Complementary currencies, short distribution channels, and digitalisation

Sothearath Seang

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Sothearath SEANG

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Dirigée par : Dominique TORRE
et Amel ATTOUR

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Devant le jury, composé de :
Amel ATTOUR, Maîtresse de Conférences HDR, Université Côte d'Azur
Jean-Michel CLOPPET, Président de la Fédération des Associations de Commerçants et Artisans Cagnois
Jean-Marc FIGUET, Professeur des Universités, Université de Bordeaux
Georgina GOMEZ, Associate Professor, Erasmus University Rotterdam
Thierry PENARD, Professeur des Universités, Université de Rennes
Dominique TORRE, Professeur des Universités, Université Côte d'Azur

RÉGION SUD PROVENCE ALPES CÔTE D'AZUR

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Jury :

Président du jury
Jean-Marc FIGUET, Professeur des Universités, Université de Bordeaux

Rapporteurs
Georgina GOMEZ, Associate Professor, Erasmus University Rotterdam
Thierry PENARD, Professeur des Universités, Université de Rennes

Examinateur
Jean-Michel CLOPPET, Président de la Fédération des Associations de Commerçants et Artisans Cagnois

Directeurs de thèse
Amel ATTOUR, Maîtresse de Conférences HDR, Université Côte d'Azur
Dominique TORRE, Professeur des Universités, Université Côte d'Azur

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Résumé

Cette thèse propose une analyse du potentiel des monnaies locales complémentaires (ci-après monnaies locales) à aborder des questions liées à la soutenabilité et à l'innovation technologique au niveau local à travers différentes perspectives. Le premier chapitre examine l'application d'une technologie émergente, la blockchain, pour gérer les monnaies locales. Ces dernières sont utilisées pour promouvoir des objectifs tels que les circuits courts, les produits de qualité, et les comportements soutenables. La première partie de ce chapitre expose comment la blockchain peut aider à résoudre les problèmes traditionnels liés aux monnaies locales et comment la tendance croissante à la digitalisation de ces dernières appelle à de meilleures solutions technologiques pour répondre aux problèmes de coût, de sécurité, et d'évolutivité. Nous analysons comment le modèle d'une monnaie locale basée sur la blockchain fonctionnerait d'un point de vue économique. Le choix d'un protocole de gouvernance approprié est important dans ce cas, mais il en va de même des incitations des agents tels que les mineurs et les validateurs à participer au processus. La deuxième partie du premier chapitre propose un cadre théorique pour analyser la possibilité de mettre en oeuvre un protocole de preuve de travail (PoW) aux monnaies locales. Les résultats analytiques évaluent les conditions de pérennité du système et les simulations numériques à partir du modèle illustrent les diverses spécifications des compromis entre les coûts et les avantages d'un tel système pour la population. Ils montrent qu'une gestion via le PoW est réalisable à différents stades de développement d'une monnaie locale. Le chapitre 2 explore le potentiel des monnaies locales en tant qu'outil de signal pour les produits de haute qualité et dans la promotion des circuits courts. Les conditions d'émergence et de répartition spatiale des magasins vendant des aliments biologiques produits localement, dans différents modèles de villes, sont favorisées par les monnaies locales. Nous élaborons sur cette base, des extensions du cadre spatial d'Hotelling et envisageons pour différents modèles de villes l'implantation possible de commerces capables de proposer des produits bio. Les scénarios de villes sont étudiés avec et sans la présence d'une monnaie locale. La reconversion des monnaies locales en monnaie officielle joue un rôle crucial dans la garantie de la qualité du produit puisque les conditions et les coûts de reconversion sont les mécanismes sous-jacents qui assurent la fonction d'effet de signal dans notre modèle. Le troisième chapitre est consacré à une étude empirique originale sur les facteurs intrinsèques influençant l'adoption d'une monnaie locale dans le cas de Cagnes-sur-Mer avec la monnaie locale Renoir. Notre approche consiste à aborder le problème en étudiant les caractéristiques des répondants pour certaines de nos variables d'intérêt et à établir un modèle prédictif pour l'adoption ou non de la monnaie. Les résultats du modèle révèlent l'importance de facteurs propres aux individus tels que le sentiment de solidarité, l'intérêt pour les activités communautaires, et l'expérience dans les mouvements économiques alternatifs dans l'adoption d'une monnaie locale. Les caractéristiques sociodémographiques telles que le sexe, le statut matrimonial, et le niveau de revenu semblent également jouer un rôle important. Cette étude exploratoire aborde le sujet du côté du consommateur, fournit des recommandations pour le développement du Renoir et contribue à la littérature liée à l'adoption des innovations sociales et technologiques. Les résultats de cette thèse fournissent un aperçu nouveau et stimulant sur l'application d'une technologie nouvelle à un système de paiement spécifique qui est celui d'une monnaie locale, sur la façon dont cette dernière peut servir d'outil de signal pour la qualité des produits, et sur les études des déterminants de son adoption.

Mots-clés : adoption d'innovations, effet de signal, modèle prédictif, soutenabilité, système de paiement

Complementary currencies, short distribution channels, and digitalisation

Abstract

This thesis proposes an analysis of the potential of local complementary currencies (hereafter local currencies) in addressing major problems concerning sustainability and technological innovation at the local level through different perspectives. The first chapter examines the application of an emerging technology, which is the blockchain, to manage local currencies. They are used to promote objectives such as short distribution channels, high quality products, and sustainable behaviours at the local level. The first part of this chapter exposes how the blockchain can help solve traditional issues related to local currencies and how the growing digitalisation trend of the latter calls for better technological solutions to ensure low costs, security, and scalability. We analyse how the model of a blockchain-based local currency would operate from an economic perspective. The choice of a proper governance (consensus) protocol matters in this case, but so do the incentives of agents such as miners and validators to participate in the process. The second part of chapter 1 proposes a theoretical setting to analyse the possibility of implementing a Proof of Work protocol to local currencies. Analytical results evaluate the conditions of sustainability of the system and numerical simulations from the model illustrate the diverse specifications of the trade-offs between the costs and advantages of such system for the population: a management via a PoW protocol is feasible in different stages of development for local currencies. The second chapter explores the potential of local currencies in promoting short distribution channels and in serving as a signalling tool for high quality products. In this regard, local currencies should help consumers and residents of the city adopt new consumption habits, and retailers to switch from selling standard goods to selling higher quality ones. Additionally, the conditions of emergence and spatial distribution of stores selling organic food that are produced locally, in different models of cities are fostered by local currencies. We elaborate on this basis, extensions of the Hotelling spatial setting and consider for different models of cities the possible location of shops capable of proposing organic products. The scenarios of cities are studied with and without the presence of a local currency. Reconversion of local currencies to legal tender plays a crucial role in guaranteeing product quality since the conditions and costs to reconvert are the underlying mechanics that ensure the function of signalling effect in our model. The third chapter is devoted to an original empirical study on the intrinsic factors influencing the adoption of a local currency by delving in the case of the city of Cagnes-sur-Mer: the Renoir local currency. Our approach consists in addressing the problem by studying the characteristics and preferences of respondents for some of our variables of interest and establish a model capable of predicting the adoption or not of the currency. Estimation results reveal the importance of factors proper to individuals such as the sense of solidarity, interest in community activities, and experience in alternative economic movements in the adoption of a local currency. Socio-demographic characteristics such as sex, marital status, and income level also seem to play an important role. This exploratory study addresses the subject from the consumer side, provides recommendations for the development of the Renoir, and contributes to the literature on the adoption of social and technological innovations. The findings of this thesis provide novel and stimulating insights on the application of a foundational technology to a specific payment system that is a local currency, on the way the latter can serve as a signalling tool for product quality, and on the studies of its determinants of adoption.

Keywords: innovation adoption, payment system, predictive model, signalling effect, sustainability

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GENERAL

INTRODUCTION

The last decade has seen a growing proliferation of community-based or complementary currencies around the world in response to the many issues of conventional money and the traditional banking system. Among those issues, we can point out a few of them that are considered as major such as the centralised governance, the inevitable inflation, and the lack of inherent power of conventional money to boost local economies and communities. Complementary currencies attempt to solve these problems through their specific functionalities and objectives. By complementary currency, we refer to any types of payment systems that are not legal tenders and operate generally around a community. Its definition greatly varies from one author to another, and there is no commonly agreed typology for now. For instance, Tichit, Lafourcade, and Mazenod (2017) distinguished currencies based on a list of criteria comprising their value (commercial, environmental, social, and/or solidary), their end-goal (lucrative, non lucrative), and their independence from legal tender in terms of creation and circulation. Martigoni (2012) suggested grouping complementary currencies according to four principles (purpose, trust, creation, and circulation), each composed of an additional five levels of ratings. Blanc (2011) proposed a more complex classification based on the generations to which the complementary currencies belong, and these generations are characterised by a type of monetary organisation and relationships with governments and the socio-economic world.

There are around more than 5000 complementary currencies according to the mapping work of Seyfang and Longhurst (2013), and most of them are based in Europe. Some prominent figures include the WIR in Switzerland, the Chiemgauer in Germany, the Bristol Pound in the UK, and the Eusko in France. The most common forms of complementary currencies are barter or mutual credit systems (time-banks and Local Exchange Trading Systems (LETS)), and local currencies. Complementary currencies aim to contribute to the achievement of many different objectives such as revitalising local businesses and fostering short distribution channels (Renoir currency in Cagnes-sur-Mer, France), strengthening social relations and community welfare (Fureai Kippu currency in Japan, the BerkShares and Ithaca in the U.S.), promoting and protecting local identities (Eusko in Basque country, France), helping people in difficulty and alleviating poverty (Palmas currency in Brazil and MonedaPAR in Argentina), acting as an alternative payment method during financial crises (Tem currency in Greece), as well as promoting sustainable behaviours. The effects of complementary currencies on the social, environmental, and economic spheres have been widely studied over the last decade (Boonstra et al., 2013; Groppa, 2013; Hayashi, 2012; Nakazato and Hiramoto, 2012; Zagata, 2012; Walker, 2009; Gómez and Helmsing, 2008; Seyfang, 2007).

Barter systems go way up to thousands of years ago around 4500 B.C. during the Phoenicians era, and have evolved since the 1980s into mutual credit systems using points and credits to exchange goods and services. Their limitations in terms of exchanges naturally entail the emergence of currency systems such as time-based (time banks) and local currencies. A local currency is a type of complementary currency which generally is restricted to a specific geographical area (*e.g.* a town, a city, or an agglomeration) and has a rate of exchange of one-to-one with legal tenders. It usually takes the form of paper notes like a common bank note with its own security features but can also exist in digital form. By

definition, a local currency is the closest form of currency to legal tender. Because of its nearly identical properties as fiat money, a local currency provides ease of use for consumers and most importantly, allows businesses to adopt and transact with it. It does not ensure the function of a store of value since it is designed to be spent and re-injected actively in the local circuit. There are around more than 300 local currencies worldwide. This specific type of complementary currencies will be the sole focus of this thesis.

With the advent of crypto-currencies in the past few years, the definitions of complementary currencies have become blurry, and require more precision than ever because they usually make ground for confusion and misconception. For example, it is not uncommon for people to instinctively associate Bitcoin with complementary currencies. Even though crypto-currencies aim to solve conventional money problems since they function in a decentralised way (removing the 'middleman'), and some of them have deflationary mechanics, they are considered as speculative assets and stores of value rather than mediums of exchange because of their extreme volatility, lack of consumer trust, and sometimes lack of real-world use cases (*e.g.* meme coins like Dogecoin). In this sense, crypto-currencies should be seen as an alternative currency rather than a complementary one. Local currencies substantially differ from crypto-currencies and a logical way to address this ambiguity would be to limit ourselves to the dimension of 'complementarity', *i.e.* the ability of a currency to function alongside legal tenders by having the same rate of exchange as the latter. On the one hand, the one-to-one rate of exchange with legal tenders totally suppresses the possibility of speculation, and on the other hand, the possibility of reconversion to legal tenders backs up business trust and thus, allow local complementary currencies to perfectly ensure the function of medium of exchange in an economy.

Nevertheless, we must be mindful of the fact that the most important notions of a local currency go way beyond its mere role as a means of payment that defends and promotes identity and ideological motives, or that is used for tax optimisation considerations (which is totally misconceived). Instead, one of them stem from its ability to act as a reliable signalling tool that helps consumers make better decisions in the face of information asymmetry (moral hazard and adverse selection) especially regarding sustainability issues. For instance, local currencies can be used to signal high quality and organic products, in which case they may replace the myriad of complex food labels that currently exist. Different mechanisms such as reconversion conditions for shops or controls by the administration of the currency can be put in place to achieve this objective. In the case of the Eusko currency, the association that manages the local currency use a different approach by making shops that want to adhere the association (*i.e.* accept the local currency and be part of the network) commit to completing one environmental challenge in two years (*Les défis de l'Eusko*, n.d.).

Given the ever-increasing complexity and puzzling features of local currencies, a proper management system is necessary for such projects to perdure and play the roles they are intended in conducting positive societal and environmental changes. Furthermore adoption, security, and costs issues are the principal concerns for small scale projects like local currencies. While crypto-currencies are beyond the scope of our interest, the blockchain

technology on which they are built has an enormous potential in managing and innovating payment systems in general. A few authors such as Friis and Glaser (2018), and Pinos (2020), have started looking into how blockchain could benefit community currencies but from a non-economic perspective. Provided the technology is still in its emergence phase and at times convolutive, it is of our interest to study it from an economic angle with a focus on a specific governance protocol, and on interactions between agents of the system. In the future, can the blockchain become one of the solutions for managing a nationwide network of local complementary currencies? And if so, in what way? The answers to these questions are the object of the first chapter of this thesis.

Considering the current state of the world where transition towards more sustainable economic models has become a priority and an ideal, recourse to short distribution channels and peasant agriculture have been continuously increasing over the last decade in cities and many industries (transport, clothing). These types of 'territorial innovation', considered as an engine of development and a marker of territorial dynamism, reveal the vitalities of territories even in those where there is not a strong technological intensity, high level of industrialisation, or specialisation of production (Torre, 2015). In economic structures like cities, cooperation between agents and their interactions in terms of consumption habits for residents and the choice of products that retailers sell have a substantial impact in contributing to the sustainability transition. Every city has a different configuration from one another, and the proximity of shops to consumers has always played an important role in the planning and decision-making processes of agents. In this respect we are interested in studying the conditions of emergence and geographical distribution of shops selling products of various quality ranges in different models of cities. Local currencies in this case can help foster consumers' adoption of sustainable consumption habits because it can be used as a signalling tool for high quality products in lieu of food labels. The way local currencies achieve this is discussed in the second chapter of this thesis.

Every now and then, new experiments of local currencies emerge. Unfortunately, the lack of standardised methods and indicators to measure the impact of local currencies, let alone analyse their adoption pattern, has partially made them and complementary currencies in general difficult to grasp within conventional economics (Fare and Ahmed, 2017). Besides to this day, we do not have a clear understanding yet as to why people would adopt this or that currency, what are the preliminary studies that must be carried out before launching a project, or what type of population is more likely to use a local currency, if there is any. This issue has an adverse effect on the development of complementary currencies and their legitimacy in the long run. Most empirical studies on the topic focused on the motivations of users and the conditions of success of the projects. They tend to make use of documentary and interviews data from project leaders and members rather than from consumers (users and non-users) and there are also hardly any proper statistical methods used. The determinants of adoption of local currencies has never been studied before in the literature. To fill this gap, it is of our interest to approach the issue through a novel approach aiming to capture the intrinsic factors that could influence the adoption or not by consumers of a specific payment system that is the local currency. In the case of the city of Cagnes-sur-Mer in the French Riviera, the Federation of associations of merchants launched a local currency

called the *Renoir* in 2016 with objectives to revitalise the city centre shopping environment and to promote short distributions channels and sustainability practices. The local currency has been experiencing some challenges throughout its development in terms of project and user management, and communication. Along with these managerial and marketing problems and despite its remarkable volume of transactions in 2020, the project seems to face challenges that curb the growth of its number of users which has been stagnating, if not decreasing. To contribute to the scarce literature of empirical studies on complementary currencies, and to explore the intrinsic factors influencing the adoption of a local currency, we dedicate the third chapter of this thesis to this matter.

Objective and structure of the thesis

This thesis aims to study the potential of local complementary currencies in addressing major problems concerning sustainability and technological innovation at the local level. We achieve this by tackling the subject through different perspectives that are analysed in three chapters.

