**(2), 197–210.

Kalish, S., Mahajan, V. and Muller, E.: 1995, Waterfall and sprinkler new-product strategies in competitive global markets, *International Journal of Research in Marketing.* . **12**, 105–119.

Kamssu, A.: 2005, Global connectivity through wireless network technology: A possible solution for poor countries, *International Journal of Mobile Communications* **3**(3), 249–262.

Kates, S. M.: 2001, Disposition of possessions among families of people living with aids, *Psychology & Marketing* **18**(4), 365–387.

Kauffman, R. J. and Techatassanasoontorn, A. A.: 2005, International diffusion of digital mobile technology: A coupled-hazard state-based approach, *Information Tecnology and Management* **6**, 253–292.

Knussen, C. and Yule, F.: 2008, "I'm not in the habit of recycling" - the role of habitual behavior in the disposal of household waste, *Environment and Behavior* **40**(5), 683–702.

Kohli, R., Lehmann, D. and Pae, J.: 1999, Extent and impact of incubation time in new product diffusion, *Journal of Product Innovation Management* **16**(2), 134–144.

Koski, H. and Kretschmer, T.: 2007, Catching up? Differences in 2G mobile diffusion in industrialized and developing countries, *Journal of Scientific and Industrial Research* **66**(4), 305.

Kotler, P.: 1965, Phasing out weak products, *Harvard Business Review* **43**(2), 107–118.

Kotler, P.: 1991, *Strategic Marketing for Nonprofit Organizations.*, Prentice Hall, New Jersey.

Kotler, P.: 2003, *Marketing management*, Pearson education, New Jersey.

Kotler, P. and Lee, N.: 2005, *Corporate Social Resposibility: Doing the Most Good for Your Company and your Cause*, Wiley, Hoboken, NJ.

Kotler, P. and Levy, S.: 1969, Broadening the marketing concept, *Journal of Marketing* **83**, 10–15.

Kotler, P. and Levy, S. J.: 1971, Demarketing, yes, demarketing, *Harvard Business Review* **79**(6), 74–80.

Krishnan, T. V. and Thomas, S. A.: 2009, *Handbook of International Marketing*, Sage, Beverly Hills, chapter International diffusion of new products, pp. 325–345.

Kroonenberg, P. M.: 2008, *Applied Multiway Data Analysis.*, Hoboken, NJ: Wiley.

Kumar, A., Baisya, R., Shankar, R. and Momaya, K.: 2007, Diffusion of mobile communications: Application of Bass diffusion model to BRIC countries, *Journal of Scientific and Industrial Research* **66**(4), 312–316.

Kumar, V., Ganesh, J. and Echambadi, R.: 1998, Cross-national diffusion research: What do we know and how certain are we?, *Journal of Product Innovation Management* **15**(3), 255–268.

Kumar, V. and Kirishnan, T. V.: 2002, Multinational diffusion models: An alternative framework, *Marketing Science* **21**, 318–330.

Lambert-Pandraud, R. and Laurent, G.: 2010, Why do older consumers buy older brands? The role of attachment and declining innovativeness, *Journal of Marketing* **74**(5), 104–121.

Lastovicka, J. L. and Fernandez, K. V.: 2005, Three paths to disposition: The movement of meaningful possessions to strangers, *Journal of Consumer Research* **31**(4), 813–823.

Lemmens, A. and Croux, C.: 2006, Bagging and boosting classification trees to predict churn, *Journal of Marketing Research* **43**(2), 276–286.

Lemmens, A., Croux, C. and Stremersch, S.: 2011, Dynamics in international market segmentation, *Journal of Marketing Research (Forthcoming)* .

Lilien, G., Rangaswamy, A. and De Bruyn, A.: 2007, *Principles of Marketing Engineering*, Trafford on Demand Pub, chapter The Bass model: marketing engineering technical note.

Linton, J. D., Yeomans, J. S. and Yoogalingam, R.: 2004, Enabling industrial ecology through the forecasting of durable goods disposal: Televisions as an exemplar case study, *Canadian Journal of Administrative Sciences* **21**(2), 190–207.

