Charge it: Applying IT investment decision theory to payment card upgrades

By

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Abstract

The new Europay-MasterCard-Visa (EMV) Chip-and-PIN payment cards are slowly replacing traditional magnetic stripe cards worldwide. Although it makes little economic sense for the individual firm to take on the significant cost required to upgrade hardware and software to convert to the new standard, wide-scale adoption results in positive externalities such as a reduction in payment card fraud that benefit all interested parties. This study investigates the investment decision at the country level and examines the variability of when countries choose to adopt the new standard as a unique application of existing theoretical economic models of IT investments. It finds evidence supporting a relationship between high payment system switching costs and delayed EMV conversion as shown through several separate regression models, where switching cost is represented by the level of payment card utilization.

Key words: EMV, payment cards, credit cards, Chip-and-PIN, IT investment

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1. Introduction

Payment cards touch almost every facet of everyday commerce: buying groceries, filling up with gas, getting cash from an ATM, or paying for parking on the way out of a lot. Since the inception of electronic processing of payment cards, the industry has relied on a single technology, the magnetic stripe, to encode all relevant information about the card and cardholder. As the industry evolved, however, so did those trying to take advantage of it. Payment card fraudsters devised several methods to get access to sensitive card information in order to use these cards for fraudulent purposes. These methods included skimming the information off the magnetic stripe with a device attached directly to the payment terminal. Fraud from methods like this, among others, cost the United States alone over $3.4 billion in financial losses in 2009 (Sullivan, 2013).

The advent of payment card fraud motivated the creation of a new payment standard, one with more security features to protect this sensitive information. The Europay-MasterCard-Visa (EMV) Chip-and-PIN cards are embedded with a microprocessor to provide enhanced security for payment card transactions. Adopting this new payment standard, however, is a daunting and expensive task, requiring the hardware, software, and physical cards all to be updated worldwide. For the individual firm, it is very difficult to justify the costs of upgrading to this new standard unless it is adopted globally, so mechanisms had to be put in place to encourage adoption. Interestingly, there is variation among when particular countries finally converted to this new standard.

This paper intends to explore the relationship between the relative cost of switching to the new standard and how quickly it was adopted. The decision theory behind this major IT investment has gone unaddressed in the existing literature, and this thesis seeks to evaluate concepts that exist only in theoretical models using empirical evidence. The large impact payment cards have on everyday transactions for consumers and businesses justifies research further examining the forces at play. Specifically, this paper addresses the question: does the existing economic decision theory on IT investments hold in the payment card industry's migration to the new Chip-and-PIN standard? In order to address the question, this thesis applies the existing decision theory to the EMV upgrade, runs a base analysis to establish a relationship between switching costs and speed to EMV implementation, and looks further to compare the relative predictive power of each metric.

The following section will detail the state of the payment card industry conversion as well as examine relevant academic literature. Section 3 will describe the methodology to address the research question, sections 4 and 5 will display, interpret, and discuss the results of the analysis, and section 6 will conclude the paper.

2. Literature Review

Despite being one of the largest and most complex initiatives in the history of non-cash payments affecting everyday consumers worldwide, there is surprisingly little academic research focusing on the migration to EMV Chip-and-PIN payment cards. The following section will address the existing academic and trade literature about the mechanisms used to encourage implementation of the technology, the associated costs, the business case for upgrading, and the economic theory affecting the decision to adopt.

2.1 New technology conversion incentives

Establishing and maintaining a worldwide standard for card payments is difficult because under the umbrella of payment processing companies such as Europay, Visa, or MasterCard, three parties across the globe must agree to operate on the same standard: the bank issuing the cards, the consumer using the cards, and the merchant accepting the cards. If a single standard is adopted worldwide, however, it provides significant benefits for all consumers and merchants by allowing worldwide compatibility of hardware, software, and international transactions. The primary payment card method used in the United States and much of the world through the 1990s had been the traditional magnetic stripe payment card. As these cards became more prevalent, so did fraudulent transactions; by 2009, the United States alone saw over $3.4 billion in financial losses due to payment card fraud. This card information to execute this fraud was generally obtained through three methods: data breaches, social engineering/phishing (i.e. manipulating people into disclosing otherwise private info), and skimming the card data directly from the magnetic stripe (Sullivan, 2013).