The first chapter is organised in two parts. The first part examines, without theoretical modelling, the application of the blockchain technology to local complementary currencies through two consensus protocols: the Proof of Work (PoW) and the Proof of Stake (PoS). Given the increasing digitalisation of local currencies, and the challenges affecting their management and operation, we analyse the potential of a technological solution in addressing these issues. We provide a description of the main features of the blockchain technology, its potential and applications in numerous sectors along with a detailed comparison of the PoW and PoS protocols. After reflecting on the management and digitalisation landscapes of local currencies, we analyse how the model of blockchain-based currency will operate from an economic perspective. We find that the choice of a proper governance protocol matters in this case, but so do the incentives of agents such as miners and validators to participate in the process.

The second part of chapter 1 proposes a theoretical setting to analyse the possibility of implementing a blockchain governance to local complementary currencies. The local currency that we capture is used to promote objectives such as short distribution channels, high quality products, and sustainable behaviours at the local level. Its viability relies on the ability of shops to support their engagement in the advantages derived from the use of the currency, on the interest of consumers in said advantages, and on the cost of the governance method used. The blockchain solution appears to be suitable in this specific setting that requires a substantial level of security and reproducibility. The model that we develop encompasses a control by the issuer or administrator of the currency of the advantages perceived by heterogeneous consumers. It also integrates the specifications of the blockchain (rewards of miners in a PoW protocol, number of transactions per block) and their cost for the collectivity. Analytical results evaluate the conditions of sustainability of the system and numerical simulations from the model illustrate the diverse specifications of the trade-off between the costs and advantages of such system for the population. Our findings from chapter 1 provide novel and stimulating insights on the application of a foundational

technology to a specific payment system and serve as a basis for future studies on the subject.

Chapter 2 explores the potential of local complementary currencies in promoting short distribution channels and in serving as a signalling tool for high quality products. What are the consequences of the implementation of a local currency which promotes short distribution channels on the type, location, and density of shops of a city? We elaborate on this basis, extensions of the Hotelling spatial setting and consider for different models of cities the possible location of shops capable of proposing organic products. The scenarios of cities are analysed with and without the presence of a local currency. Reconversion from local currencies to legal tender play a crucial role in guaranteeing product quality since the permission, conditions, and costs to reconvert are the underlying mechanics that ensure the function of signalling effect in our model. In this regard, local currencies should help consumers and residents of the city to adopt new consumptions habits, and retailers to switch from selling standard goods to selling organic goods.

The third chapter makes use of survey data and draws on the literature of consumer adoption of social, technological, and 'green' innovations, and previous empirical studies on complementary currencies to explore the intrinsic factors influencing the adoption of a local currency. We delve in the case of the city of Cagnes-sur-Mer with their local currency, the Renoir. Our approach consists in addressing the problem by studying the characteristics and preferences of respondents for some of our variables of interest. The original design of the study combines various survey and statistical tools to establish a model capable of predicting the adoption or not of the local currency via a set of parameters estimates selected by our analyses. Estimation results reveal the importance of some embedded intrinsic factors pertaining to the community and emotion dimensions of individuals, confirming past findings from the literature on the adoption behaviour of such innovation product. A few novel socio-demographic characteristics also seem to play an important role in the outcomes of our model. Regrettably and as expected, some factors relevant to the objectives of the local currency project failed to properly affect the adoption choice of consumers. These results hint at a few underlying issues such as the lack of employees, customer management, proper preliminary market studies, and communication effort from the administration team. The digitalisation of the currency in this case may not really prove to be helpful for improving the adoption if the latter does not depend on the form of the currency but rather on the target population and administration itself. This exploratory study addresses the subject from the consumer side, and serves to provide interesting insights (some never preconised before in the literature) on the determinants of adoption of a payment system, and recommendations for the development of the Renoir as well as for future research related to the subject of local currencies.

Chapter 1
Part 1

WHICH KIND OF BLOCKCHAIN APPLICATION FOR LOCAL COMPLEMENTARY CURRENCIES?

A product of the first part of this chapter is based on a joint research with Dominique Torre and has been published in the *Revue Économique* journal:

Seang, S. and Torre, D. (2021).
Which Kind of Blockchain Application for Local Complementary Currencies?. *Revue économique, 7*(7).

The blockchain technology has sparked much interest around the world in recent years, and its applications are being tested across many sectors such as finance, energy, public services and sharing platforms. Although the technology has not matured sufficiently to be operable in all domains, and is being subjected to numerous ongoing experiments, the potentially diverse benefits and opportunities deriving from its decentralised and open-to-innovation nature are attracting huge attention from researchers and investors. Its mainstream adoption will take time and will require a certain degree of novelty and a certain level of technological, social and regulatory effort to coordinate it (Iansiti and Lakhani, 2017). The first ever and most well-known application of the blockchain is the Bitcoin. Its advent has triggered the emergence of thousands of other crypto-currencies, each with different aims and properties. The controversial success of crypto-currencies has promoted the blockchain as one of the symbols of a globalised market without seat nor frontiers, which facilitates speculation and promotes anonymous mechanisms and irresponsible behaviours. As a counterpoint to this universe without distance and identity, have also emerged from the late 2010 decade new needs for authenticity, proximity, local anchoring, that echo with the rise of ecological attitudes and as a reaction against the scourge of standardisation. Local initiatives have emerged to allow local government and citizens to re-appropriate for themselves distribution channels, to develop traceability, to revitalise the commercial activities of their city centres,...*etc.* This paper wishes to point out the role of the blockchain in these local universes, where proximity makes actions less anonymous, and where sustainability is frequently a substitute for profitability. In these local circles, the blockchain should surely have its place, but we cannot imagine reproducing *stricto sensu* the same model that was adopted for crypto-currencies.

Provided the increasing digitalisation of local currencies, and the current challenges affecting their management and operation, we analyse the potential of a technological solution in addressing these issues. The objective of this paper is to analyse the application of two blockchain consensus protocols to manage a local currency or a network of local currencies. The case of local currencies with a blockchain is different from the case of crypto-currencies as there is no speculation possible due to the one-to-one fixed exchange rate with the legal tender, and the geographical limit of use for local currencies. These specificities, combined with those of the blockchain, allow for a relevant study of two models of blockchain-based solutions with heterogeneous agents who interact with each other and have different objectives and characteristics.

The paper is organised as follows. The second section describes the main features of a local currency and the motives behind its recent increasing digitalisation. The third section provides an overview of the blockchain technology - its foundations, and its application in different sectors. The fourth section 4 analyses the blockchain application in the context of local currencies by addressing the potentials of the technology, the two models of consensus protocols (Proof of Work and Proof of Stake), and the eventual concerns for such application. The fifth section exposes the alternative consensus protocols, opens the discussion and provides some suggestions for further research. The sixth section concludes the paper.

1. Local currencies and their digitalisation

1.1. Management of local currencies

The local currency issuer or project leader is usually a non-profit association but could be a local government or a merchants' federation or association. Management of the currency is ensured by the issuer, or can be delegated to an external financial agent. This management includes printing the notes if the chosen form is fiat money, providing conversion services through exchange offices (usually merchants who accept the local currency) and determining the properties of the local currency *i.e.* additional advantages to the users such as a 10% benefit when converting from legal tender to local currency, or guaranteed access to higher quality products. The issuer generally deposits legal tender which are converted by users at a partner bank. Generally, one means of covering the operating expenses of the local currency is to charge a percentage to merchants reconverting the local currency. This could be perceived as a constraint to adoption of the local currency but is actually an additional incentive for merchants to find business partners or ways to re-inject the money back into the local community.

In general, businesses that accept a local currency must adhere to the community values and abide by specific rules which generally are defined by a chart (*e.g.* guarantee ethical and sustainable practices by its members, and high quality of products sold in the community (Blanc and Fare, 2016)). For instance, in the French Basque country, merchants who accept the local community currency (Eusko) as a payment must display product labelling in both French and Euskara since one the objectives of the association is to promote and protect use of the local language (*Statuts de l'Association Euskal Moneta - Monnaie locale du Pays Basque*, n.d.). If the local currency takes the form of notes, security features such as specially watermarked paper and bubbles patterns protect them from counterfeiting and provide assurance of their authenticity. In general, there is a fixed one to one exchange rate between the local currency and the legal tender which reduces the possibility of speculation. To avoid local currency hoarding, several different methods may be employed. For instance, some local currencies are defined as melting currencies *i.e.* the local currency note loses $x\%$ of its value if it is not spent within a given period of time (usually a few months) so there is an incentive for currency holders to spend it as quickly as possible which increases the velocity of circulation of the currency.

1.2. Digitalisation of local currencies

Some local complementary currencies exist only in digital form, for instance the *SoNantes* currency in the Loire Atlantique county in France. These digital currency forms usually are administered by one or a few central entities such as a bank or an information technology (IT) firm. Recent years provide many examples of local currencies originally introduced in the form of notes and transitioning to a digital version. The change to digital version is a crucial milestone on the path to an improved local currency; it especially alleviates the burden associated to traditional paper based business-to-business (B2B) transactions in local

currencies (Blanc and Fare, 2018). Groppa (2013) finds also that the spending multiplier is greater in digital community currencies systems compared to the regular money market. Having a digital version of a local currency may also signify a better control of the money supply, and of the transactions' management, since most of the tasks and statistics are automated. Taking the example of the Eusko, which is the most important local currency in Europe, it is available in both in notes and digital form. Therefore, the motives behind digitalisation of a complementary currency might be multiple: elimination of paper printing costs, facilitating B2B transactions, reducing administration costs and reliance on third-parties, and increasing the likelihood of attracting younger users, alongside all the potential benefits and opportunities that can be derived from use of a decentralised management solution such as blockchain. The advantages derived from the use of the blockchain in different sectors will be discussed in section . Table 1 provides an overview of local currencies in Europe that have transitioned or are in the process of transitioning to a digital form, and those already in digital form. It is therefore reasonable to imagine decentralised solutions to managing these currencies that would not include banks or other financial agents (with a possible monetary motivation). Application of the blockchain via different consensus protocols could be relevant in this context.

Currency name	City/Town/Area of use	Country	Form
Boniato	Madrid	Spain	Digital
Bristol Pound	Bristol	United Kingdom	Notes & Digital
Brixton Pound	Brixton	United Kingdom	Notes & Digital
Chiemgauer	Prien am Chiemsee	Germany	Notes & Digital
Eusko	Pays Basque	France	Notes & Digital
Gonette	Lyon	France	Notes & Digital
Grama	S. Coloma de Gramenet	Spain	Digital
Kingston Pound	Kingston	United Kingdom	Digital
Léman	Lake Geneva	France/Switzerland	Notes & Digital
Pive	Franche-Comté	France	Notes & Digitalising*
Racine	Chevreuse Valley	France	Notes & Digitalising
Renoir	Cagnes-sur-Mer	France	Notes & Digitalising
Sol-Violette	Toulouse	France	Notes & Digitalising
Sonantes	Loire-Atlantique	France	Digital
Stück	Strasbourg	France	Notes & Digitalising
Trèfle	Périgueux	France	Digital
Turuta	Vilanova i la Gellrù	Spain	Digital
Vilawatt	Viladecans	Spain	Notes & Digitalising

Table 1: List of digital local currencies in Europe as of December 2019 (non-exhaustive)

*In the process of or considering a digitalisation according to the official website of each currency. The same applies to the Renoir, the Sol-Violette and the Stück currency.

2. The blockchain technology

2.1. Overview and applications of the technology

A blockchain is a general purpose technology and a type of distributed ledger technology (DLT) which is secured by cryptography. A DLT is a record-keeping system where all or some of its users possess a copy of the ledger and cryptography is the science of mathematical codes and techniques to enable secure communication with unknown third parties (Pilkington, 2016), so the blockchain is a cryptographic-based DLT. Information is gathered into blocks that are linked to one another and constitute a chain of information that is immutable, therefore serving as a proof of existence of a transaction, or of any type of information at any given point in time. Because there is no central authority to regulate and control the system, consensus among users is paramount to guarantee the security and sustainability of the system. This is valid for a public or permission-less blockchain but for private, permissioned, or consortium blockchains, one entity or a group of entities can control who sees, writes and modifies the data on it. The decentralisation aspect is essential and is the core value in the blockchain, so in what follows we consider only the case of a public blockchain. Global agreement on the blockchain is facilitated by the implementation of a consensus protocol which dictates the rules by which users must play and abide.

The blockchain technology is being studied and tested in many sectors including finance, energy, cybersecurity, healthcare, government services and e-residency. Fully functional blockchain applications include control of supply chain management using the Everledger blockchain which tracks diamonds (from their discovery to their final form) and guarantee of the authenticity of diplomas (at the École Supérieure d'Ingénieurs Léonard-de-Vinci in France). Wolfond (2017) explains how implementation of a decentralised and collaborative identity verification model based on the blockchain that possesses certain characteristics could allow for a substantial reduction in the healthcare and government services costs in Canada which would benefit businesses and citizens. Kshetri (2017) presents the example of a blockchain applied to the healthcare industry to point out the potential improvements in terms of security and privacy, and the possibilities for the technology to resolve certain major problems related to the current cloud-based Internet-of-things (IoT) systems. In the energy sector, blockchain applications via Ethereum-based smart contracts are being tested to understand distributed market coordination and data management architectures for decentralised energy systems (Hukkinen et al., 2017). Sullivan and Burger (2017) examine the legal, policy and technical implications of the development of e-residency in Estonia. According to the authors, Estonia is the most advanced country in the world in terms of government-backed programs for consumers' digital identity at their time of writing. The system has minimal identity requirements and authentications and allows nationals from any country to engage in a range of economic activities in Estonia.

From an economic perspective, Catalini and Gans (2016) discuss how the reduced verification and networking costs allowed by the blockchain system change the types of transactions supported in the economy. They analyse the implications for intermediation and argue that although blockchain implementation would hugely reduce the market power of

intermediaries, they would remain necessary for some offline tasks that still required human verification. Ølnes et al. (2017) conducted an assessment of the potential blockchain benefits identified in the literature, and classified them into different categories: strategic (transparency, fraud and manipulation avoidance, corruption reduction), organisational (increased trust, predictive capability and control, transparency and suitability, clear ownership), economic (reduced costs, spam resilience), informational (better data integrity and quality, reduced human error, access to information, privacy and reliability) and technological (resilience, security, persistence and irreversibility, reduced energy consumption). They found also that a robust governance model is a condition for blockchains to yield benefits.

In the banking industry, Guegan (2017) addressed various issues related to use of private blockchains to reduce costs, increase security and simplify bank operations. He emphasised that the current benefits to be derived from blockchains are more applicable to a public, and hence a decentralised model. The work of Guo and Liang (2016) explores the potential advantages related to clearing and credit information systems, and regulation, efficiency and security issues in the context of blockchain implementation in the Chinese banking industry. They conclude that those problems will be solved over time, and the technology will be incorporated in the future. In the case of payment systems, Ripple is an interbank solution which allows high speed transactions (across the world in seconds), transparency and simplicity for users. It seeks to create a universal payment protocol and uses a digital currency called XRP for blockchain transactions (Schwartz et al., 2014). Similarly, Jaag and Bach (2016) present the possibilities related to using blockchain for postal financial services to improve financial inclusion, and the creation of a postal crypto-currency to counter the high levels of volatility that plague most crypto-currencies. By backing coins with a national currency such as the US dollar, projects like CryptoBucks (Conley, 2017) and stablecoins like Tether (USDT) and USDC, seek to overcome the market volatility of crypto-currencies, induce consumer trust, and enhance ease of use and financial connections to the outside world. In the context of creating contracts and programs, the Ethereum blockchain allows its users to build, buy and sell smart-contracts based on the currency Ether which is the second largest crypto-currency in terms of market capitalisation according to CoinMarketCap (https://coinmarketcap.com) at the time of our writing.

2.2. The Proof of Work and Proof of Stake consensus protocols

The first blockchain system application employed the PoW consensus protocol as its backbone and was introduced in the Bitcoin network in 2008 by Satoshi Nakamoto. Collomb and Sok (2017) describe the Bitcoin system as a combination of past developments: Napster's 1999 peer-to-peer (P2P) protocol (a music exchanging platform), the 1970 cryptographic hash functions and encrypted block chaining mechanism, the 1993 PoW introduced to combat spamming, the 1979 Merkle tree compression mechanism to stock and manage big data and the concept of timestamp introduced in 1990 to ensure good IT security protocols. Since 2008, the Bitcoin blockchain has served as a reference for studies and applications of the technology.