Mahajan, V.: 2009, *Africa Rising: How 900 Million African Consumers Offer More Than You Think*, Wharton School Publishing.

Mahajan, V. and Muller, E.: 1996, Timing, diffusion, and substitution of successive generations of technological innovations: The IBM mainframe case, *Technological Forecasting and Social Change* **51**(2), 109–132.

Mahajan, V., Muller, E. and Bass, F. M. .: 1990, New product diffusion models in marketing: A review and directions for future research., *Journal of Marketing* **54**, 1–26.

Mahajan, V., Muller, E. and Wind, Y.: 2000, *New-Product Diffusion Models*, Kluwer Academic Publishers, Norwell.

Mahajan, V. and Peterson, R.: 1985, *Models for Innovation Diffusion*, Sage, Beverly Hills.

Mannetti, L., Pierro, A. and Livi, S.: 2004, Recycling: Planned and self-expressive behaviour *Journal of Environmental Psychology* **24**(2), 227–236.

Marell, A., Davidson, R. and Gärling, T.: 1995, Environmentally friendly replacement of automobiles, *Journal of Economic Psychology* **16**(3), 513–529.

Midgley, D.: 1976, A simple mathematical theory of innovative behavior, *Journal of Consumer Research* **3**, 31–41.

Midgley, D.: 1981, Toward a theory of the product life cycle: Explaining diversity, *Journal of Marketing* **45**(1), 109–115.

Mills, M.: 2010, *Introducing Survival and Event History Analysis*, Sage Publications Ltd.

Morgan, L. and Birtwistle, G.: 2009, An investigation of young fashion consumes' disposal habits, *International Journal of Consumer Studies* **33**(2), 190–198.

Morosini, P., Shane, S. and Singh, H.: 1998, National cultural distance and cross-border acquisition performance,, *Journal of International Business Studies* **29**(1), 137–158.

Murray, M.: 2009, Waste management in Ireland: Discourses of domination in an (un)reflexive society, *Sociological Review* **57**(1), 81–101.

Nixon, H. and Saphores, J. D. M.: 2007, Financing electronic waste recycling: Californian households' willingness to pay advanced recycling fees, *Journal of Environmental Management* **84**(4), 547–559.

Nnorom, I. C. and Osibanjo, O.: 2008, Overview of electronic waste (e-waste) management practices and legislations, and their poor applications in the developing countries, *Resources Conservation and Recycling* **52**(6), 843–858.

Norton, J. and Bass, F.: 1987, A diffusion theory model of adoption and substitution for successive generations of high technology products, *Management Science,* **33**(9), 1069–1086.

Norton, J. and Bass, F.: 1992, Evolution of technological generations: The law of capture, *Sloan Management Review* **33**(2), 66–77.

O'Brien, M.: 1999, *Consuming Cultures*, Macmillan, Basingstoke, Hants, chapter Rubbish power: Towards a sociology of the rubbish society, pp. 262–277.

Okada, E.: 2001, Trade-ins, mental accounting, and product replacement decisions, *Journal of Consumer Research* **17**(4), 433–446.

Olavarrieta, S., Manzur, E., Hidalgo, P. and Farias, P.: 2008, An analysis of the attributes of flea markets considered relevant by shoppers: Evidence from Latin America, *Revista de Ciencias Sociales* **14**(3), 468–478.

Osibanjo, O. and Nnorom, I. C.: 2007, The challenge of electronic waste (e-waste) management in developing countries, *Waste Management & Research* **25**(6), 489–501.

Osibanjo, O. and Nnorom, I. C.: 2008, Material flows of mobile phones and accessories in Nigeria: Environmental implications and sound end-of-life management options, *Environmental Impact Assessment Review* **28**(2-3), 198–213.

Paden, N. and Stell, R.: 2005, Consumer product redistribution: Disposition decisions and channel options, *Journal of Marketing Channels* **12**(3), 105–123.

Palacios Fenech, J.: 2008, *Diffusion rates of consumer goods: Different approaches*, Master's thesis, Universitat Pompeu Fabra.