As early as 1994, the first prototype of a chip-enabled payment card was developed, and in 1999, a new governing body, EMVCo[1], was created to facilitate a worldwide migration to the new payment method (Povey, 2008). As card issuers and merchants began producing and accepting cards, the need for method standardization was apparent. In order to be sustainable long term, issuers, merchants, and consumers must all be operating on a single standard worldwide. Because this new technology required significant hardware and software upgrades,

[1] It is worth noting that contactless Near Field Communication (NFC) cards, commonly referred to as "touch-and-go," have also been incorporated into the EMV standard as well. Although not the most common method of payment, EMVCo has specified protocols to keep this technology compliant with the new standard (EMVCo, 2015).

the participating payment card institutions, Europay, MasterCard, and Visa, began to drive nationally coordinated efforts through the use of liability shift dates (Povey, 2008).

According to Povey (2008), these industry leaders "communicated regional dates for EMV compliance [which were] communicated via a strategy known as a 'liability shift'" (p. 351). These liability shift dates are official changes in policy regarding the chargeback process for fraudulent transactions. For example, pre-liability shift, if a consumer's card is used fraudulently, it is the responsibility of the payment company – such as MasterCard or Visa – to reimburse the consumer. After these announced liability shift dates, the party which is the least secure or using the most outdated standard in the chain of payments processing will be responsible for any fraudulent charges. By implementing these liability shift dates, Europay, MasterCard, and Visa, essentially set deadlines for all parties to adopt the newer, more secure technology or else face the risk of significant fraud chargebacks if any card information was compromised at their terminal. Some constraints have led to the creation of exceptions or delays for individual types of payment units, namely ATMs and self-serve gas pumps, but the vast majority of applicable payment terminals fall under the first liability shift date in a particular country (Povey, 2008).

2.2 Firm-level costs and benefits of migration

Once a liability shift date has been announced, it is still up to each individual issuing bank and accepting merchant to decide whether or not to comply with the new standard. For many issuers, the most prohibitive cost is the physical cards. The card stock for chip-enabled cards is expensive, roughly three times more than the traditional magnetic stripe cards. Furthermore, these issuers cannot over-stock these materials as the chips inside the cards expire seven years after creation, unlike the magnetic stripe payment cards, which can be stored indefinitely and expiration is determined as the card is issued (Gamble, 2014).

For smaller credit unions, these costs can be prohibitively expensive. Barney Moore, a manager of portfolio consulting services for a Credit Union association, was quoted by Gamble (2014), "It's tough to justify internally the implementation cost unless you're experiencing serious fraud losses. [. . .] The cost is real and immediate. The benefits are theoretical and delayed, except for those with large current fraud losses" (p. 14). As a result, early adoption before the liability shift in the United States has been slow, with only 1-2% of cards from US issuers complying with the new standard as of September 2014.

Mahmud (2011) demonstrates a comparable dilemma through an economic model. The benefits derived from EMV conversion are primarily from the positive externalities that result from the entire payments system being more secure. When more firms adopt, the collective benefit goes up, but if and only if a sufficient number of firms continue to use the technology. In his research, Mahmud creates a theoretical model demonstrating the difficulty of firms to form coalitions to gain a collective benefits in the future, a concept he calls dynamic externality. He specifically considers the situation where later entrants can learn from their predecessors, which decreases a large firm's likelihood of being an early mover to this collective coalition, much like a firm converting to the new payment standard would be taking on a high risk by converting early and missing the opportunity to learn from other firms who converted first.

Despite the low early adoption rate in the United States, implementations of this standard across the world have shown a strong business case for adoption. Of the major types of payment card fraud, counterfeit, lost/stolen card, and cardholder-not-present, the core EMV functionality protects against counterfeit cards, the fraud category which generated 41% of losses in the US in

2010. Data from the United Kingdom shows an overall decrease in all major types of fraud after full EMV adoption with the exception of cardholder-not-present. Total reported value of fraud losses has decreased from a peak of $1.12 billion to $547 million from 2008-2011 (Sullivan, 2013).

Sullivan (2013) also showed that overall fraud loss rates decrease on the national level. For every dollar spent in the United States using a payment card in 2009, 0.11% would be expected to be lost to fraud. By comparison, France, another early EMV adopter, only had a loss rate of 0.067%. Additionally, the loss rate United Kingdom fell from 0.097% to a low of 0.065% in 2011, a 41% reduction as compared to the US (Sullivan, 2013). Given this data, a business case can be made for adoption on a country-by-country basis, but the costs discussed above make it very difficult for individual firms to convert, and it is still unclear how this would affect the timing of the decision to upgrade.