In the PoW protocol, it is the combination of cryptography and computational power

which creates the consensus and ensures the authenticity of the data recorded on the blockchain. Other features inherent to the system such as the size of the blocks, their generation rate and the money supply limit are defined in the protocol. In the case of Bitcoin, block size is around 1 megabyte, generation rate is around 10 to 12 minutes, current bounty is 12.5 Bitcoin which is halved every 210,000 blocks or every 4 years, and the money supply limit is 21 million Bitcoins with the difficulty of the network readjusted every 2016 blocks or every two weeks. The PoW design varies greatly among crypto-currencies. For example, Litecoin has a money supply limit of 84 million Litecoins and a block generation rate of only 2.5 minutes (a.k.a finality time). This frequency may be more appropriate for small transactions such as online products or food deliveries which require only a few confirmations from the receiver (number of blocks following the block containing the transaction required to prove that the operation is authentic). Other coins with considerable market capitalisation that use the PoW besides Bitcoin include Ether, Monero, and Dogecoin, just to name a few.

To show that a block is valid and that the necessary work has been completed, the network nodes (or miners) use their computational power to validate the transaction (*i.e.* verify that the sender has sufficient funds and is not double-spending), and most importantly, compete in the race to solve the cryptographic problems imposed by the protocol. Technically, miners need to find a hash value that is less than a certain number (the target or difficulty level), usually a number with leading zeros. To achieve this, random guesses are generated by adding and varying a nonce (an integer value) to the hash of the block. This process is called mining.

The incentive for miners to join the race is twofold: the first miner to find a solution is rewarded with a bounty defined by the protocol and gets to collect all the fees associated to the transactions (borne by and varying among the users involved in the transactions) that they choose to include in the block. When a miner finds a solution, he / she creates a block X by including the hash of the previous block, the time stamp and the transactions. The miner broadcasts the newly created block X to the network and other miners verify the transactions and validate the block. The block is considered legitimate if other miners continue to work on extending the chain from block X. When a chain splits, miners will always choose the longest chain since this represents the most work. Miners can work on multiple chains but to the detriment of their computational power which is correspondingly reduced.

A miner's computational power plays a deterministic role in the PoW protocol since the greater the capacity to generate guesses (measured in hashes per second), the higher the probability of finding a solution. The computers run at full capacity 24 hours a day, thus the mining process consumes considerable amounts of electricity. That makes the PoW a extremely resource-intensive model, and the time and energy involved serve as proofs that the work has been done. In 2014, the total power consumed by the Bitcoin network was equal to the total electricity consumption of the island of Ireland (O'Dwyer and Malone, 2014). This protocol was approved by users and miners, and its wide adoption by other crypto-currencies has made it popular and recognised as a successful model. However, de-

	PoW	**PoS**
Security ensured by	Miners	Validators
Block creation	By capacity of hardware	By amount of deposit
Type of rewards	Block bounty + *transactions fees*	Transactions fees
Units creation	Degressive	None

Table 2: Simplified differences between a PoW and PoS protocol

spite this, the future of the PoW remains unclear because it was not designed initially to manage a speculative asset which Bitcoin has become.

As Zhang (n.d.) puts it: 'Like all distributed systems, blockchain systems are challenged with network latency, transmission errors, software bugs, security loopholes and black-hat hacker threats. Moreover, its decentralised nature suggests that no participant of the system cannot be trusted'.[1] Malicious nodes may emerge, as does data difference due to conflicting interests.' Problems inherent in distributed and decentralised systems continue to constitute a threat to their large scale implementation. In theory, the PoW system can be attacked if a lone miner or a group of miners control more than half of the network's total mining power. This is described as a 51% attack. In practice, attackers would create their own secret chain and once it exceeded the length of the honest chain broadcast it to the network in an attempt to double-spend or compromise the whole system. This new chain would be considered valid by other miners based on it being the longest chain, and these others would move on to work on subsequent blocks. At the start of 2014, the *G.HashIO* mining pool was near to reaching 51% then, fearing an attack several miners left the pool (CoinDesk, 2014).

The alternative to the PoW is the PoS protocol. It confers decision power on system stakeholders (called validators, minters, or forgers). Unlike the PoW where everyone can become a miner and participate in the process, not everyone can join the PoS protocol network. Ownership of a currency or having a deposit in the network allows nodes (validators) to participate in the minting process (*i.e.* validating transactions and creating blocks.) Again, unlike the PoW system, no computational power is required to solve cryptographic puzzles. There are no rewards in the form of a money creation process: validators usually collect fees from users and are paid by them as an intermediary. Many forms of PoS protocols exist and each version has its own set of rules and properties that constitute new variants (*e.g.* capped maximum supply for some coins and no cap for others). Some heuristic projects include coins like NXT, Neucoin, Blackcoin, Tendermint, and Bitshares (Kiayias et al., 2017). Overall, the main differences between the PoW and the PoS are simplified and summarised in table 2 along with a list of crypto-currencies that use the PoW and pure form of the PoS.

Since validators receive only transaction fees, the scenario in which validators create empty blocks is avoided because they have an incentive to include the maximum number

[1] We believe the author made a typographical error and the phrase should be understood as '*no participant of the system can be trusted*'.

of transactions in order to maximise their gains. In the Bitcoin network miners can create empty blocks which contain only the coin-based transaction (their reward transaction), *e.g.* at block height 459713 (https://blockchain.info/block/00000000000000001bf525682830b4f77612eb36c2e73754345a7f91aebf7ea). One of the reasons for this behaviour is that miners prefer to conserve their hash power and time to work on subsequent blocks rather than including transactions in current blocks.

If the money supply is based on what is issued originally (no money is created in this case), one problem that may arise is the initial fair coin distribution at the launching phase. Moreover, if the PoS includes a selection process for validators (the greater the stake, the higher the probability of being selected as the creator of the next block), then additional balancing mechanisms are required to mitigate the risk of rich validators getting richer. One way of addressing this issue is to combine the PoW with the PoS. For instance if we look at the case of PeerCoin, it is a crypto-currency which employs a PoW scheme for its initial deployment phase and a PoS-based protocol (Delegated PoS) to validate transactions and reward their validators (King and Nadal, 2012). It uses the *Coinage* concept and a stochastic PoS minting process. The duration of an unspent coin determines its *coinage* *e.g.* an individual who holds 4 coins for 10 days will have accumulated 40 coin-days and will have 4 times more chances to generate profit compared to someone with 10 coin-days. Once a miner is chosen to create a block, his/her coinage resets to zero and the individual must wait to accumulate coinage again. The minting process is designed to yield around 1% profit per year.

Another problem related to PoS is the *nothing-at-stake* case which means that it costs a validator nothing to vote for more than one block. Peercoin, as an early adopter of the PoS, did not escape from this issue. One way of solving this problem is for instance to allow validators to vote only once or to penalise them heavily if they vote on more than one chain. In practice, it may be more complicated to solve this problem due to possible network delays and latency issues which might cause validators to receive offset chain information.

3. The blockchain application for local currencies

3.1. Potentials of the blockchain for local currencies

• Removing intermediaries and improving management

One of the main ideas behind the Bitcoin is to allow individuals to transfer money between each other without the need of a bank, or to put it simply, a third-party who acts as a financial intermediary. As this is made possible thanks to the properties of the blockchain, in the same way, the technology can be used to free small communities from banks and third-party I.T. companies by respectively allowing transactions to occur without the need for confirmation from a bank and establishing a direct connection between the managers of the local currencies and the users for technical specificities.

As such, payments made by a user to a shop owner can occur instantly without asking for confirmation to a middle-man. Sending and requesting money can be done in the same way. In the traditional model, the technical team is distinct from the managerial one whereas for a blockchain-based local currency, the technical and managerial are regrouped under one entity that is the administrator. For the technical aspect, by not depending on a private I.T. solution, issues can be directly addressed between the users and the administrator of the local currency.

• Becoming a cost-competitive alternative

Compared to other digital solutions in the complementary currencies marketplace nowadays, the blockchain may appear as a more cost-competitive alternative. A well-known solution to community currency management is online and mobile banking software *Cyclos*. The costs of using a private software such as Cyclos can amount to 8000 euros per year (*Cyclos price list*, 2016). Their price vary according to the size of the project (number of users and turnover) and there are additional fees for the installation, the licence and the yearly maintenance of the platform. This could represent an extremely high investment for small communities. In addition to the cost, third-party centralised systems are vulnerable to cyber-attacks and most important, local currency communities are heavily dependent on them if they wish to add specific features (additional cost) or encounter technical issues.

Com'Chain, a private for-profit blockchain-based solution operating on the Ethereum blockchain, currently manages the e-Leman local currency in France and Switzerland (*Présentation Com'Chain*, n.d.). In the case of the Eusko, the company offers their service with a cost of up to 20000 euros per month if the entire service is delegated to the company, according to Pinos (2019). The example of the peer-to-peer and zero-interest mutual credit system of MonedaPAR in Argentina running on the Bitshares blockchain shows that it costs as low as 0.5$ PAR to perform a transaction (*Comenzá hoy a usar tu Billetera Digital Par*, n.d.). Furthermore, as the blockchain is becoming more mainstream, and if blockchain-based local currency projects emerge more and more from the local authority, or communities with non-lucrative objective to serve the public interest, we can expect the possibility of a much lower cost solution to implement a blockchain-based solution in the very near future since the open-source nature of the technology allows for greater flexibility, rules and system designs.

• Increasing legitimacy and credibility for stakeholders

One of the many challenges that local currencies face is the lack of impact measurement tools to support their legitimacy amongst stakeholders and the public (Fare and Ahmed, 2017; Place and Bindewald, 2015). It has always been difficult to measure the efficacy, let alone the actual impact of a local currency initiative over the community due to several factors that are sometimes inherent to the ways the project is implemented. Digital tools help to automatise various tasks and ease the record-keeping work for many local currencies but it usually comes at the cost of third-party dependency and transparency issues. With a blockchain-based local currency, records of transactions could be publicly accessible and because of its immutable property, the counterfeiting and double-spending issues are avoided,

and stakeholders can fully trust what they see and act accordingly. The open access nature of the blockchain makes is a community-rooted initiative and implies open collaboration from any or potential stakeholders that may want to participate and improve the local currency community.

3.2. Model of a blockchain-based local currency

A blockchain associated to a local currency is introduced in the usual interactions of the community's stakeholders: administrator/issuer of the currency, its users, and its member shops, with whom miners/validators interact. The incentives of this community are intrinsic for the most and have no reason to change radically with the introduction of the blockchain. For-profit local currencies also exist (such as the Renoir in Cagnes-sur-Mer in France with multiple goals in which one of them is to help local merchants) but they are infrequent as most initiatives are solely centred around societal and environmental objectives rather than economic ones. Only the validation of transactions and the nature of incentives and payments for miners/validators differ from the case where a centralised system is used. For transparency and traceability purposes, the blockchain-based solution for local currencies should be made public, and could employ a PoW or a PoS consensus protocol. It would interact with other members of the community as follows:

• Miners or validators

Miners or validators could be or not be members of the community associated to the local currency project. When they are members, they generally have intrinsic incentives like improving the security of the system. They are in this case comparable to the developers of Open Source communities: their contribution is motivated by signalling effects on job markets, or by their implication in other initiatives of the local government. They could also be physically distant from the local complementary currency ecosystem and operate simultaneously as miners or validators of other blockchains: in this case, their motivation would probably be more extrinsic and associated to the gain generated by the rewards they expect from mining or staking.

• The administrator of the local currency and its interaction with miners and validators

Local currencies are usually administered by people who act as volunteers or through local governments. This form of governance could be maintained with the introduction of a blockchain. The administrator issues at a fixed exchange rate the local currency in counterpart of the legal tender. It also operates the retro-conversion of complementary currency into legal tender, for member shops (participants of the local currency network) who wish to. The administrator team is complemented by I.T. specialists who ensure the technical and technological aspects of the digitalisation. In the same way, the administrator defines and modifies if necessary the conditions of admission for member shops in the community. The amount of rewards is also controlled by the administrator. For the reserve of legal tender, the administrator should place it preferably in a mutual bank for ethical purposes,

conforming to social and solidary economic movements. The management and technical teams constitute the administrator agent.

- **Users of the local currency**

Users are citizens who live in or near the geographical area in which the local currency is accepted. They may use the local currency in a regular or irregular manner according to their convictions in the values that the local currency conveys, promotes and protects. They are motivated by the objectives of the community which could be to develop short distribution channels, fair trade, organic productions, *...etc.* They cannot convert local currency into legal tender and have to pay a very small fee for each transaction. This fee is a part of the rewards served to miners and validators.

For users, the local currency is stored and managed in a digital wallet. A private and public key will be issued for each user, and the operation principles are the same as a cryptocurrency wallet. Via the digital wallet application, users can convert legal tender into local currency via credit card and bank transfer, pay merchants, and transfer local currency from peer to peer.

- **Member shops**

Member shops (grocers, mini-markets, clothing stores, pubs, restaurants, *...etc.*) are located in the area of circulation of the local currency and accept the local currency as a means of payment. They are authorised to convert the local currency into legal tender if they sign and adhere to a chart of values defined by the local currency community. This commitment provides the intrinsic motivation for users. For instance, they commit to be respectful of the environment, to sell local and/or organic products, to promote short distribution channels, to reduce and prevent waste, to improve their packaging design, *etc.* The conversion from local currency to legal tender entails a small fee percentage, which will complement transaction fees from users to fund validators' rewards. The idea behind the fee is to encourage B2B transactions so that the currency keeps circulating in the community.

- **Payments**

When the motivations of miners/validators are intrinsic, rewards are only optional. On the contrary, when they are are extrinsic, they must be adapted to the type of consensus protocol.In many situations, public blockchains would host miners/validators who have different motivations: this context requires to address the payment question in a more serious way. With the PoW or PoS protocol, a lottery or a contest, combined with another criterion (the performance of mining equipment or the validator's stake), determines which miner/validator will be paid. With this system, the total validation cost, *e.g.* the financial contribution of the community to the validation activity does not depend on the number of miners/validators but only on the number of transactions/blocks to validate. However, the expected payment for each miner/validator decreases as the total number of miners/validators increases since their probability to win the lottery or the contest depends

on the number of total participants in the network.

Each time the rewards proposed by the administrator increase, there is an entry of participants in the network, and the opposite occurs when the rewards decrease. Given opportunity costs and other costs supported by miners/validators, the number of effective miners/validators then increases with the rewards. The blockchain network must be sufficiently active to be efficient and reliable: this creates a lower bound for a decrease of rewards and generates a trade-off for the administration between cost and reliability.

- **Operation of the model**

The administrator has the leadership and the authority to make decisions. It evaluates the reactions of other stakeholders to its possible choices: what kind of commitments are appreciated by users, which ones are enforceable, what terms for the trade-off between cost and reliability of the blockchain application? In time, given in particular the number of effective transactions but also the evolution of the technology, the administrator could adjust fees, reconversion penalties, and the amount of rewards. This control has its specificities depending on the consensus protocol employed.

- **Proof of Work protocol (PoW)**

In the case of a PoW validation system, the computational power of miners is important both for validating transactions, and for determining the individual probability for each participant to win the rewards. Now, the computational power of each miner evolves in time with technological progress and costs of equipment. The number of potential miners also evolves because of different circumstances as the available existing of opportunities in other I.T. activities. These changes could modify in time the number of effective participants to a given blockchain. If this question is not so relevant for crypto-currencies where the number of miners is rather large, it could become critical for local currencies if they are not constituted in networks. It is then important to control that technological innovations do not create distortions such that the heterogeneity between the computational power of the most and the less efficient miners increases during time. All increase of the heterogeneity among miners could crowd out the less efficient participants, weaken the reliability of the system and increase the risk of attacks.

It is inefficient for an individual miner to spend energy to create malicious blocks, since they can be verified by other miners and a block is considered valid only if there is a majority of miners who confirms it. However, if malicious miners pool their mining capacity together (which is the equivalent of voting power) sufficiently to obtain at least 51% of the total network power, they could agree to vote or validate on whatever they wish to. In the case of Bitcoin, the share of mining pools is publicly accessible via https://blockchain.com/pools. We could imagine the same situation for a single or a network of local currencies where miners have access to information about their blockchain network at all time. This is known as the 51% attack which remains an important threat in the PoW protocol. The income generated by those attacks may be limited to a single local complementary currency but if many local currencies are associated to form a network, it becomes much more interesting

for malicious miners to conduct an attack as they can have access to a more important amount of local currency that can be spent or converted in legal tender.