Pearson, K.: 1901, On lines and planes of closest fit to systems of points in space, *Philosophical Magazine* **2**(6), 559–572.

Peres, R., Muller, E. and Mahajan, V.: 2010, Innovation diffusion and new product growth models: A critical review and research directions, *International Journal of Research in Marketing* **27**(2), 91 – 106.

Pickering, J., Harrison, J., Isherwood, B., Hebden, J. and Cohen, C.: 1973, Are goods goods? Some empirical evidence, *Applied Economics* **5**(1), 1–18.

Pieters, R. G. M.: 1991, Changing garbage disposal patterns of consumers - motivation, ability, and performance, *Journal of Public Policy & Marketing* **10**(2), 59–76.

Pokharel, S. and Mutha, A.: 2009, Perspectives in reverse logistics: A review, *Resources Conservation And Recycling* **53**(4), 175–182.

Prahalad, C.: 2009, *The Fortune at the Bottom of the Pyramid: Eradicating Poverty through Profits*, Wharton School Publishing.

Prahalad, C. and Hart, S.: 2002, The fortune at the bottom of the pyramid, *Strategy and Business* **7**, 38–48.

Price, L. L., Arnould, E. J. and Curasi, C. F.: 2000, Older consumers' disposition of special possessions, *Journal of Consumer Research* **27**(2), 179–201.

Prince, J.: 2008, How do households choose quality and time to replacement for a rapidly improving durable good, *International Journal of Industrial Organization* **27**(2), 302–311.

Prins, R., Verhoef, P. C. and Frances, P. H.: 2009, The impact of adoption timing on new usage and early disadoption, *International Journal of Research in Marketing* **26**(4), 304–313.

Purohit, D.: 1992, Exploring the relationship between the markets for new and used durable goods: the case of automobiles, *Marketing Letters* **6**(2), 154–167.

Putsis, Jr., W. P., Balasubramanian, S., Kaplan, E. H. and K., S. S.: 1997, Mixing behavior in cross-country diffusion, *Marketing Science* **16**, 354–369.

Raghavan, S.: 2010, Don't throw it away: The corporate role in product disposition, *Journal of Business Strategy* **31**, 50–55.

Redmond, W. H.: 1996, Product disadoption: Quitting smoking as a diffusion process, *Journal of Public Policy and Marketing* **15**(1), 87–97.

Ripley, B.: 2008, *Pattern recognition and neural networks*, Cambridge Univ Pr.

Rogers, E. M.: 2004, *Diffusion of Innovations*, The Free Press, New York.

Rogers, E. M. and Shoemaker, F. F.: 1971, *Communication of Innovations: A Cross-Cultural Approach (2nd ed. of Diffusion of innovations)*, The Free Press, New York.

Roster, C. A.: 2001, Letting go: The process and meaning of dispossession in the lives of consumers, *Advances in Consumer Research* **28**, 425–430.

Roster, C. A. and Richins, M. L.: 2009, Ambivalence and attitudes in consumer replacement decisions, *Journal of Consumer Psychology* **19**(1), 48–61.

Rouvinen, P.: 2006, Diffusion of digital mobile telephony: Are developing countries different?, *Telecommunications Policy* **30**(1), 46–63.

Rubio, S., Chamorro, A. and Miranda, F. J.: 2008, Characteristics of the research on reverse logistics (1995-2005), *Journal of Production Research* **4**(4), 1099–1120.

Rucker, M., Balch, T., Higham, F. and Schenter, K.: 1992, Thanks but no thanks - Rejection, possession and disposition of the failed gift, *Advances in Consumer Research* **19**, 528–531.

Saied, M. and Velasquez, G. T.: 2003, PCs and consumers - a look at green demand, use, and disposal, *Computers and The Environment: Understanding and Managing Their Impacts* **14**, 161–181.

Salverda, W., Nolan, B. and Smeeding, T.: 2009, *The Oxford Handbook of Economic Inequality*, Oxford University Press, USA.

Schemper, M. and Stare, J.: 1996, Explained variation in survival analysis, *Statistics in Medicine* **15**(19), 1999–2012.