2.3 Economic theory on early adoption of IT investments

Given the strong business case for the benefits of EMV adoption and the high initial cost to upgrade the hardware, software, and cards for the new standard, it is still unclear how a firm or region would make the decision of when and if to adopt the standard. Research by Demirhan, Jacob, and Raghunathan (2007) suggests that IT investments with high switching costs put the early mover at a disadvantage. By building an economic model rooted in game theory, they were able to determine that "the declining cost of information technology over time provides the later entrant in information-intensive industries a cost advantage" (p. 208).

This game theory model theoretically assumes a duopoly of two firms entering a new technology space at different times and accounts for perceived benefits and disadvantages for being a pioneer. It specifically accounts for the uniqueness of the IT market where both switching costs and IT costs decline with time. Each model is then built with a layer of assumptions to arrive at a functional framework to manipulate variables and find the relative costs and benefits of being an early or late mover. The core finding from this research is that an early mover advantage in the IT space can quickly be negated by the decline in IT costs for later entrants to join (Demirhan, et al., 2007). When applied to EMV adoption, this model would suggest that there is an incentive for countries with higher switching costs to adopt later relative to those with lower switching costs.

A similar model was developed by Barua, Kriebel, and Mukhopadhyay (1991) relating switching costs, consumer preference, relative IT-efficiency of the firm, investment mode, and collective industry profits. By looking at both the firm level and the industry level, this model showed a negative overall effect on industry profitability when firms made decisions misaligned with the prevailing economic theory. For example, when investments are made sequentially as opposed to simultaneously, the second mover makes more profit and boosts the industry-wide profit as compared to a simultaneous investment. When applied to the payment card space, these economic models would suggest that the firms which have a higher switching cost to migrate to the new EMV payment standard would derive a greater benefit from implementing later as opposed to being a pioneer in the industry.

2.4 Conclusion

With existing literature covering the change mechanisms for EMV payment, costs and benefits for firm-level adoption, the business case for wide-scale migration, and theory behind economic motivators for IT investment decisions, there is a lack of attention on the variability of the barriers for adoption of the new EMV standard. This thesis examines one possible factor as an empirical example of the theoretical economic model discussed in section 2.3: how the switching cost to upgrade to the new technology affects the time to adoption.

3. Methodology

As national and international technology standards evolve, it is important to better understand what factors influence when and how these standards are implemented. Often times, these systems represent a significant investment on both the business and consumer ends in the unique real of technology investments. In order to expand upon the existing literature on these system-wide change management topics, this study tests a single hypothesis regarding the speed of EMV technology implementation as it relates to switching cost, evaluated through five measures of payment card utilization as detailed in the following section.

3.1 Application of the decision theory to the EMV upgrade and hypothesis statement

Switching costs have been shown as a deterrent to early adoption of a new technology. Pioneers in a new technology space take on an inherent risk by being an early mover. Furthermore, late adopters benefit from a larger body of relevant information as well as lower direct costs as the technology matures (Demirhan, Jacob, & Raghunathan, 2007). In a global payment system, all players – merchants, companies, consumers, and issuers in each country – should be utilizing the same technology, as it would be impractical for these parties to be operating on multiple different standards. In the long run, countries which delay adoption of the EMV standard will eventually be brought on board to the migration of the technology in order to maintain compatibility for international payment transactions.

This pattern of switching costs deterring investment in a new standard – early adopters spreading the new system, and initial objectors finally adopting – can be applied to the EMV Chip-and-PIN payment card migration that has taken place from 2005 to 2015. As the payments industry in a particular country takes hold, more consumers utilize their services, requiring a greater investment in hardware, software, and physical payment cards. The new standard, which requires updating all three components, represents a relatively larger switching cost for the nations where existing payment card utilization is high as compared those with to less frequent users of payment cards. Therefore, the primary hypothesis this paper evaluates is:

Hypothesis: There is a negative relationship between system switching costs and the speed of EMV payment technology adoption.

3.2 Measurement and data collection

There are many ways to define speed of EMV payment adoption, but this paper focuses exclusively on the counterfeit card fraud liability shift dates. This measure is generally accepted to be the effective date of EMV conversion (Povey, 2008). Due to information availability, this paper uses the liability shift date as defined by MasterCard[2] in each country examined. As discussed in Section 2, some regions provide delayed implementation dates for specific uses that may be even more expensive or cumbersome to upgrade, examples of which include self-service gas pumps and ATMs. Although these conversion deadline extensions are published on a regional basis, they are not evaluated in this study. The earliest date that merchants experience a