To prevent this risk, the administrator first needs to maintain the rewards at a sufficiently high level. This control regulates the concentration of the miners' network. If this concentration increases, it is indeed easier for the most efficient participants to constitute a pool that can control 51% of the network power. The control could however be imperfect if it is limited to the adjustments of rewards. Each member of the blockchain network can contribute to the validation of the transactions of many local currencies and the administration of one single currency has only a limited influence on the global structure of the network. This fluidity of the miners' network must encourage administrators to cooperate in the determination of rewards and to coordinate their actions, including different forms of monitoring.

• **Proof of Stake protocol (PoS)**

In the PoS protocol, the validator must first convert in the local currency the revenue (in legal tender) it intends to transmit to the future. In this case, the heterogeneity of the participants is no longer determined by the computational power of their mining equipment but by their capacity to constitute deposits, and by their preference for the present which determines for most the cost of opportunity associated with those deposits. Wealth or liquidity and time preference then determine the decision of each potential participant to contribute and their probability to win the lottery and the rewards. All things equal, increasing the rewards also increases the size of the blockchain's network, and again, the smaller the size of a given local currency, the less efficient the adjustment of rewards.

However, this positive effect of rewards is less decisive in the PoS case than in the PoW one. Increasing the number of participants still increases the rapidity of the mechanism but it does not help radically to prevent attacks. In the PoS case, attacks are indeed not generated by pooling mechanisms buy are for the most individual initiatives. They are associated to the possibility of each validator to mint (bet on) several blocks (branches) simultaneously and consequently increase their probability of winning. When a chain has forked for different reasons, each validator has indeed the possibility to mint several blocks at the same time, without increasing its deposit, and to increase its probability to be chosen by the lottery. It is reasonable to think that, in this case also, wealth or liquidity, and opportunity costs associated to the preference for the present, are also decisive in the propensity for a given participant to validate simultaneously many blocks and to increase the risk of success of a malicious attack. Only an adapted and costly monitoring of the system, associated with strong penalties for each deviating behaviour, could perfectly be a remedy to this risk.

Another difference between the risks of the two validation systems is that the *nothing at stake* case does not depend on the size of the network. This risk depends on the amount of rewards but also naturally on the number of transactions to validate. Mechanically, the reliability of the PoW then increases with the volume of circulation of the local currency or of the network of local currencies to which a given blockchain is associated. This remark seems

to indicate that, all things equal, the smaller the local currency community, the greater the interest to adopt a PoS protocol.

3.3 Concerns for blockchain-based solutions

• Common misconceptions of the blockchain

The blockchain is often perceived as a disruptive technology, one that will radically change the ways we conduct business. In fact, it should be considered more as a foundational technology that would, in contrast to a disruptive one, not attack traditional business models but rather provide the foundations for our economic systems: it can be compared to the transmission control protocol/internet protocol (TCP/IP) (Iansiti and Lakhani, 2017). In this sense, the blockchain can be seen as a stepping stone for solving issues that traditional solutions fail to address, *e.g.* immutability, decentralisation...*etc.*

The second misconception and probably the most common one is the systematic association of the blockchain to high electricity consumption and environmental issues. This concern stems from one particular consensus protocol that is used by Bitcoin and a handful of other crypto-currencies: the PoW protocol. Because whenever the blockchain is mentioned, people tend to think about Bitcoin as well and every consequence derived from the latter. In reality, a blockchain can operate withtout the PoW protocol as there exist other consensus protocols can could ensure the same security and validation roles as the PoW such as the PoS and the Byzantine Fault Tolerance (BFT) protocol.

• Objectives and development of local currencies

While blockchain is not the panacea to all the problems a local currency might face, it surely does alleviate some of them and provides a reflection room for complementary solutions. For instance, Pinos (2019) found that the blockchain is not suitable for the Eusko local currency for now since it does not create public value and the project itself does not require a technical solution to address its issues. In fact, the novelty of the technology constitutes one of the reasons that made the managers reject the technology, for now. This example provides insight on a local currency that does not need the blockchain to solve their issues even though it sparked some interest for the managers and the author of the study. In contrast, some local currencies have experienced or showed interest in a blockchain-based solution such as the Liverpool Pound operated by Colu (the project stopped in 2019 according to their website) and the Monnaie Léman and Racine run by Com'Chain (the Racine announced on their website that an electronic version of the currency running on the blockchain will be available soon and Com'Chain included on their website the Racine as one of their clients). Because each local currency project has different objectives and develops at its own pace, the needs and size of the project are important factors that will influence the consideration of a technical solution that is the blockchain.

4. Alternative consensus protocols

Operating a blockchain with a hybrid consensus protocol could also be a possibility and should be explored further in the context of local complementary currencies (*e.g.* some crypto-currencies such as Peercoin and Dash have a hybrid protocol). There exist an important number of consensus protocols that aim to solve the issues inherent to the current PoW and PoS protocols. Table 3 provides some examples of alternative consensus protocols that are used by operating blockchains around the world.

Blockchain	**Protocol**
Dash	PoW & Proof of Service
Gridcoin	PoS & Proof of Research (PoR)
NEM	Proof of Importance (PoI)
NEO	Delegated Byzantine Fault Tolerance (dBFT)
Ark, Bitshares, Peercoin	DPoS
Polkadot	Nominated PoS (NPOS)
Reddcoin	PoS-Velocity (PoSV)
Ripple	Ripple Protocol
Stellar	Stellar Consensus Protocol (SCP)
VeChain	Proof of Authority

Table 3: Examples of blockchains that use other consensus protocols

We take a look at two promising protocols backing large-scale projects that present remarkable features capable of solving issues related to the PoW and PoS protocols: the Casper protocol (finality protocol for the Ethereum ecosystem upgrade) and the Chain of Activity (randomised selection protocol).

4.1. Casper protocol

The Casper protocol proposed by Buterin and Griffith (2017) is a consensus model designed to allow upgrading of an existing and operating PoW chain through implementation of a PoS-based system. The Casper protocol was proposed to replace the current PoW system in the Ethereum blockchain. It includes some interesting new features which fill some of the gaps in existing consensus models such as accountability (imposing a penalty equal to the whole of the malicious validator's deposit a.k.a. *slashing*), setting dynamic validators set and more effective protection against reversion attacks. The notion of accountability implies that the size of the deposits determines the security of the protocol not the number of validators. Technically in Casper, the concepts of finalised and justified checkpoints are introduced: every block which is a multiple of 100 from the original block can become a checkpoint, and the guiding rule is always to follow the chain with justified checkpoint at the highest block height. For validators who that go offline intentionally or unintentionally, the protocol proposes implementation of an inactivity leaks system. It works by draining

a proportion $d = D$ x p - where D is the deposit amount and $0 < p < 1$ - of the offline validators until the online ones take them over and become a super-majority, with the right to make decisions and keep the system functioning. The protocol solves the nothing-at-stake problem by slashing malicious nodes and will be implemented as the finality mechanism for the upcoming and long-awaited Ethereum 2.0 upgrade. However, the problem of 51% attack is still being studied among the developers.

4.2. Chain of Activity (CoA)

Bentov et al. (2016) focus on the problem of depletion of a physical scarce resource posed by the PoW system to maintain its security and operability. They propose the idea of a chains of activity (CoA) concept which is an extension of the Proof of Activity (PoA) protocol (Bentov et al., 2014) and employs a hybrid PoW / PoS system. The CoA employs the *follow-the-satoshi* method to achieve consensus: it derives from the PoA protocol and consists mainly of a lottery which determines that the creator of the next block is the owner of a randomly selected smallest unit of the currency, the selection process is described in detail in their article. Although it employs the PoW system to generate coins during the early stages of the currency to solve the fair initial coin distribution problem posed by the PoS system, the protocol stops the PoW system once a defined number of blocks has been mined. The differences between the CoA and Bitcoin mining are unproblematic readjustment so the block generation interval is not constant but requires definition of a minimum time gap (*e.g.* at least one minute gap between two blocks), fixed coin production costs (electricity and equipment) independent of overall network mining power, a number of blocks after the mined coins that can be spent that is greater than 100 to avoid an inflationary early phase, and a coin value pegged to its production costs. In the case of the PoS part of the CoA system, stakeholders are not allowed to double sign (those that do have their coins confiscated) which is an important difference compared to the PeerCoin system. The authors claim that the CoA protocol is more secure and has a more detailed design which makes it more resistant to bribe attacks, dishonest collusion, and majority takeovers than the Bitcoin and Peercoin systems.

Conclusion and discussion

The study of blockchain applications in local complementary currency systems is an emerging field which is attracting the interest of researchers and practitioners around the world. Since complementary currency systems are being digitalised, blockchains could provide communities with substantial benefits including the absence of intervention from a bank or financial intermediary. In this paper, we analysed two blockchain consensus protocols. They could be implemented in an isolated local complementary currency system or used to manage a number of local currency systems with the collaboration of the administrators of each currency. The need for reliability and trust on such systems with complex interactions calls for a variation in the design of the consensus protocol, where the administrator adjusts

the amount of rewards and the miners and validators are still the sole ensurers of the validation process for the network.

Each of the consensus protocols examined has a different set of properties. The PoS protocol does not involve high costs and encourages validators to hold local currencies thereby fostering their adoption. Attacks on this system are possible but are to some extent limited and are relatively easy to control or tolerate. A sufficiently severe sanction would deter attackers. The system seems to be adapted to small sized experiences. Future work could also consider other derivations of the PoS protocol like the DPoS for example.

In the PoW, the variation in the mining capacity distribution has an effect on the number of end users. If their number is limited, the PoW protocol presents more risks with 51% attacks more likely to be launched by - fairly small sized - pools of miners. An increased number of users also augments the risk for attacks, but the effect is countered by an increase in the number of miners, which strengthens the network security and dampens malicious behaviours. Controlling the amount of rewards produces the same effect. The PoW seems to be more adapted for large sized experiences. Therefore, besides the environmental concerns caused by the energy-intensive validation process of the PoW, risks of attacks and collusions could be other reasons to consider and to seek for alternative consensus protocols such as PoS for example.

Chapter 1
Part 2

A BLOCKCHAIN APPLICATION TO THE MANAGEMENT OF LOCAL COMPLEMENTARY CURRENCIES

The second part of this chapter is based on a joint research with Dominique Torre and has been submitted to the *Economic Bulletin* journal under reference EB-21-00504.

Consumers' interests in environmental issues and short distribution channels have significantly developed since the 2010s. Food quality and product traceability are growing consumer concerns, along with the desire to limit the carbon footprint. However, despite the many food labels (organic, local produce, ...*etc.*) that exist, the average consumer is not capable of discerning the difference between the labels, let alone understand truly what each label means (Anstine, 2007; Dahl, 2010; Roitner-Schobesberger et al., 2008). In particular, there is a growing tendency to propose organic products that come from usually very far away from their selling point. A local complementary currency which is used alongside the legal tender can be used as a signalling tool for 'quality goods' that are produced in a sustainable way and close to the consumption point. It does so by only allowing merchants who respect the quality chart of the currency, to reconvert their local currency into legal tender.

The security aspect of the local currency is ensured by the blockchain, which is also known as the mainstream technology behind crypto-currencies. The blockchain provides an impeccable level of security and traceability for transactions, and is designed to function in a decentralised way. Although its first applications are for crypto-currencies, the blockchain has developed beyond the financial sphere, and is now being used to improve the processes in multiple sectors including supply chain (Min, 2019; Saberi et al., 2019). In the case of alimentary supply chain, problems stemming from the traditional supply chain model which include the lack of information on the origins of products for consumers, call for alternative solutions like the governance of the food supply chain via blockchain (Casado-Vara et al., 2018). In the same perspective, a local currency coupled with the blockchain can be used to signal the quality of products via their incentives system and highly secure technology. The issue of volatility does not exist in our case since the rate of exchange is one-to-one with legal tender, similar to some crypto-currencies that are pegged to the U.S. dollar (stablecoins) such as Tether (USDT) and USD Coin (USDC). We propose a model encompassing the interactions among consumers, shopkeepers, validators of the transactions (miners) in local complementary currency, and an administration of the system, studying the way of activation of such a local system of diffusion of 'quality products'. This theoretical model is followed by numerical simulations mimicking different scenarios of development of these interactions, in which the blockchain is used to govern a local currency system, or a network of local currencies across a number of cities.

1. The model

1.1. Agents

The local currency system associates four types of agents: n potential consumers, s shopkeepers, m potential miners (or validators) of the transactions, and an administration of the system which also issues the local currency digitally against legal tender and conditionally convert it back to legal tender at a fixed exchange rate. The administration determines a list of enforceable commitments binding the participating shops, relating to the origin and nature of the products they sell and different environmental-friendly practices (promotion of short distribution channels, of organic goods, of ethical products, participation to waste

recycling, to various collective solidarity projects, ...*etc.*). The cost of commitments for the shops increases with the advantage they provide to consumers. Committed shopkeepers have the possibility to convert the local currency they receive in payments back to legal tender. Consumers interested in environmental protection and in promoting local and organic products can become clients of the committed shops and pay in local currency which is accepted only by shopkeepers who can convert it back to legal tender. Transactions in local currency are validated and settlements are realised on a blockchain using a PoW-like protocol. Miners of the blockchain are interested in rewards associated to the validation process. Rewards are paid by the administration and funded by the conversion cost paid by consumers clients of committed shops. The reliability of the validation system depends on the number of participating miners which itself depends on the level of rewards. Finally the administration maximises the welfare under the expression of the total surplus.

• **Shopkeepers**

There are s heterogeneous shops (mini-market, food-store, fishmonger, clothing store, drug store, book store, hair salon, pub, restaurant,...*etc.*) that are able to commit or not to the chart of values and practices proposed by the administration. Committed shops have in counterpart the possibility to access the retro-conversion of the local currency to legal tender. Their choice to accept or not the local currency in payment depends on the additional income and costs generated by their commitments. When a shop decides to accept the local currency, its extra income is given by the number of new clients n^* it attracts. Each client is supposed to consume one unit of 'quality' good or service at a fixed price equal to 1 by convention. The cost of commitment increases quadratically with the advantages provided to consumers. It also depends on idiosyncratic components differing from one shop to another (*e.g.* it is easier to serve a beer brewed locally in Munich than in Lisbon, and harder to sell local electronic components in both cities).

The extra profit π_k of shopkeeper $k, (k = 1, 2, \ldots, s)$ who accepts the local currency in payment is given by expression (1):

$$\pi_k = n^* - (c_1 k + c_2 a^2) \tag{1}$$

where n^* figures the number of consumers using the local currency as payment, and $c_1 k$ and $c_2 a$ are respectively the idiosyncratic and basic components of the cost of commitment $(c_1 > 0, c_2 > 0)$.

• **Consumers**

There are n potential consumers who use or not the local currency according to the content of the chart of values proposed by the administration. Their utility as clients of the committed shops increases with the level of commitment of the shops, but decreases depending on the transaction fees they have to pay to convert the legal tender to local currency They are differentiated by their sensibility to the excess price of quality goods and services of the committed shops, by the limitations in terms of variety of quality goods and services, or by other disadvantages of committed shops compared to their competitors (including hypermarkets) offering 'normal' goods and services. The differential of utility of

consumer $i, (i = 1, 2, \ldots, n)$ when it chooses to pay a given variety of goods/services using local currency is given by expression (2):

$$u_i = a(1 - t) - i\tau \tag{2}$$

where t relates to the rate of conversion of legal tender to local currency and τ to the idiosyncratic opportunity cost associated to the use of the local currency.

• Miners

The m potential miners can use their interconnected computers to run a blockchain node capable of validating local currency transactions. The payment of miners is determined by the PoW contest: the computational power of computers determines also the miners' probability to win the unit reward r associated to each block which includes l transactions. Computational powers are uniformly distributed on the segment $[\underline{j}, \bar{j}]$. When the time devoted to validation and other opportunity costs are considered, the number of effective participants in the blockchain depends on the amounts of rewards. The expected gain for a given block for the miner endowed with the computational power j (or miner j) is given by expression (3):

$$\pi_j = \left(\frac{jr}{\sum_{j^*}^{\bar{j}} j} - \theta \right) \frac{n^* s^*}{l} \tag{3}$$

where j^* figures the marginal participating miner, *i.e.* the miner for whom the expected profit vanishes, the first term in the parenthesis representing the gross expected gain of miner j given its equipment and the level of rewards r. θ represents his opportunity cost.