Schultz, R. S. and Rao, S. R.: 1986, Product life cycles of durable goods for the home, *Journal of the Academy of Marketing Science* **14**, 7–12.

Sego, T.: 2010, Mothers' experiences related to the disposal of children's clothing and gear: Keeping mister clatters but tossing broken barbie, *Journal of Consumer Behaviour* **9**, 57–68.

Sherry, J. F., McGrath, M. A. and Levy, S. J.: 1992, The disposition of the gift and many unhappy returns, *Journal of Retailing* **68**(1), 40–65.

Sherry, J. J.: 1990, A sociocultural analysis of a Midwestern American flea market, *the Journal of Consumer Research* **17**, 13–30.

Shim, S.: 1995, Environmentalism and consumers' clothing dispsal patterns: An exploratory study, *Clothing and Textile Research Journal* **13**(1), 38–48.

Shinkuma, T.: 2007, Reconsideration of an advance disposal fee policy for end-of-life durable goods, *Journal of Environmental Economics and Management* **53**(1), 110–121.

Shocker, A., Bayus, B. and Kim, N.: 2004, Product complements and substitutes in the real world: The relevance of "other products", *Journal of Marketing* pp. 28–40.

Sirgy, M. and Lee, D.: 2008, Well-being marketing: An ethical business philosophy for consumer goods firms, *Journal of Business Ethics* **77**(4), 377–403.

Sneath, J., Lasey, R. and Kenett-Hensel, P.: 2009, Coping with natural disaster: Losses, emotions and impulsive and compulsive buying, *Marketing Letters* **20**(1), 45–60.

Sood, A., James, G. and Tellis, G.: 2009, Functional regression: A new model for predicting market penetration of new products, *Marketing Science* **28**(1), 36–51.

Sood, A. and Tellis, G.: 2005, Technological evolution and radical innovation, *Journal of Marketing* **69**(3), 152–168.

Srinivasan, R., Lilien, G. and Rangaswamy, A.: 2004, First in, first out? the effects of network externalities on pioneer survival, *Journal of Marketing* **68**, 41–58.

Srinivasan, V. and Mason, C. H.: 1986, Nonlinear least squares estimation of new product diffusion models, *Marketing Science* **5**(2), 169–178.

Steenkamp, J., Hofstede, F. and Wedel, M.: 1999, A cross-national investigation into the individual and national cultural antecedents of consumer innovativeness, *Journal of Marketing* **63**, 55 – 69.

Sterman, J.: 2000, *Business dynamics: systems thinking and modeling for a complex world*, Vol. 53, Irwin McGraw-Hill.

Stevenson, G. J. and Kates, S. M.: 1999, The last gift: The meanings of gift-giving in the context of dying of aids, *Advances in Consumer Research* **26**, 113–118.

Stremersch, S., Muller, E. and Peres, R.: 2010, Does growth accelerate across technology generations?, *Marketing Letters* **21**(2), 103–120.

Stremersch, S. and Tellis, G.: 2004, Understanding and managing international growth of new products, *International Journal of Research in Marketing* **21**, 421–438.

Sundqvist, S., Franck, L. and Puumalainen, K.: 2005, The effects of country characteristics, cultural similarity and adoption timing on the diffusion of wireless cmmunications, *Journal of Business Research* **57**(1), 107–110.

Takada, H. and Jain, D.: 1991, Cross-national analysis of diffusion of consumer durable goods in pacific rim countries, *Journal of Marketing* **55**(2), 48–54.

Talukdar, D., Sudhir, K. and Ainslie, A.: 2002, Investigating new product diffusion across products and countries, *Marketing Science* **21**(1), 97–114.

Tellis, G., Stremersch, S. and Yin, E.: 2003, The international takeoff of new products: The role of economics, culture and country innovativeness, *Marketing Science* **22**(2), 188–208.