[2] Other companies such as Visa and American Express were considered, but MasterCard had the most complete data published for liability shift dates. Although liability shift dates for all major companies are quite similar and often are the exact same, this study uses exclusively MasterCard liability shift dates for consistency.

liability shift is considered the date of conversion in this study, as this is most representative of when the bulk of consumers and merchants will have to upgrade; anything remaining is just an exception. This data was collected from the MasterCard merchant guide, which is published on an annual basis and includes updates on the liability shifts and EMV migrations across the world. These dates are summarized in the table in Appendix A. For the purposes of the models, all dates are coded as the number of days since 1/1/2004, the beginning of the baseline year for the analysis as it is before any country had implemented EMV; the first countries adopted the new standard in 2005. All payment amount, volume, population, and exchange rate data is also pulled from the year 2004.

The independent variable, size of switching cost, is represented by five different measures of payment card usage, each of which is examined individually. Based on the research by Demirhan, Jacob, and Raghunathan, high credit card usage can be interpreted as having high switching costs (2007). The measures used in this paper are listed in Table 1.

Table 1: Card Utilization Measures and Summary Statistics

Measure	Median	Std. Dev.
Total US dollar (USD) value of all payment card transactions (millions)	$4,875	$205,900
Total volume of payment card transactions (millions)	74	2,292
Total USD value of all payment card transactions per capita	$247.8	$1,587
Total volume of payment card transactions per capita	3.5	14.71
Average USD value per transaction	$8.613	$5.641

The expectation is that all five measures will be very similar and highly correlated, but each measure is examined separately and compared later in the analysis section. All payment value, payment count, exchange rate, and population data were collected from the Passport database.

3.3 Analytical framework

In order to perform a quantitative analysis of the data to determine if there is support for the above hypothesis, multiple simple linear regressions were run relating implementation to existing credit card use. The regression took the form:

$$Time\ to\ implementation\ date = \beta_0 + \beta_1 utilization_1 + \varepsilon$$

This same equation was applied to relate all five utilization measures listed in the previous section – Total Value of Payment Card Transactions, Total Volume of Payment Card Transactions, Value of Payment Card Transactions per Capita, Volume of Payment Card Transactions per Capita, and Average Value per Transaction – to the time to implementation date.

Note that, when defined as above, that the hypothesis of "a negative relationship between switching costs and the speed of EMV payment technology adoption" will actually be supported with a positive Beta coefficient because the implementation date measure is coded as the amount of time to adoption, the inverse of speed. Therefore, the hypothesis is supported if $\beta_1 > 0$.

By using five different measures to assess payment card utilization, all of which are proxies for switching cost, this paper does not necessarily require all five to have a positive relationship with time to adoption in order for the hypothesis to be considered supported. The primary goal of using these five measures is to find the strongest, most robust measure to best predict how early a country is likely to migrate. This additional analysis will be included in the discussion section.

3.4 Assumptions

This paper operates under several assumptions. First, it assumes that credit card transaction value and volume are appropriate proxies for the utilization of the technology and, by extension, the switching cost of migrating to the new standard. This is the most logical metric with available data to represent this because higher usage rates imply that there are more cards, payment terminals, and software in use, all of which would need to be updated to comply with the new standard. With regards to the EMV migration date, this paper assumes that the first MasterCard liability shift date for a particular country is a legitimate representation of when the technology was actually adopted by the country. MasterCard was chosen because of the availability of data and prominence throughout the world as a common payment card processor. The use of liability shift dates has been commonly used as the key date of migration (Povey, 2008).

For the analysis, there are admittedly other factors than just switching costs that will affect the migration date. Many of the smaller, earlier adopters did so on a coarser, regional basis, for reasons beyond just the low switching costs. This paper does not deny the existence of these mechanisms, but recognizes the difficulty of quantifying them into a measureable variable for multivariate regression analysis. Additionally, there may be mechanisms unknown at this time that may drive the relationship between card utilization and speed to implementation. This paper takes the first step, however, by analyzing the existence or nonexistence of a relationship.

4. Results

I collected payment card utilization data and the dates of EMV conversion for 46 countries to perform regression analyses to address the research question and assess the hypothesis in section 3. This section details the results of the regression analyses.

4.1 Base analysis and determination of relationship

Table 2 below summarizes the key outputs of the base regression analysis for each of the five measures of card utilization. Each output includes the β_1 coefficient, level of significance, and standard error in parentheses.