The potential miners decide to participate in the blockchain as soon as their net expected profits are positive.

• The administrator of the currency

The administrator charges a rate of t to each unit converted from legal tender to local currency, and allows free reconversion of local currency to legal tender for committed shopkeepers. The content of the chart of the local currency (*i.e.* the level of commitments) a is also determined by the administrator. The conversion tax t funds the miners' activity. Indirectly, the blockchain activity then determines the conversion tax t when the administrator budget constraint is balanced as written by equation (4):

$$n^* s^* \left(t - \frac{r}{l} - c_3 \right) = 0 \tag{4}$$

where s^* figures the number of committed shops and c_3 a unit operational cost of the administration.

Given that the amount of reward r is given by the validation market (miners participate in various blockchains which for a given size of block, places the administrator in a price-taker position relative to the amount of a), the administrator finally determines the level of

commitment a^* maximising the welfare (5) of the members of the community (consumers and member-shops), given its budget constraint (4):

$$W = s^* a n^* (1-t) - s^* \tau \left(\sum_0^{n^*} i \right) + s^* n^* - c_1 \left(\sum_0^{s^*} k \right) - c_2 s^* a^2 \tag{5}$$

1.2. Sequence of actions and solution concept

The interactions among agents and the control of actions by the administration can be presented in a sequential way. The sequence is as follows:

- At the beginning of the period, the administration determines the content of the chart a in order to maximise welfare (5) under the budget constraint (4), using rational expectation of other agents actions given parameters c_1, c_2, c_3, τ, l and the value of r given by the market.
- At stage 2, potential member-shops choose to sign or not the chart (and to accept or not the local currency as payment).
- At stage 3, potential users choose to adopt or not the local currency and to become or not clients of the member-shops.
- At stage 4, potential miners choose to participate or not in the blockchain.

The solution concept is the subgame perfect equilibrium of the previous sequence in which for each period, agents choose the best action to maximise respectively the welfare, profits, utilities, and expected mining gains. It is solved in backward induction and with the help of the *Mathematica* software.

2. Solution of the model

2.1. Fourth stage of the game

Lemma 1. *The effective number of miners is* $\bar{j} - \frac{1}{2} + \frac{r}{\theta} - \frac{\left(4r(r-\theta)+\theta^2(1+4\bar{j}+4\bar{j}^2)\right)^{1/2}}{2\theta}$. *This number increases with the level of rewards* r.

Proof: The expected profit of the threshold miner j^* vanishes in expression (3). Among the two roots as solutions, and given $r \geq 3\theta$ is a necessary condition to have at least 2 participants in the blockchain, the relevant solution is $j^* = \frac{1}{2} - \frac{r}{\theta} + \frac{\left(4r(r-\theta)+\theta^2(1+4\bar{j}+4\bar{j}^2)\right)^{1/2}}{2\theta}$, from which is deduced the number of miners $\bar{j} - j^*$.

From Lemma 1, are deduced the following remarks:

- Given the opportunity costs of miners, the number of active miners only depends directly on the amount of rewards and not on the level of commitment of shopkeepers and the level of circulation of the local currency.

- Given the administration 'budget constraint' (4), the amount of rewards has also an indirect influence on conversion costs t and on the level of transactions in local currency. Finally it determines also the number of blocks and the profit π_j for each miner.

Indirectly, from their effect on the conversion tax, the blockchain technology and the level of rewards have then an influence both on the number of consumers using the local currency and on the number of shopkeepers accepting it as payment.

2.2. Third stage of the game

The third stage of the game corresponds to the determination of the number of consumers who use the local currency, given the level of commitment of shopkeepers a^* and the conversion fee t.

Lemma 2. *The effective number of local currency users among consumers is* $n^* = \frac{a(1-t)}{\tau}$. *This number increases with the level of commitment of shopkeepers and decreases with the conversion fee.*

Proof: The threshold local currency user i^* cancels expression (2), *i.e.* $i^* = \frac{a(1-t)}{\tau}$. Given the form of (2), $n^* = i^*$ and this equality is derived from the first part of the lemma. The second part of the lemma is directly derived from the study of n^*.

2.3. Second stage of the game

The second stage of the game corresponds to the determination of the number of shops s^* that sign the chart and accept the local currency. This number depends on the level of commitment a previously proposed by the administration and on the value of their profit function (1).

Lemma 3. *The effective number of shops that accept the local currency is* $s^* = \frac{a(1-t-ac_2\tau)}{c_1\tau}$. *This number decreases with* t. *It first increases then decreases with* a.

Proof: The threshold shop k^* cancels expression (1), *i.e.* $k^* = \frac{a^*(1-t-ac_2\tau)}{c_1\tau}$. Given the form of (1), $s^* = k^*$. The second part is the consequence of the form of expression s^*.

It is interesting to observe that the number of participating shops increases with the level of commitment as far as the 'good' effect on the latter dominates its counterpart the 'bad' effect on shopkeepers' costs.

2.4. First stage of the game

Finally, once we determined the level of conversion taxes $t = \frac{r}{l} + c_3$ of legal tender to local currency from expression (4), the welfare that maximises the value of a^*, can be derived from expression (5) where the values of n^* and s^* are expressed as obtained in Lemmas 2 and 3.

Proposition 1. *Under the mild condition of* $c_2\tau^2 < \left(1 - \frac{r}{l} - c_3\right)^2$*, there exists a positive value of* a^* *that maximises the welfare.*

Proof: Given expression (5) and Lemmas 2 and 3, the welfare is a polynomial expression of degree 4, continuous in the whole range of definition of a. Its term of highest degree is positive. It has then in general two local mimima and one single local finite maximum. The expression vanishes for $s = 0$, which corresponds to two different values of a, namely $a = 0$ and $a = \frac{(1-t)}{c_2\tau}$. Its first derivative in a is negative for $a = 0$ which means that it becomes negative for small values of a. A sufficient condition for which it becomes positive is when the two components of W, namely $W = s^*an^*(1-t) - s^*\tau\left(\sum_0^{n^*} i\right)$ and $W = s^*n^* - c_1\left(\sum_0^{s^*} k\right) - c_2s^*a^2$ are positive, which corresponds respectively to $a > \frac{\tau}{1-\frac{r}{l}-c_3}$ and $a < \frac{1-\frac{r}{l}+c_3}{c_2}$, which summarises in the condition $c_2\tau^2 < \left(1 - \frac{r}{l} - c_3\right)^2$. When this condition is observed, and given the form of w and its values when $s^* = 0$, a maximum of W exists for positive values of a^*, s^*, and n^*.

The condition of the proposition could be easily commented as follows. The left part of the inequality $c_2\tau$ refers to the cost of commitment for shopkeepers, and to the heterogeneity of consumers related to the opportunity costs when they choose to be clients or not of committed shops, while the right part of the expression refers to the costs of the validation system, namely the rewards paid to the blockchain which runs the system. It then exists a positive level of commitment maximising welfare if opportunity costs of consumers and commitment costs of shopkeepers are not too high when compared to the cost of operating a blockchain.

2.5. Simulation results

We present in this section numerical illustrations able to capture different levels of extension of the network of agents paying in local complementary currency and using it as a way to disclose committed stores.

The four columns of Table 6 could be interpreted as different stages of adoption of the complementary currency. Scenario 1 may depict an early stage of the project characterised by an important opportunity cost of adoption by users (τ), high rewards for miners (r), high costs for the administration (c_3) and for the merchants to be engaged in the advantages (commitments) provided by the local currency (c_2). The subsequent scenarios may depict further adoption stages of the project respectively in evolution with our variables, with scenario 4 being the latest stage in which the project has reached its maturity and the possibility of a network of multiple local currencies governed by a blockchain could become a reality.

Figures 1, 2, 3, and 4 show the evolution of the total welfare (blue curve, left y-axis), the number of shops accepting the local currency (purple curve in bottom-most position, right y-axis), and the number of users (straight purple line) for each scenario of table 6.

Variable	Scenario 1	Scenario 2	Scenario 3	Scenario 4
c_1	0.75	1	1.5	2
c_2	2	1.5	1	0.5
c_3	0.7	0.5	0.4	0.3
r	0.1	0.075	0.05	0.01
l	20	20	20	20
τ	0.015	0.01	0.0075	0.005
a^*	7.05	24.72	59.67	209.79
W	15 995.2	4 707 180	135×10^6	$15\ 826\times10^6$
n^*	142	1 227	4 754	29 349
s^*	51	310	795	3672
n^*/s^* in %	35.44	25.27	16.73	12.51

Table 4: Simulation results of each stage of adoption of the local currency project

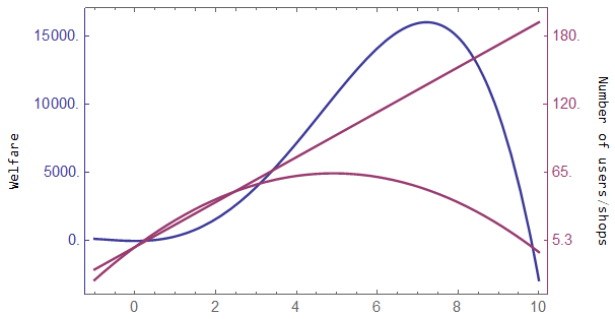

Figure 1: Scenario 1 for W

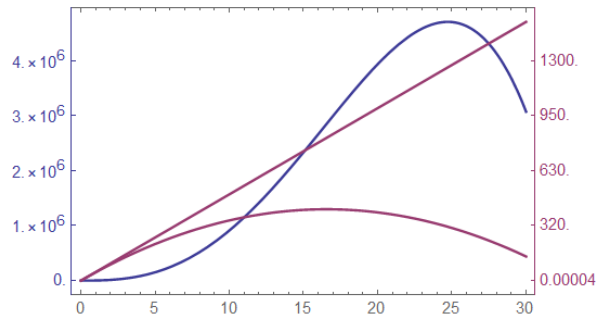

Figure 2: Scenario 2 for W

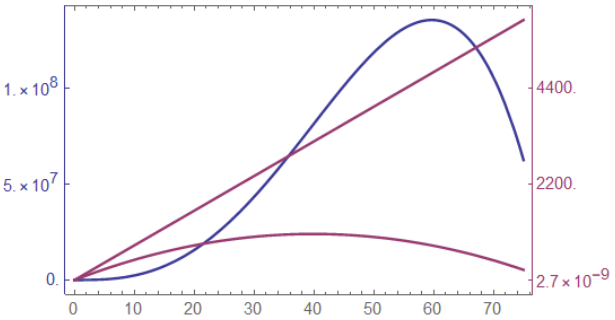

Figure 3: Scenario 3 for W

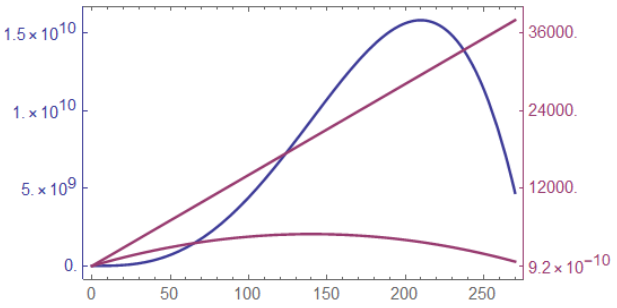

Figure 4: Scenario 4 for W

Despite important differences in the level of adoption and use between cases, and mild (visual) nuances in the range of positivity of W close to $a = 0$ - in reality, these nuances are for the most the consequence of the difference in scale among the 4 cases - the same observations can be made for every situation: the number of consumers increases linearly with a, the number of involved shops reaches a maximum before total welfare and ends up having a negative influence on the latter, until making it vanish. Only changes the size of users' network and the gain in term of welfare. The amount of rewards r plays a role in

the success of the experience, as part of the costs, but the other costs (opportunity costs for consumers and commitment costs for shopkeepers) are also decisive in the success of the experience.

Conclusion and discussion

In general, achieving mainstream adoption is the objective of a currency. Conversely, in the case examined in this paper, the adoption should be restricted to a limited number of shops to enforce the role of the local complementary currency as a signalling tool. In this sense, the local complementary currency does not position itself as a 'rival' to the legal tender. The increasing need for security and viability for a payment system in a world where technology is advancing at a fast pace calls for alternative solutions that are easily reproducible across spaces and cities. The blockchain seems to be one of the solutions to this problem. Our model and its simulation results showed that a local complementary currency or a network of local complementary currencies governance via blockchain is feasible in many circumstances. It is in line with rational behaviour of agents, and comes at a low cost, if not nearly no cost, for the collectivity. Two prominent examples of blockchain applications in complementary currencies are the Monnaie Léman (*Le Léman, concrètement?*, n.d.) local currency in France and Switzerland, and the MonedaPAR mutual credit system in Argentina (Orzi et al., 2021). The digitalisation of local currencies via blockchain is gaining momentum as more projects are adopting the solution and we expect this trend to continue growing rapidly in the next few years.

Chapter 2

LOCAL COMPLEMENTARY CURRENCIES, SHORT DISTRIBUTION CHANNELS, AND MODELS OF CITIES

This chapter is a product of a joint research with Dominique Torre and Maëlle Della Peruta, and was showcased in different conferences such as the 2019 AFSE and the 2021 GDRE.

Developing short distribution channels is considered today as a way to improve the sustainability of economies, enhance food quality and diversity of agricultural productions, and to fight effects of greenhouse gases. This is also a way to encourage the development of local employment and to revitalise proximity areas. Whilst the quality of technology goods (electronics and computers) is rather easy to observe, it is not the case for food or other agricultural products. Labels play a signalling role but their extent is limited: they are not available for all types of goods and creating new ones needs time. Local complementary currencies (hereafter used interchangeably with complementary currencies to emphasise the complementarity dimension) could however be used as an alternative way to signal the quality of products. In many cases, their implementation by a local association or a local government is motivated by the protection of the local production and distribution channels. Charts that state the types of retailers authorised to reconvert complementary currencies in legal tender, help identify retailers that offer organic products and those who are partners of local producers. The objective of this chapter is to test the capacity of local currencies and their charts of value in developing the distribution of local organic products, that we identify as 'quality products' according to the type of city in which the experience is being studied.

We then consider cities that differ from one another through the initial location of stores selling standard products as well as the distribution of the level of incomes of residents. In developed countries, city centres sometimes go through gentrification; others are occupied by commercial and/or business centres. Shopping malls and large concentration of activities that important spaces to operate are usually implanted in outskirts of cities. Between the city centre and the outskirts, there is frequently a more or less residential area with a reduced commercial activity. The research question of this chapter is: in which part of the city would the services offered by a local currency be the most efficient and useful for the collectivity?

The theoretical model that we elaborate, on the basis of an extended Hotelling spatial setting, can capture different initial locations and/or nature of food stores, and different distribution of level of incomes of residents of a city. Going from there, we present three different specifications of cities and test the effect of the use of a complementary currency, through its capacity to foster the emergence of high quality food stores. We also consider the possible location of these stores, depending on each city model. The question of the possibility for retailers and producers to reconvert or not the complementary currency back to legal tender is also analysed. The reconversion must be limited and subject to restrictions in order for the quality signal of products to be credible. For this reason, the extension of the area of use of the complementary currency is not an objective. It is however interesting that producers could integrate a network of complementary currency users, not only because this is an incentive for retailers to switch from standard quality products to high quality products and short distribution channels, but also because they could in turn pay their own inputs and consumptions in complementary currency, and finally improve the sustainability of complementary currency. Hence, we consider the possibility to fully exonerate the local producers from reconversion costs, while we maintain small reconversion fees for retailers selling high quality products.