Tibben-Lembke, R.: 2002, Life after death: Reverse logistics and the product life cycle, *International Journal of Physical Distribution & Logistics Management* **32**(3), 223–244.

van Birgelen, M., Semeijn, J. and Keicher, M.: 2009, Packaging and proenvironmental consumption behavior investigating purchase and disposal decisions for beverages, *Environment and Behavior* **41**(1), 125–146.

van den Bergh, J. C. J. M.: 2008, Environmental regulation of households: An empirical review of economic and psychological factors, *Ecological Economics* **66**(4), 559–574.

Van den Bulte, C.: 2000, New product diffusion acceleration: Measurement and analysis, *Marketing Science* **19**(4), 366–380.

Van den Bulte, C. and Stremersh, S.: 2004, Social contagion and income heterogeneity in new product diffusion. a meta-analytic test, *Marketing Science* **23**(4), 530–544.

Van den Bulte, C. and Yogesh, V.: 2007, New product diffusion with influentials and imitatiors, *Marketing Science* **26**(3), 400–421.

Van Everdingen, Y., Aghina, W. and Fok, D.: 2005, Forecasting cross-population innovation diffusion: A Bayesian approach., *International Journal of Research in Marketing* **22**(3), 293–308.

van Everdingen, Y., Fok, D. and Stremersch, S.: 2009, Modeling global spillover of new product takeoff, *Journal of Marketing Research* **46**(5), 637–652.

Van Houtven, G. L. and Morris, G. E.: 1999, Household behavior under alternative pay-as-you-throw systems for solid waste disposal, *Land Economics* **75**(4), 515–537.

van Nes, N. and Cramer, J.: 2006, Product lifetime optimization: A challenging strategy towards more sustainable consumption patterns, *Journal of Cleaner Production* **14**(15-16), 1307–1318.

van Nes, N. and Cramer, J.: 2008, Conceptual model of replacement behaviour, *International Journal of Product Development* **6**(3-4), 291–309.

Varadarajan, R., DeFanti, M. and Busch, P.: 2006, Brand portfolio, corporate image, and reputation: Managing brand deletions, *Journal of the Academy of Marketing Science* **34**(2), 195.

Varadharajan, S.: 2007, Growth of mobile services across regions of India, *Journal of Scientific and Industrial Research* **66**(4), 281–289.

Vencatasawmy, C. P., Ohman, M. and Brannstrom, T.: 2000, A survey of recycling behaviour in households in Kiruna, Sweden, *Waste Management & Research* **18**(6), 545–556.

Volpato, R.: 2011, Letting data speak: Enunciative modalities of correspondence analysis, *Correspondence Analysis and Related Methods - CARME*, Agrocampus Ouest, Rennes FRANCE, p. 13.

Waheeduzzaman, A.: 2006, Can modernization explain the consumption of durables in emerging markets?, *Journal of Global Marketing* **19**(3), 33–62.

Waheeduzzaman, A.: 2011, Are emerging markets catching up with the developed markets in terms of consumption?, *Journal of Global Marketing* **24**(2), 136–151.

Walker, R. E.: 2006, *Product Disposal*, PhD thesis, University of Texas.

Ward, J. H.: 1963, Hierarchical grouping to optimize an objective function, *J. Amer. Stat. Ass* **58**, 236–245.

Wiebe, G. D.: 1951, Merchandising commodities and citizenship on television, *Public Opinion Quarterly* **15**(4), 679–691.

Wilk, R.: 2001, Consuming morality, *Journal of Consumer Morality* **1**(2), 245–260.

Wiorkowski, J. and Gylys, V.: 2006, An empirical real-time test for takeoff with applications to cellular telephony, *Review of Marketing Science* **4**(1), 1–39.

Young, H. P.: 2009, Innovation diffusion in heterogeneous populations: Contagion, social influence, and social learning, *The American Economic Review* **99**(5), 1899–1924.

Young, M. M.: 1991, Disposition of possessions during role transitions, *Advances in Consumer Research* **18**, 33–39.

Young, M. M. and Wallendorf, M.: 1989, Dust to dust, ashes to ashes: Conceptualizing consumer disposition of possessions, *AMA Winter Educators Conference Proceeding* pp. 33–39.