Table 2: Relationship between card utilization and conversion date (All data, unstandardized)

	1	**2**	**3**	**4**	**5**
Total USD Value	0.0027*** (0.000)				
Total Volume		0.2406*** (0.037)			
Total Value per Capita			0.3149*** (0.059)		
Total Volume per Capita				35.4139*** (6.144)	
Avg Value per Transaction					-1.1558 (2.114)

*,**,*** denotes significance at the $p < .1$, .05, and .01 levels, respectively
Output shows four statistically significant predictors. Only average value per transaction was not significant.

For models 1 and 2, the USD value and volume are measured in millions, while the time to implementation is measured in days. With statistical significance at the $p < .01$ level, this implies that for approximately every additional $1 million spent using payment cards in a particular country, implementation would be delayed by 0.0027 days. Also, for every incremental 1 million transactions, the model would expect that particular country would implement 0.2406 days later. For models 3 and 4, each card utilization metric is measured on a per capita basis, so model 3 can be interpreted as suggesting that a $1 increase in card spend per capita results in an expected EMV implementation of 0.3149 days later and model 4 implies 1 additional transaction per capita per day delays expected EMV implementation by just over one month. Model 5, average USD value per transaction, is not a significant predictor as it did not reach any level of statistical significance.

Note that the data were not standardized in this initial analysis, so the magnitude of these coefficients are not directly comparable. Section 4.3 presents additional analysis to directly compare the relative influence of each measure.

4.2 Analysis excluding outlier

Additional analysis revealed that the United States is an outlier in both payment card utilization and implementation date, an example of which can be seen in Section 5, Figure 1. Because of the effect such outliers have on regression analyses, each model was run a second time with the United States excluded. The results from this second run are summarized in table 3.

Table 3: Relationship between card utilization and conversion date (Excluding US, unstandardized)

	1	2	3	4	5
Total USD Value	0.0031** (0.001)				
Total Volume		0.3509** (0.151)			
Total Value per Capita			0.2283*** (0.050)		
Total Volume per Capita				24.6764*** (5.846)	
Avg Value per Transaction					-1.0348 (1.619)

*,**,*** denotes significance at the *p*<.1, .05, and .01 levels, respectively.
All four significant metrics from base analysis maintain significance at least at the p < .05 level

Even when excluding the outlier, the data still shows significant support for the hypothesis. Total value per capita and total volume per capita are particularly robust measures, both significant at the $p < .01$ level with and without the outlier. On these measures, it can be interpreted that a $1 increase in value per capita would result in an expected implementation of 0.2283 days later, and 1 additional transaction per capita per year would result in a predicted liability shift delay of just over 24 days. The relatively large sample size of countries, 45, contributes to the robustness of these findings.

4.3 Comparison of relative influence of the five measures

As an additional analysis, each card utilization measure was standardized to more appropriately compare the relative predictive power of each metric. Each measure was standardized with the following method:

$$x_{new} = \frac{x - \mu}{\sigma}$$

Each base model was then run using the standardized measures for the five card utilization metrics two times, once including the United States and once excluding the United States with the goal of finding which measure or set of measures of card utilization were the most predictive of a change in conversion date. The coefficient from this model corresponds to the expected change in the implementation date given a one standard deviation change in the card utilization metric. The results are summarized in Figure 1 below and detailed in Tables 4 and 5 in Appendix B.

Figure 1: Regression coefficients for standardized metrics (All data and excl. US shown, Standardized)