The rest of the chapter is presented as follows. Section 2 summarises the results and observations from the literature on the subject. Section 3 presents a benchmark model, that captures schematically the interactions between retailers and residents according to the characteristics of residents and the distribution of stores in the city. Three models of cities are considered. In the first one, the demographics of the city follow a phenomenon of gentrification of the down-town area, with a per capita income decreasing with the distance to the centre and a distribution of small shops in the city conform to this spatial distribution of residents. In the second one, are introduced mass-stores located at the periphery and providing various advantages to consumers as diversity and accessibility. In the third case, the centre city has a cultural and leisure attractiveness, pedestrian areas, and all residents tend to be both clients of proximity retailers and of centre city shops. Section 4 considers the possibility to sell high quality local productions, with the help of a complementary currency and the signalling effect of its associated chart. Interesting results are yielded, especially on the location of the stores selling high quality products. Even if high quality products could frequently be assimilated to luxury goods (they are more expensive than standard goods, and do not satisfy more fundamental needs than cheaper products), it is not reasonable to develop them in proximity to residents with high level of income. This provides the basis to an extension of the first model of city initially presented. The models with mass-stores and cultural centre are also considered and the possible location of quality good shops and complementary currency acceptability analysed. Section 5 concludes and opens the subject for discussion.

1. Literature review

1.1. Short distribution channels, proximity, and organic food

According to the French Ministry of Food and Agriculture, a short distribution channel or short food chain is a 'marketing method of agricultural products that consists of either direct sales from the producer to the consumer or indirect sales, provided that there is only one intermediary between the producer and the consumer'. As new consumption behaviours emerge in response to ecological, ethical and health concerns, a growing number of consumers turn to a more responsible buying behaviour that would consist in reducing their ecological footprint and consuming more organic and local products. The notion of proximity may therefore play a significant role in shaping the buying behaviours of consumers. This sensitivity to physical distance entails an important interest in short distribution channels (Martin, 2010). Short distribution channels may contribute to change the relations of consumers to products and consumption, and thus play the role of catalysts for sustainable consumption (Chiffoleau et al., 2017).

In the food industry, the organisation of short distribution channels is being greatly improved and their expansion is benefiting with important support from local governments (Guiraud et al., 2014). They have been diversifying greatly and are now being borne by various groups who prioritise impacts other than those of economic nature. In this sense, short distribution channels may answer to new expectations from consumers who are looking

for a different experience with complementary activities such as farm visits, tasting, conferences... *etc* (Chiffoleau and Prevost, 2012). Among the existing structures that operate in short distribution channels, farmers or agricultural cooperatives have direct territorial anchorage and contribute to sustainable development objectives through their aims and legal specificities (Mauget, 2008). In the European Union, the average market share of all agricultural cooperatives was 40% in 2010 (Bijman *et al.*, 2012) and in the United states, supply cooperatives counted for 42% of the total number of agricultural cooperatives in 2016 (Demko, 2018). They are 'systems that underline the willingness to make of the firm a structure that serves the interest of its members and not one destined to maximise the profit of capital holders' (Bocquet et al., 2010). Moreover, agricultural cooperatives are often subjected to expectations of high-quality products delivery since they usually provide production practices, set up rules and quality standards for their members to meet (Olson, 1996) like for instance in New Generation Cooperatives in the United States (Coltrain et al., 2000). Agricultural cooperatives can also ensure their quality through the implementation of quality control systems and with aids for improvement of quality systems for ecological production, like for instance in Spain (Giagnocavo et al., 2012). With pressure from anti Genetically Modified Organism (GMO), agricultural cooperatives are more cautious and intervene quite widely to give advice for a sustainable and organic agriculture (Filippi et al., 2008). Although this sort of quality assurance exists, it varies greatly from one country, region and cooperative to another one so it still constitutes a challenge for consumers to verify it.

Local currencies can help fostering short distribution channels since they circulate in a given area and gather local resources and actors, creating coordination and a shared identity between them (Leloup et al., 2005). Local currencies are then a component of a territorial process of coordinating economic activities. Because they contribute to redeploy local resources and promote local development, they are bottom-up solutions that meet the interests and correspond to the values of the communities (Seyfang and Smith, 2007). Therefore, local complementary currency systems are mainly dedicated to serve the activities of the local professionals and producers, constituting the short distribution channels.

In parallel with the development of these short channels, the exigency for high quality food among consumers has significantly increased over the past decade. By high quality, we refer to organic food. Worldwide sales of organic food has grown nearly sixfold between 1999 and 2016 according to Statista (Wunsch, 2021). Definitions of organic food slightly defer from one continent to another. The United States Department of Agriculture (USDA) defines organic food as food that 'is produced by farmers who emphasise the use of renewable resources and the conservation of soil and water to enhance environmental quality for future generations'. Organic meat, poultry, eggs, and dairy products come from animals that are given no antibiotics or growth hormones. Organic food is produced without using most conventional pesticides; fertilisers made with synthetic ingredients or sewage sludge; bioengineering; or ionising radiation according to the U.S. Department of Agriculture (Mary, 2020). The European Commission defines organic food as the products from farming practices that comply with certain objectives and principles similar to the ones specified by the USDA (*Organics at a glance*, n.d.). Many studies has been done to understand the determi-

nants behind consumers' choice of buying or not buying organic food. Among them, using data from a national survey in the U.S., Zepeda and Li (2007) showed that despite the high average price of organic food, no positive relationship was found between the income level of consumers and the demand for organic demand. But interestingly, the shopping venue appeared as the most important and significant factor: the probability of buying organic food is increased by 31% and 23%, respectively when consumers shop at a health food store or food cooperative and is only increased by 10% when they buy directly from farmers. These types of shopping venue may therefore influence the purchase of organic food by consumers.

A study conducted in Hedmark county in Norway revealed that consumer orientation in the food market was linked to two most important factors: (i) high quality foods and (ii) a pleasant and friendly shopping atmosphere (Torjusen et al., 2001). The same study also found that the most relevant underlying factors for the market orientation from consumers are local (also called food system awareness *i.e.* food produced locally and support for local production) and social (pleasant shopping experience and personal contact for giving and receiving information) orientations. The third factor was practical orientation (low price and convenience in general). The findings further showed that people who are 'locally oriented' were more likely to purchase organic foods than those who are 'practically orientated'. However, these results are only pertinent to the studied region and may not be generalised. By bringing in the proximity, solidarity and consumer self-empowering aspects, local complementary currencies could favour the sale of organic products by small shops in city centres.

1.2. Complexity and issues of food labels

Labels are intended to work as a signal of high quality products for consumers, but they don't always succeed in providing relevant information for consumers, and are sometimes subject to confusion and mistrust. Food labels vary greatly from one country to another and the average consumer is not always capable of distinguishing them nor fully understand what they are purchasing (Anstine, 2007; Dahl, 2010; Roitner-Schobesberger et al., 2008). In France for instance, there are five high quality labels according to the National Institute of Origin and Quality (Les signes officiels, n.d.). Regarding organic labels, we can find over 7 of them in the country just to name a few: *Agriculture Biologique* (AB), *Bio cohérence*, *Bio partenaire*, *Nature & Progrès*, *Meilleur produit bio*, Demeter, FairTrade - Max Havelaar, and USDA Organic. A study by the *Institut français d'opinion publique* IFOP in 2011 showed that 80% of French people would like to obtain more information about the benefits and inconveniences of organic products on labels and another survey by the International Food Information Council (IFIC) and the American Heart Association in 2019 revealed the same results for U.S. consumers. Moreover, many studies confirmed the puzzling aspect of food labels for both consumers, producers, and legislators. For instance Simeone et al. (2016) studied the factors that affects the interpretation of food labels in the EU and found that even with the new legislation 'No. 1169/2011 on the provision of information to consumers on food', the main problems leading to food label complexity for consumers are still their lack of knowledge regarding environmental labelling and niche certifications.

The efficiency of organic labels in modifying the motivations of consumers for purchasing a certain brand of product has also been studied. Larceneux et al. (2012) showed that brand equity should be taken into consideration when assessing the efficiency of organic labels as these two notions are linked. They found that the organic label seems to produce less effect on consumers when the brand equity of products is high and vice-versa. This is because consumers' trust in the products due to their reputation and image greatly overtakes the organic labelling, and thus labels become less useful in this context. Among the recommendations made by the authors for policy makers, one consists in the clarification of labels to reduce their complexity and polysemy, emphasising once again the problems of misinformation and confusion of food labels.

On top of green-washing and overuse of organic labels, Bauer, Heinrich, and Schäfer (2013) found in their study in Germany that a private brand profits more from the use of organic labels than local and global brands since their conventional products are often perceived as lower quality products, the organic labelling helps them catch up in the rank with local and global brand products. This clearly shows that organic labels are used not only as a differentiation tool, but also as repositioning one that acts rather like a misguided signal for consumers. Different organic food certifications organ such as state-centred and non-state driven ones have their own procedure of control and conformity so there are no standardised rules for all organic labels (Boström and Klintman, 2006; Janssen and Hamm, 2014). This divergence in certification bodies adds another layer of complexity to the organic labels system.

Overall, the landscape of organic labels still remains very complex and blurry for consumers and the scientific community. The use of a local currency as an alternative may just prove to partially solve the problem since consumers can be reassured of the quality of their products with the reconversion mechanism imposed to merchants.

1.3. Charts and quality guarantees of products

Local professionals and food producers can be chosen to be part of the local currency network if they respect the ecological and social objectives (part of the sustainable development goals) set by members of the network. In general, a chart of values is established and is available to the public. However, some local currencies do not have a chart because they serve purposes other than ecological, ethical or social ones, *e.g.* the Occitan and the Cigalonde in France. Two reasons may explain the absence of a chart: (i) the project leaders consider that the guarantee of respect for values is provided by a spatial and cognitive proximity that binds professionals and (ii) the launching phase of a currency that includes an uncertainty partially masks the values of the project, in order to satisfy the most urgent need, which is its survival and the expansion of the number of users (Blanc and Fare, 2012). From interactions between participants of the network, the chart defines the different ecological and social values promoted by the local complementary currency association and the rules by which the members must play and respect to be part of the network. In most local complementary currency systems, one of the conditions to comply with the production of goods and services within the local area. One of the advantages of the chart is that it is

offers flexibility as a non-statutory text and may therefore be amended without convening an extraordinary general meeting (Blanc and Fare, 2012).

Any professional who wishes to take part in the local currency network needs to submit its registration by indicating how it fits with the values of the association or how it can achieve/help to achieving objectives set by the association. A decision-making committee will then give its [dis]approval to the professional. Members are then controlled on a regular basis before granted permanent permission to be part of the network. With the chart, the decision-making committee and the regular control of members, the local currency system acts as a label of quality for consumers. The quality of products and the ecological and social values that they carry is guaranteed for end users. The local currency associations are the entities that guarantee the aforementioned characteristics of the products sold in the network (Blanc and Fare, 2016). For consumers, buying certified organic food with an additional label guarantee form the local currency could serve as a way to compensate the non-observable quality trait of food. Interviews of four French complementary currency associations namely the *Gonette* in the city of Lyon, the *Sol-Violette* in Toulouse, the *SoNantes* in Nantes and the *Eusko* in the municipal community of Basque, reveal for instance that in each case, entities in charge of the complementary currency management have edited charts in the form of criteria or objectives and have defined a periodic control of local professionals who chose to join the network.

1.4. Conversion of local complementary currencies

Since local development is promoted by the integration of local professionals and producers in a complementary currency network, this latter must be sufficiently large to ensure that the multiplier effects of the complementary currencies on the local development. Each of the four associations interviewed has developed a communication strategy to attract and encourage professionals and producers to be part of the network. One of the reasons why professionals are unwilling to participate is the difficulty for them to use complementary currency to pay for their own expenses. Most of the time, members are discouraged by the difficulty to spend complementary currency units that they receive (Carvalho de França Filho et al., 2012).

Complementary currency systems in which reconversion is allowed seem to be more attractive for professionals (DeMeulenaere, 2006). To tackle this problem, some of the complementary currency systems allow professionals to convert back to national currency *e.g.* the Gonette, the Eusko and the BerkShare in Massachusetts. However, the possibility of a reconversion slows down exchange dynamics (Blanc, 2009; Carvalho de França Filho et al., 2012). When reconversion is allowed, members make fewer efforts to find partners able to accept complementary currency as payment: the number of users is then restricted, and local multipliers are not effective. To avoid money escaping from the system, some local currencies prohibit currency reconversion (the SoNantes) and others have introduced reconversion fees. For example, a 5% of the fee (of the converted amount) is applied to professionals who reconvert Euskos to Euros in the municipal community of Basque. In sum, 40% of the fee

cover the operational costs of the association and the remaining goes to a local association partner of Euskal Moneta (the currency association). Every time a consumer buys the local currency, 3% of what they buy are promised as a donation in local currency to a local association that they have chosen by themselves.The reconversion fees act as an incentive for professionals to find alternative ways to spend their complementary currency *e.g.* payment of wages, wholesalers, ...*etc.* It is then crucial for professionals and producers to have the possibility to find other agents in the network who accept in counterpart the complementary currency for payments (Carvalho de França Filho et al., 2012).

2. Three models of cities

We present in this section three possible models of distribution, inside a given city, of retailers providing a standard consumption good produced by the agriculture industry. The city is represented by a segment capturing its topological form. The extremities of the segment are the outskirts and the centre of the segment represents the centre of the city. n final consumers are uniformly distributed along the segment. The nature and location of retailers determine the model of the city. We consider 3 specifications:

1. In the first case, consumers living in the city centre have a higher budget. However, as the standard quality product is a basic good (bread, potatoes, tomatoes, ...*etc.*), the demand for this good is homogeneous throughout the city. The resulting effect is that retailers are uniformly distributed all along the city as long as there are no high quality products to offer.

2. In the second case, there are two categories of retailers: mass-market retailers and small retailers. Mass retailers are generalists and need spacious areas to operate *i.e.* they need to provide easy access and car parks for customers. They are located outskirts of the city. Small retailers are located in the city centre where they exploit advantages from proximity.

3. In the third case, similarly to the first one, there is one single category of retailers. However, for different reasons, all consumers tend to be customers of both local stores and retailers in the city centre which is attractive for exogenous reasons (concentration of leisure activities, pedestrian areas, ...*etc.*).

In the first and third case, retailers will be considered at the free entry long term equilibrium. In the second case, the two mass retailers play as co-leaders (in each equal portion of the city) and small retailers compete in price in the city centre.

2.1. Small stores and heterogeneous consumers

There are n end consumers and m retailers ($m \leq n$) Consumers and retailers are located uniformly on the a segment of size 2 (cf. Figure 5). The centre of the segment could be

assimilated to a city centre and the extremities of the segment to the outskirts. Consumers living in the city centre have a higher budget, but as the standard quality product is a basic good, the demand for this good is homogeneous throughout the city. The resulting effect is that retailers are uniformly distributed inside the city as long as they only sell standard quality products.

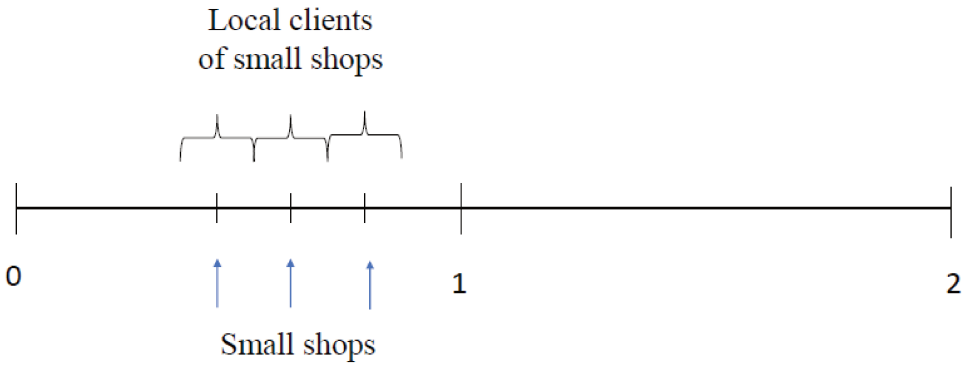

Figure 5: Retailers location: small shops

Each consumer demands 1 unit of standard quality product. When k_i figures the distance of consumer i from the closest shop, its utility is given by expression (1):

$$u_i = u - k_i - r \tag{1}$$

where r figures the price of the standard quality product: given the structure of the model, and in particular the identity of the costs of retailers, their prices are uniform.

Retailers determine the price r to maximise their profit given by (2) where $\bar{p}$ figures the wholesale price of this kind of good, C_r their fixed cost, and n_r their number of clients.

$$\pi_j = n_j(r - \bar{p}) - C_r \tag{2}$$

We then derive lemma 1:

Lemma 1. *At competitive equilibrium, the price of standard quality products is* $r = \bar{p} + (\frac{C_r}{2n})^{1/2}$ *and the number of retailers is* $m = (\frac{2n}{C_r})^{1/2}$.