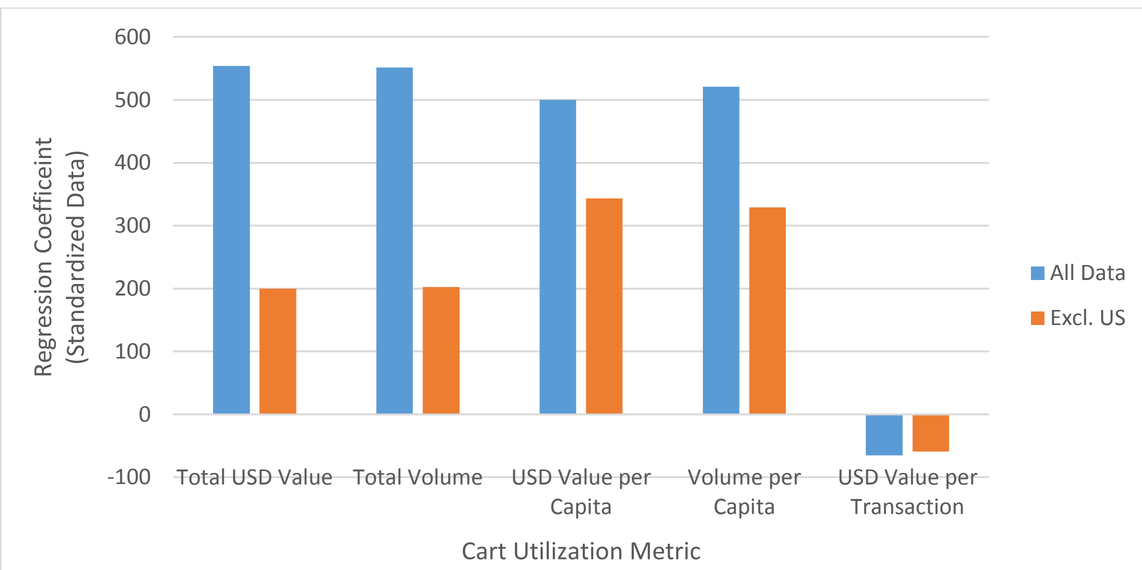

Figure 1 compares the relative predictive power of each measure. The most predictive metrics change depending on whether or not the United States in included in the analysis

Interestingly, the most predictive measures change depending on whether or not the United States is included in the analysis. These results show that when including the United States, all of the top four measures – total dollar value, transaction volume, dollar value per capita, and transaction volume per capita – are relatively similar in their predictive magnitude, with Total Value showing the strongest relationship by a slim margin. However, when excluding the United States, Total Value per Capita and Total Volume per Capita are the most descriptive measures. This particular model suggests that a one standard deviation change in Total Value per Capita ($1,587) results in a change of approximately 343 days until EMV implementation, just under one year. Given the strong effect outliers have on the regression tool, the Total Value per Capita and Total Volume per Capita measures are considered the most robust measures of payment card utilization.

5. Discussion

The results discussed above do show strong statistical support for the primary hypothesis, demonstrating a negative relationship between payment card utilization and speed to conversion, conversely stated as a positive relationship between payment card utilization and time to conversion. Despite showing strong statistical significance, the relationship between card utilization and EMV conversion date is far from perfectly linear. The scatterplots below show variance from a clean line of best fit, but do indicate a general positive relationship between card utilization and time to adoption. Note that the following figures do include the United States.

Figure 2: Relationship between total value of card transaction and conversion date (All data, unstandardized)

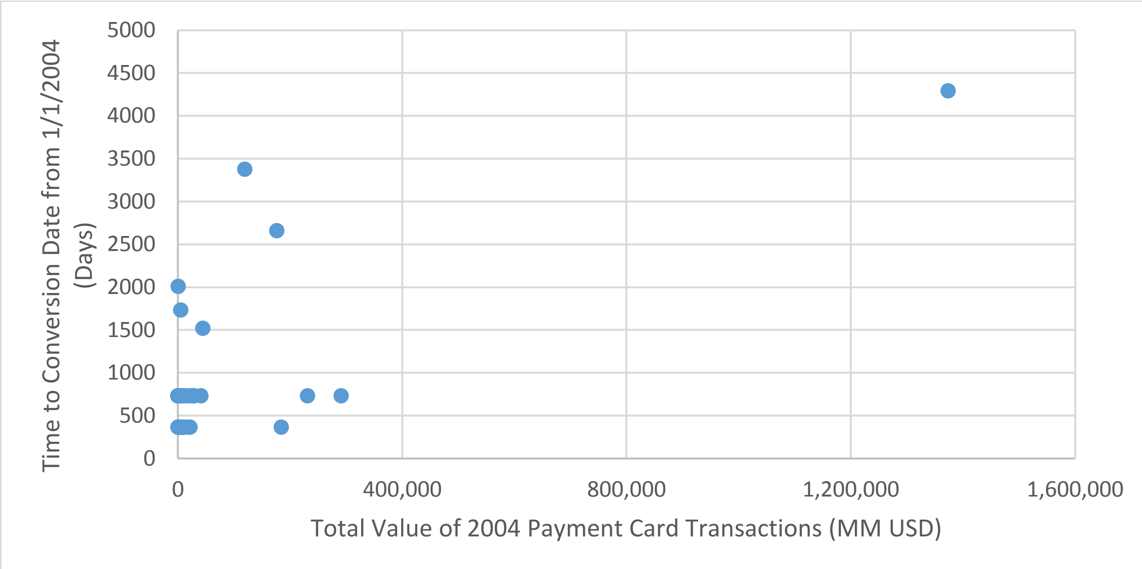

Figure 2 shows the United States as an outlier in both value of card transactions and conversion date

Figure 3: Relationship between number of transactions per capita and conversion date (All data, unstandardized)

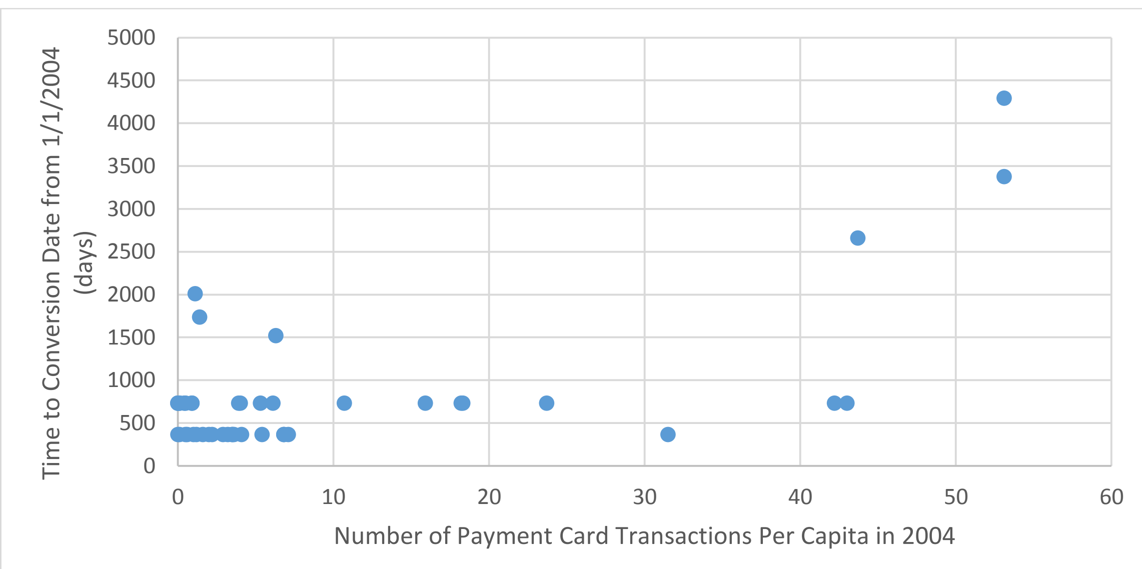

Figure 3 demonstrates the general positive relationship between transactions per capita and conversion date

There are a number of factors that can be driving the decision for conversion timing, many of which are difficult to identify or measure. The goal of this thesis, however, is not to prove causality or build an accurate predictive model, but rather to show support for the relationship between switching costs and the decision of when to upgrade a technology. This is an empirical application in a unique field of economic ideas which have thus far existed only in theoretical models. The interesting nature of payments processing is that, as compared to most business decisions involving two parties, a buyer and a seller, this particular environment operates with three underlying actors: the card issuer, the consumer, and the merchant. This additional complexity makes this a particularly compelling case for analysis.

The one measure that showed no significant relationship was the average USD value per transaction. This is not surprising, as it was the measure expected to be the most loosely related to accurately capturing payment card usage. Even when including the United States outlier, the regression model was not statistically significant. One advantage of including this metric, however, is giving a basis upon which to compare the other measures of card utilization, showing that a related possible predictor does not have the same amount of predictive power as the other four measures.

With regards to the additional analysis of standardized card utilization metrics presented in section 4.3, the result is somewhat surprising as the per capita measures were stronger predictors than the raw value and volume data. At first glance, adjusting for population size makes sense given the wide variety of country sizes included in this analysis. Further thought, however, could argue that population should not be a factor in the predictive value of the model because the population of a country is not necessarily reflected in the switching costs of the payment card system; raw transaction volume better indicates the total number of terminals, cards, and software systems that would need to be replaced. A counter argument could be that adjusting for population shows how broadly a particular country utilizes payment cards; the population-adjusted data would reflect how engrained the payment card system is into daily life. This could be presented an alternative view of measuring switching costs, an analysis which, although important and interesting, is beyond the scope of this paper and a possible topic for further study.

6. Conclusion

The results of this study contribute to the existing literature by providing an empirical application of what has previously existed in theoretical economic models. Furthermore, the interesting and unique case of upgrading international payment card systems and standards has gone unexamined in an academic setting. This thesis examined the relationship between five different measures of payment card utilization, a proxy for switching cost of the payment system, and the date of EMV conversion. The models did show that higher payment card utilization was related to a slower, longer implementation of the new technology. Further analysis showed that of the five measures used to describe payment card utilization, total dollar value of card transactions was the most predictive when analyzing the full dataset, and total value per capita was the most robust while excluding the US outlier. These results provide a concrete example to examine existing theoretical economic models, as well as shed light on the international payment system migration to EMV technology.