Proof: At competitive equilibrium, the market is covered. Consider retailer j. Given expression (1), the threshold consumer i between retailer j and its neighbour is then such that $u - k_i - r = u - (\frac{2}{m} - k_i) - \bar{r}$, where $\bar{r}$ is the price proposed by the closest competitor of retailer j, *i.e.* $k_i = \frac{\bar{r}-r}{2} + \frac{1}{m}$. From expression (2), $\pi_j = \frac{n}{2}(\bar{r} - r + \frac{2}{m})(r - \bar{p}) - C_r$, which is maximised in r. Given the free competition condition ($\bar{r} = r$), $r = \bar{p} + \frac{2}{m}$. The free entry makes the price decrease until profit vanishes, which determines $m = (\frac{2n}{C_r})^{1/2}$, and finally $r = \bar{p} + (\frac{C_r}{2n})^{1/2}$.

Comparative statics show as predicted by intuition that the price increases with fixed costs and wholesale price while the number of retailers finally decreases when their cost increases. It also obviously increases with the density of the city.

2.2. Mass-market retailers in outskirts and small stores in city centres

Suppose now that two mass-market retailers are set up in the outskirts at opposite sides of the city while small stores already exist and are at a free entry situation. Big malls are generalist stores and generate externalities for customers who purchase standard quality products. That is, the more customers there are, the more adapted they will become to sell different types of products and services in the same place. For a customer i of the mass-market retailer M, utility provided by a visit to buy one unit of standard quality product expresses as (3):

$$u_i = u + \alpha n_M - k_M - r_M \tag{3}$$

where n_M represents the number of customers of the mass-market retailer M, α positive parameter, and r_M the consumption price charged by the mass-market retailer.

For the sake of simplicity and without prejudice on results, we will suppose that the profit of the mass-market retailer is decomposable: the price of standard quality product proposed by the mass-market retailer and its number of customers for standard quality products do not depends on prices of other goods offered by the store, except via the consumption externalities. Their (partial equilibrium) profit then expresses as (4):

$$\pi_M = n_M(r_M - \bar{p}) - C_M \tag{4}$$

where $C_M (C_M \geq 0)$ figures the part of the fixed cost affected to the offer of the standard quality product by the mass-market retailer. Note that, given scale economies realised with mass distribution, C_M could be considered as small or even neglected in this case.

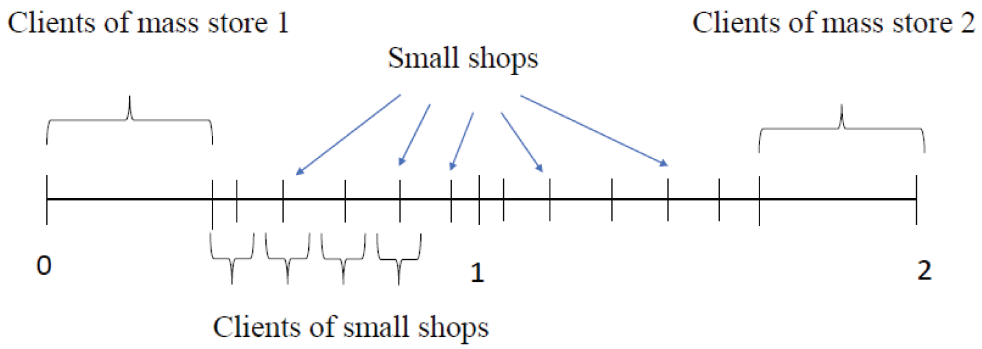

Figure 6: Mass stores and small shops

Mass stores determine symmetrically their prices, given prices of existing small stores. Their size and price are determined by Lemma 2:

Lemma 2. *With reasonable consumption externalities ($\alpha < \frac{2}{n}$), each mass-market retailer sells the standard quality product at a price $r_M = r = \bar{p} + (\frac{C_r}{n})^{1/2}$ and the number of its*

customers for this good is $n_M = (\frac{C_r}{n})^{1/2} \times \frac{n}{2-\alpha n}$. *In this case, small stores remain in the city centre, with the same price and size than in the previous specification. With stronger externalities, mass-market retailers fully crowd out small city centre stores.*

Proof: From expression (3), the threshold customer i of the mass-market retailer M is indifferent between buying to the mass-market retailer or to the closest small store j, *i.e.* $u + \alpha n_M - k_M - r_M = u - k_i - r_j$, where k_i and r_i have their free entry values determined in Lemma 1, *i.e.*, $k_i = (\frac{C_r}{2n})^{1/2}$ and $r_j = \bar{p} + (\frac{C_r}{2n})^{1/2}$. If $A = \bar{p} + 2(\frac{C_r}{n})^{1/2}$, given that $k_M = \frac{2n_M}{n}$ (if there are no 'rural' customers for hypermarkets) and under the condition $\alpha < 2/n$, $n_M = \frac{n(A-r_M)}{2-\alpha n}$. If $B = \frac{n}{2-\alpha n}$, from (4), $\pi_M = (AB - Br_M)(r_M - \bar{p}) - C_M$. After maximisation in r_M, and given the small value of C_M, $r_M = r = \bar{p} + (\frac{C_r}{n})^{1/2}$, $n_M = (\frac{C_r}{n})^{1/2} \times \frac{n}{2-\alpha n}$.

Externalities are decisive in the equilibrium size of hypermarkets. The stronger they are, the bigger the utility of the standard quality product for hypermarket customers, the wider the shares of market of mass distributions, and the lower those of small stores consequently.

2.3. Small stores concentrated in a commercial centre district

In this last specification, there are no mass-market retailers. The city is divided in two different zones. Outside the city centre, there are still small stores attracting local customers. The city centre is by contrast devoted to leisure and cultural activities. Stores located there are perceived as distinct from the proximity shops by residents, and eventually answering to another need, due to their environment and customisation. Consumer share their expenses among proximity retailers and city centre shops. They buy δ unit of goods to proximity retailers ($0 < \delta < 1$), but also variable units to city centre shops, independently of their location in the centre but only in consideration with their price and other advantages of city centre. Goods bought to the city centre shops indeed provide them a positive externality related to the number of shops present in the centre, the diversity increases the value of the shopping environment. Their demand for goods bought in the city centre then depends negatively on prices and positively on externalities associated to the number of shop in the city centre. The specification given by expression (5) integrates these properties:

$$d = (1 - \delta)(1 + \beta \tanh m_c - r_c) \tag{5}$$

where 1 represents the intrinsic utility of the good, r_c its price, and $\beta \tanh m_c$ the positive externality provided by the city centre environment, depending on the number of city centre shops $\tanh m_c$ and other components of city centre environment captured by $\beta, (0 < \beta < 1$. The form tanh(.) has been chosen to encapsulate the saturation effect: the demand of each consumer to the central city shops increases with the number of shops but at a decreasing rate, which avoids the commercial district growing indefinitely.

The profit of the j proximity shops now writes as expression (6).

$$\pi_j = n_j \delta (r_p - \bar{p}) - C_r \tag{6}$$

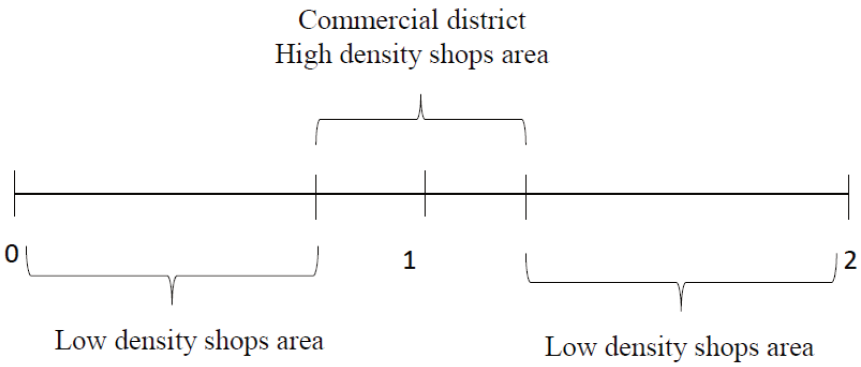

Figure 7: Commercial district

where r_p figures the price of the proximity shop j, $n_j\delta$ figures the localised demand, and n_j the effective demand of retailer j.

The individual profit of the each of the m_c city centre shops expresses as (7):

$$\pi_c = \frac{nd}{m_c}(r_c - \bar{p}) - C_d \tag{7}$$

where r_c figures the price of these shops.

From this specification is derived Lemma 3:

Lemma 3. *The consequence of the central commercial district is to decrease the density of proximity shops, and to increase their price. The number of city centre shops and their prices depend positively on the 'city centre' externalities.*

Proof: At competitive equilibrium, the proximity market is covered. Consider retailer j. Given expression (6), the threshold consumer i between retailer j and its neighbor is then such that $\delta(u - k_i - r_p) = \delta(u - (\frac{2}{m} - k_i) - \bar{r}_p)$, where $\bar{r}_p$ is the price proposed by the closer competitor of retailer j, *i.e.* $k_i = \frac{r_p - \bar{r}_p}{2} + \frac{1}{m}$. From expression (2), $\pi_j = \delta\frac{n}{2}(r_p - \bar{r}_p + \frac{2}{m})(r_p - \bar{p}) - C_r$, which is maximised in r_p. Given the free competition condition ($\bar{r}_p = r_p$), $r_p = \bar{p} + \frac{2}{m}$. The free entry makes price decreasing until it vanishes, which determines $m = (\frac{2\delta n}{C_r})^{1/2}$, and finally $r_p = \bar{p} + (\frac{C_r}{2\delta n})^{1/2}$. The distance between two proximity shops is $2/m$, which increases when δ decreases. Given expressions (5) and (7), the profit of district shops expresses as $\pi_c = \frac{n(1-\delta)(1+\beta\tanh m_c - r_c)}{m_c}(r_c - \bar{p}) - C_d$. From profit maximisation, $r_c = \frac{1+\bar{p}+\beta\tanh m_c}{2}$. Free entry determines the equilibrium level of the profit and the number of retailers m_c, such that individual profits vanishes. m_c derives from the resolution of the equation $\frac{n(1-\delta)}{m_c}\frac{(1+\beta\tanh m_c - \bar{p})^2}{4} = C_d$. m_c is solution of the equation $-n(\delta-1)(\beta\tanh m_c - \bar{p} + 1)^2 = 4m_c C_d$. Both members increase monotonously with m_c. The second increases linearly and the first in a more complex way. However, given the form of expressions $\tanh 4m_c$, it attains an upper finite limit when m_c goes to infinity while it is still positive when $m_c = 0$. These properties attest that at least one value of m_c equalises the two members of the equation. In general there is also only one value of this type. However,

given the expression of the first term, which generates one single oblique inflexion point for positive values of m_c, there could be at most three values of m_c equalising the two terms of the expression (see figures 8 to 11) simulated for different values of parameters. Precisely, if there are more than one value equalising both terms, the number is always three, never two (because of inflexion point) nor more, given that there is only one inflexion point in the left term.

Variable	Scenario 1	Scenario 2	Scenario 3	Scenario 4
β	0.4	02	0.5	0.45
$\bar{p}$	0.6	0.5	0.5	0.98
C_d	80	20	10	5
δ	0.7	0.7	0.7	0.2
n	2000	2000	1000	320
Number of interceptions	1	1	1	3

Table 5: Simulation results for π_c

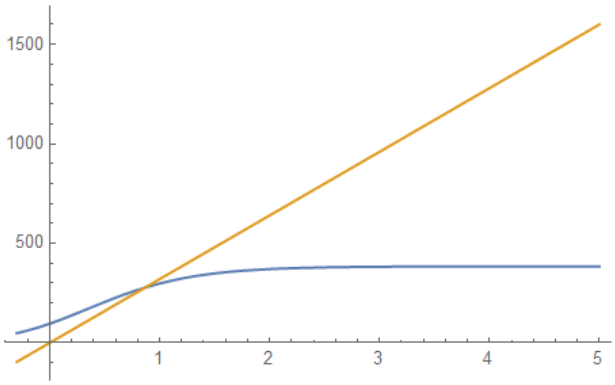

Figure 8: Scenario 1 for π_c

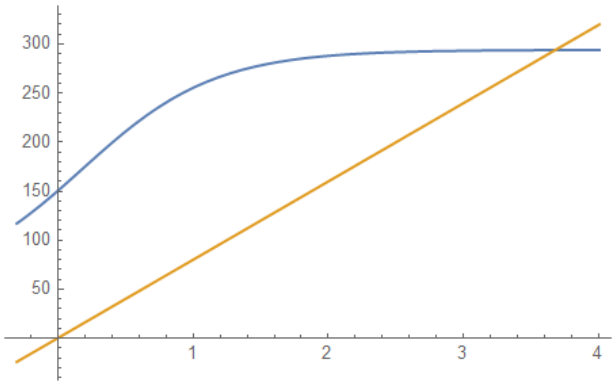

Figure 9: Scenario 2 for π_c

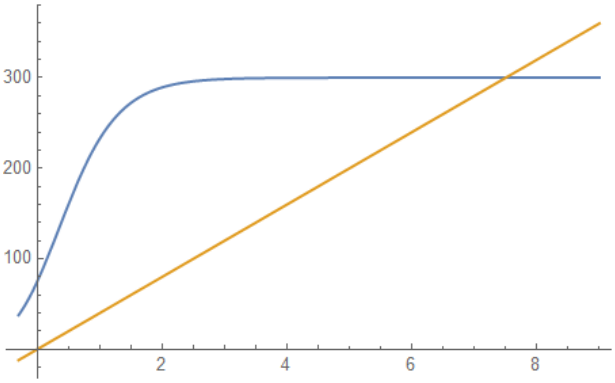

Figure 10: Scenario 3 for π_c

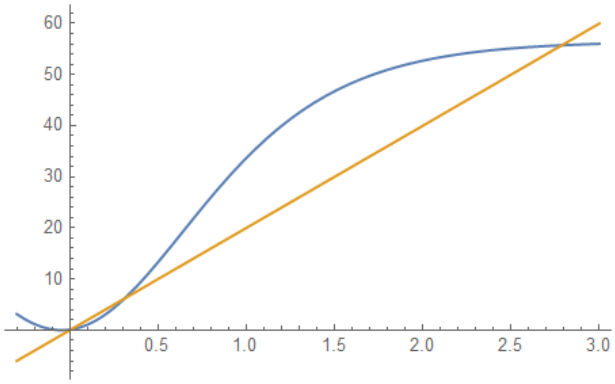

Figure 11: Scenario 4 for π_c

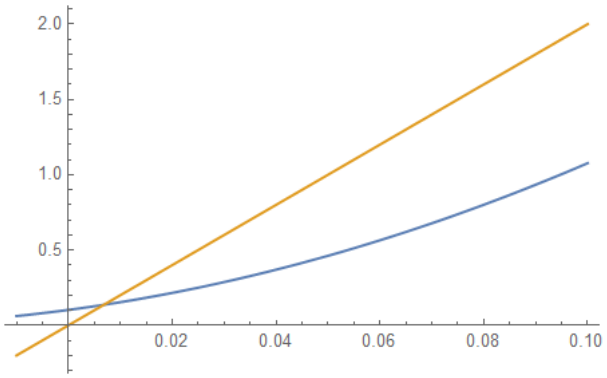

Figure 12: Scenario 4 for π_c scaled around zero

The numerical simulations used to illustrate Lemma 3 show that there are in reality three possible outcomes:

- The more frequent (Figures 9 and 10) is when the center city district integrates several stores.
- The second (Figure 8) is the case where no central district emerges, due to the low enthusiasm of residents. Mathematically, the optimal number of shops is in this case under 1.
- In the last case (Figure 11), 3 equilibria could emerge (see a focus on the first equilibrium in Figure 12. The intermediate equilibrium is unstable. As in similar situations with externalities, the equilibrium that will emerge will depend on initial conditions. Opening shops will attract clients and generate externalities that are able to make relevant the situation without a quite high number of shops, while an insufficient initial impulse will not be able to develop these externalities and finally result in an atrophied centre commercial district, or in the example where there is no centre district at all.

3. Where to find high quality products?

A new category of goods is now introduced. We identify them as 'high quality goods', goods that are produced locally via organic methods by small local producers, sharing costs and benefits of their sales. Land is identically distributed, fixed cost shared, and the wholesale/intermediate price to which they sell their production is determined on a mark-up basis: a margin is added to variable costs. As a first approximation we suppose proportional variable costs: we will discuss in the conclusion the influence of increasing costs. Production is only effective when total profits cover at least fixed costs. Once bought to local producers, high quality products can be proposed to consumers by retailers regardless of the nature of the retailers and their location in the city.