Furthermore, these estimates can be considered relatively conservative so the level of statistical significance indicates a very strong relationship. This is due to the idea that in a set of a greater number of overall payment card transactions, there will be a greater number of fraud instances. Since these instances of fraud can be considered costs of not upgrading, greater instances of fraud would increase motivation for high-transaction-volume countries to implement faster. Hypothetically, if there was no fraud, this effect would not be present, and the coefficients calculated from the regressions would be even larger.

This study did present several limitations, given the complex nature of international payment systems. The data did show a relationship between the two primary variables, implementation date and card utilization, but did not go so far as to prove any causality. There are many additional factors which are difficult to identify or measure that affect the decision to upgrade payment systems and the underlying mechanisms driving this change still remain unclear.

A further limitation relates to the coarseness of the implementation of the EMV standard. Because the benefits of the new standard are only realized when there is widespread adoption, many of the players in the payment card space elected to do many of the implementations on a regional basis. While viewing data at the country level was the most appropriate for this study, it is important to note that many countries coordinated implementation with their geographical neighbors, possibly affecting some inferences and conclusions from the data. These interactions are both interesting and relevant, and would be good candidates for future research on the topic of EMV conversion, as well as international technology standards. It is worth noting, however, that the EMV conversion does affect all countries in which the major payment card brands operate. The sample size for this study was only limited by the availability of payment card utilization data from the Passport database.

Although these limitations are important to acknowledge, this study does still contribute meaningfully to the academic literature. By presenting new and novel research in a previously unexamined space, this paper addresses relevant information though applying existing economic theory to the payment card industry. When large, system-wide upgrade decisions are presented in future technology-related industries, this study provides a basis upon which interested parties can better understand how high switching costs can make being a late mover more profitable, especially when the primary benefits derived from the upgrade are a result of indirect positive externalities.

Appendix A: Table of Countries and Liability Shift Dates Examined

Country	Liability Shift Date
Argentina	1/1/2005
Australia	4/1/2013
Austria	1/1/2005
Brazil	3/1/2008
Canada	4/15/2011
Chile	1/1/2005
China	1/1/2006
Colombia	10/1/2008
Czech Republic	1/1/2005
Denmark	1/1/2005
Egypt	1/1/2006
France	1/1/2005
Germany	1/1/2005
Greece	1/1/2005
Hong Kong, China	1/1/2006
Hungary	1/1/2006
India	1/1/2006
Indonesia	1/1/2006
Israel	1/1/2006
Italy	1/1/2005
Japan	1/1/2006
Malaysia	1/1/2006
Mexico	1/1/2005
Morocco	1/1/2006
Netherlands	1/1/2005
Norway	1/1/2005
Philippines	1/1/2006
Poland	1/1/2005
Portugal	1/1/2005
Romania	1/1/2005
Russia	1/1/2005
Saudi Arabia	1/1/2006
Singapore	1/1/2006
South Africa	1/1/2005
South Korea	1/1/2006
Spain	1/1/2005
Sweden	1/1/2005
Taiwan	1/1/2006
Thailand	1/1/2006
Turkey	1/1/2006
Ukraine	1/1/2006
United Arab Emirates	1/1/2006
United Kingdom	1/1/2005
USA	10/1/2015
Venezuela	7/1/2009
Vietnam	1/1/2006

Appendix B: Regression Output for Standardized Metrics

Table 4: Relationship Between Standardized Measures of Card Utilization and Conversion Date – All Data, Standardized

	1	2	3	4	5
Total USD Value	553.7*** (85.79)				
Total Volume		551.5*** (86.11)			
Total Value per Capita			499.8*** (93.01)		
Total Volume per Capita				520.8*** (90.35)	
Avg Value per Transaction					-65.20 (119.3)

*,**,*** denotes significance at the *p*<.1, .05, and .01 levels, respectively.

Table 5: Relationship Between Standardized Measures of Card Utilization and Conversion Date – Excluding US, Standardized

	1	2	3	4	5
Total USD Value	199.8** (87.63)				
Total Volume		202.2** (87.50)			
Total Value per Capita			343.2*** (76.61)		
Total Volume per Capita				329.3*** (78.02)	
Avg Value per Transaction					-59.02 (92.34)

*,**,*** denotes significance at the *p*<.1, .05, and .01 levels, respectively.

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