3.1. High quality products and complementary currency

Quality goods correspond to the category of credence goods (Darby and Karni, 1973, Emons, 1997, Baksi and Bose, 2007): quality is not directly observable, before or even after consumption, except at long term, with health assessments and comparisons on large

samples of populations consuming each category of goods. Without an available labelling policy, a complementary currency is then implemented by local government to help customers identifying high quality products and to promote local production. Everybody can convert at par official currency against complementary currency. Only retailers accepting a regular visit of inspectors and specialised in high quality products have the possibility to convert it back, with a slight unit conversion cost γ. Two options can be considered concerning local producers. The first one is that they can convert with the same conversion cost γ than retailers. The second is that they can convert it for free. This second option creates an incentive for producers to accept the payment in complementary currency, and for retailers an incentive to sell quality products.

Given the conditions relative to the acceptability of the complementary currency, some retailers can choose to offer high quality products without accepting complementary currency. However, this situation generates information asymmetry with the possibility of some retailers to cheat on the quality of goods. Cheaters are rational: they cannot sell their pseudo-high quality products at a price lower than honest retailers who do not accept complementary currency. If all retailers are rational, they will then all cheat if they do not accept complementary currency and propose it at a price sustainable for honest retailers, as soon as this price is credible, *i.e.* at least as high as the one of honest retailers. However, if they all cheat, there will be no way for consumers to know the sustainable price for honest retailers. They will then tend to compete and to decrease the price until cheating is no longer useful since consumers will from that moment understand that at such price the shops are selling standard quality products. Thee shops will then have the choice between moving back to their initial situation of standard quality products' sellers or to become high quality product sellers adopting complementary currency. As the case where high quality products' sellers who do not accept complementary currency is then only temporary and unstable, we ignore it in the following development.

We now move to the analysis of each city configuration.

3.2. Gentrification, high quality products, and complementary currency

Consumers' utility from standard quality products is still given by equation (1). High quality products are superior goods and their (indirect) utility depends on the budget of consumers. Given the gentrification of the city centre, consumers living there have a higher income than those in the outskirts of the city. The net utility of consumer i from the consumption of high quality products expresses then as (8):

$$u_i = u - k_i + \lambda d_i - r' \tag{8}$$

where d_i figures the distance from consumer i to the closeest extremity of the city, r' the price of the high quality product, and $\lambda (0 < \lambda < 1)$ is a positive parameter.

Retailers now have to choose depending on their location in the city, the type of goods

they will offer and their price. If they offer high quality products, they also accept to be paid in complementary currency. In this case, as soon as there is a conversion cost, their profit depends on the decision of the local producer to accept or not himself the complementary currency. If producers want to be paid in official currency, their profit is given by expression (9). If they accept complementary currency, they express as (10):

$$\pi_j = n_j[r'(1-\gamma) - p^*] - C_r \tag{9}$$

$$\pi_j = n_j(r' - p^*) - C_r \tag{10}$$

High quality goods' prices are expressed by equation (11) on a mark-up basis, where p^* is the wholesale price, c unit variable costs, and $\eta > 1$:

$$p^* = \eta c \tag{11}$$

The total net profit of local producers writes as expression (12) when they do not accept to be paid in complementary currency or if they accept to be paid in complementary currency without costs of conversion:

$$\Pi = N(p^* - c) - C \tag{12}$$

This profit expresses as expression (13) when they accept to be paid in complementary currency and are charged with a unit conversion cost γ.

$$\Pi = N(p^* - c) - C - \gamma p^* \tag{13}$$

We first consider as an initial condition the free entry equilibrium with standard quality products only.

The sequence of actions is as follows:

1. Given this price p^* and the price of standard quality products $\bar{p}$, retailers choose on an individual basis to offer high quality products or standard quality products and determine their price r.

2. Given the level of demand from retailers, local producers decide to produce or not given the level of the intermediate demand N.

3. Given their location, the nature of the products offered and their price, consumers choose the type of good they consume and the type of retailer they are clients of.

3.2.1. Redistribution of activity and competition in prices

Initial conditions are provided by the free entry equilibrium with standard quality products only. When high quality products are potentially available, as city centre customers are more interested than other in high quality products, retailers of the city centre tend to switch from standard quality products sellers to high quality products shops if this change is sustainable. Firstly, the price of high quality products increases with the proximity to the

Figure 13: High quality products stores at the city centre

centre since city centre customers have the highest purchasing power. Then, competition in prices between retailers makes prices decrease and tends to make them uniform. Initial conditions are provided by the results of subsection 2.1. The outcomes of short term decisions followed by a competition among existing stores are summarised in Lemmas 4, 5, and Proposition 1.

Lemma 4. *If any, stores selling high quality products are located at the city centre.*

Proof: Suppose that a given store j, not located at the centre or at the extremities of the city is able to sell high quality products. Then, its customers, or at least those between the centre and its location, prefer consuming high quality products at price r' than standard quality products at price $r, (r < r')$, while retailer j does not gain a higher profit when it sells standard quality products at price r, given $r', p^*, \bar{p}, \gamma$, and with a profit expressed as (10) or (9). Given expression (8), the same property then applies also for retailers closer to the city centre.

We now consider the conversion costs issue.

Lemma 5. *After competition in prices among retailers, and regardless of the value of parameters, local producers never accept to be paid in complementary currency when they are charged with the same conversion costs than retailers, and they always prefer to be paid in complementary currency when they can convert it for free.*

Proof: Suppose that some stores sell high quality products and that producers want to be paid in official currency. The more distant retailers from the centre are such that their own customer i is the more distant from the centre validates the equality (1) and (8), *i.e.*, $d_i = \frac{r'-r}{\lambda}$, where r' is the price of high quality products. Suppose that the profit of retailer j is given by (9). Then, given (2) and lemma 1, $(r - \bar{p}) = r'(1-\gamma) - p^*$, $r' = \frac{p^*+(C_r/2n)^{1/2}}{(1-\gamma)}$ and $d_i = \frac{\gamma(C_r/2n)^{1/2}+p^*-(1-\gamma)\bar{p}}{\lambda(1-\gamma)}$. As $N = 2(1-d_i)n$, $N = \frac{2n[\lambda(1-\gamma)-p^*-\gamma(C_r/2n)^{1/2}+(1-\gamma)\bar{p}]}{\lambda(1-\gamma)}$, and $\Pi(1) = \frac{n(p^*-c)(-2p^*-\gamma(2n/C_r)^{1/2}+2(1-\gamma)(\bar{p}+\lambda))}{(1-\gamma)\lambda} - C$. Suppose now that producers accept to be paid in complementary currency. The profit of retailer j is now given by (10), the same derivation gives $r' = p^* + (C_r/2n)^{1/2}$, $d_i = \frac{p^*-\bar{p}}{\lambda}$, and $N = \frac{2n(\lambda-p^*+\bar{p})}{\lambda}$. If producers are themselves charged with the cost γ, their profit is given by (13) and writes

$\Pi(2) = \frac{2n(p^*-c)(\bar{p}-p^*+\lambda)}{\lambda} - \lambda p^* - C$. $\Pi(2) - \Pi(1)$ is then always negative except for $\gamma = 0$ where it vanishes. The producers then never accept complementary currency in payment. When $\gamma = 0$ for producers, their profit is still $\Pi(1)$ when they do not accept the complementary currency in payment and $\Pi(3) = \frac{2n(p^*-c)(\bar{p}-p^*+\lambda)}{\lambda} - C$ when they accept it. The difference $\Pi(3) - \Pi(1)$ is then always positive, whatever the value of different parameters, except that it vanishes for $\gamma = 0$.

Given the continuity of different profit functions, this result attests that, whatever the level of conversion costs γ charged to retailers, it exists a level γ' (with $0 < \gamma' < \gamma$) charged to producers, such that producers are indifferent between accepting or not the complementary currency in payment. This level of γ' is interesting since for a given level of γ, it maintains at the same level the production of quality goods but would maximise the revenue of the complementary currency administrator (local government of associative structure).

Proposition (1) now considers the influence of different relevant parameters on the transition of city centre stores from standard quality goods to high quality goods.

Proposition 1. *Gentrification of the city centre locates stores selling quality goods in the city centre. The number of stores switching from standard quality products to high quality products varies in opposite sense of production costs of the local producer, of fixed costs of retailers, and of conversion costs when producers are charged.*

Proof: See Lemma 4 for the first assertion. The distance occupied by high quality stores in the centre city after the introduction of the complementary currency is $D = 2(1-d_i)$. Given that the total distance of the city is 2 and the initial number of stores is $m = (2n/C_r)^{1/2}$, the number of stores switching from one situation to the other is $m' = (2n/C_r)^{1/2}(1-d_i)$. The value of this expression depends of the conditions of conversion of complementary currency of producers. When producers do not accept complementary currency in payment, this expression writes as $m' = \left(1 - \frac{\gamma(C_r/2n)^{1/2}+p^*-(1-\gamma)\bar{p}}{\lambda(1-\gamma)}\right)(2n/C_r)^{1/2}$ where derivatives in C_r, c, and γ are negative. When producers accept complementary currency in payment, the same expression writes as $m' = \left(1 - \frac{p^*-\bar{p}}{\lambda}\right)(2n/C_r)^{1/2}$. The same sign characterises the derivatives of this term in C_r and c. Given the free conversion for producers, γ has in this case no influence.

3.2.2. Free entry equilibrium

In the long run, the new possibilities offered by high quality products attract new competitors and generate new locations of existing stores. As high quality products are not uniformly demanded along the city, the distribution and size of the shops selling high quality products finally evolves during time, through a free entry/exit and relocation process. The qualities of the final location, size and number of stores can be characterised by Proposition (2):

Proposition 2. *The size of stores selling high quality products decreases with their distance to the city centre.*

Proof: High quality products stores can be implemented sequentially or simultaneously. If they are implemented sequentially, the first one to open is at the city centre, the subsequent

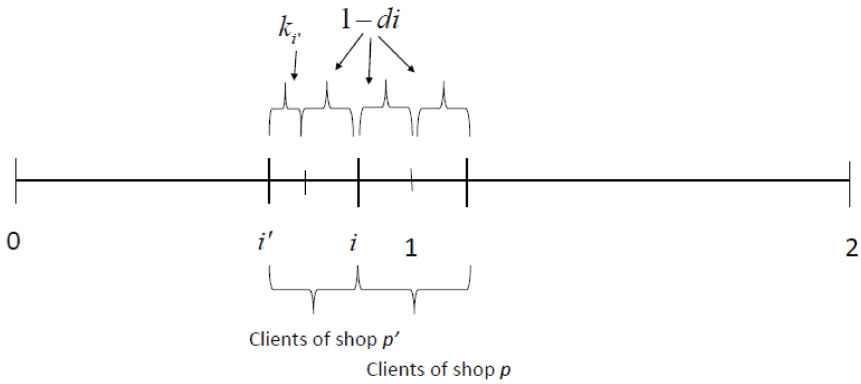

Figure 14: Size of high quality product stores

ones are located close to the centre, and less and less closer. If the entry is simultaneous and that one of them is not located at the centre of the city, free entry also finally locates an entrant in the centre since this is the best way to realise a profit. Consider then this central store, labelled p. Suppose that at the free entry equilibrium, its last customers are at a distance d_i from the extremity of the city (see figure 14). Given that for this customer, $u - (1 - d_i) + \lambda d_i - r' = u - k_i + \lambda d_i - r'$, where k_i figures its distance to the store p', the closer to p in the left side of the city, $k_i = (1 - d_i)$. The more distant the customer of p' in its left side is labelled i', and $k_{i'}$ figures its distance to p'. The utility of this customer is $u - k_{i'} + \lambda(1 - 2(1 - d_i) - k_{i'}) - r'$. Suppose that $k_{i'} \geq (1 - d_i)$. Then $u - k_{i'} + \lambda(1 - 2(1 - d_i) - k_{i'}) - r' < u - (1 - d_i) + \lambda d_i - r'$, *i.e.*, the last customer of the store p' has a smaller net utility than the last customer of the store p. Then, for price r', the profit of p does not vanish. We conclude, that $k_{i'} < (1 - d_i)$. The same deduction for shops located at left of p' and at right of p generalises the proof.

Proposition 2 tends to confirm intuition, and also meets multiple cases of observation. As city centre residents have a higher purchasing power than others, and given that high quality products are superior goods, the central location of shops selling quality goods is expected. This result reproduces stylised facts: in many cities, organic goods sellers are located in the city centre where their proximity customers have a fairly high purchasing power and accept to pay the supplement of price between high quality products and standard ones. The complementary currency signalling effect is then to help sellers of high quality products' sellers to limit uncertainty about their quality. Without any label, uncertainty would crowd out or dramatically limit the extent to which the shop is able to sell these goods.

3.3. City centre small stores, mass-market retailers, and satellites

Mass stores could be interested in the possibility of selling high quality products. Even if they do not highly contribute to their profit, they generate externalities, avoid them losing customers changing their habits, and attract new ones seduced by this new category of goods. For instance, some clients could buy standard food and digital goods and other clients quality food and digital goods inside the same store. However, as mass-market retailers do not limit to supplying high quality products, they cannot convert complementary currency,

even at cost γ. They are then obliged to sell them without this help. Usually, they have their own label, with its own reputation. This reputation is national or international, which is an incentive to avoid deviating. Many mass-market retailers are involved in adopting such policy and offer quality organic goods under such labels (French Carrefour and LeClerc groups for instance). These labels offer a way to avoid any strict local dependency and allow mass-market retailers to enlarge or diversify their customer base.

3.3.1. Mass stores selling high quality products

When mass-market retailers sell themselves high quality products, there is however a residual moral hazard about the quality they provide: reputation is not always as strong as control to reveal quality. For the same price and when externalities are not considered, they are less attractive than small stores. Utility of agents is given by expression (14) when they buy high quality products directly to the mass-market retailer:

$$u_i = u + \alpha n'_M - k'_M + \lambda' d_M - r'_M \tag{14}$$

where r'_M figures the price of the high quality product sold by the mass-market retailer and $\lambda' < \lambda$. n'_M now figures the new size of the mass-market retailer given the new offer and k'_M the distance of i to the mass-market retailer. The profit of the mass-market retailer coming from the high quality products selling is given by expression (15):

$$\pi'_M = N'_M(r'_M - qp^* - (1-q)\bar{p}) \tag{15}$$

where q corresponds to the fraction of high quality products mass-market retailer buys to local producers and N'_M the number of customers of the mass-market retailer buying high quality products. The mass-market retailer continues to offer standard goods to those preferring this category of goods: for his reason, there is no additional fixed cost when the mass store chooses this diversification. The profit resulting from this offer is still given by expression (4).

The profit of the local producer is then (16):

$$\Pi = (N + qN'_M)(p^* - c) - C_M \tag{16}$$

In this kind of configuration, given the distribution of agents in the city, mass stores customers the more distant for them buy high quality goods and the closest standard goods. Considering these two categories of clients, it is now possible to determine the condition at which it is profitable for the mass store to offer this new category of goods.

Proposition 3. *Mass stores can sell themselves quality goods only if consumers sufficiently trust them, and if production costs of local products are sufficiently low.*

Proof: If the mass market retailers sell quality goods, given utility functions, its most distant clients buy quality goods and $k'_M = \frac{2n'_M}{n}$, $d_M = k'_M$. Given expressions (14) and (1), $n'_M = \frac{n(A-r'_M)}{2(1-\lambda')-\alpha n}$. Considering the threshold mass store customer between standard goods and high quality goods buyers, $r_M = r'_M - \frac{2\lambda' n_M}{n}$ where n_M is the number of clients of the mass store buying standard goods. The total profit of the mass-store when it sells both types of

goods writes as $\Pi_M = \frac{n(r'_M - r_M)}{2\lambda'}(r_M - \bar{p}) - C_M + \left(\frac{n(A-r_M)}{2(1-\lambda')-\alpha n} - \frac{n(r'_M - r_M)}{2\lambda'}\right)(r'_M - qp^* - (1-q)\bar{p})$. It has to be compared with the profit of the mass-store when it does not propose high quality goods, *i.e.* $\pi_M = (\frac{C_r}{n})^{1/2} \times \frac{n}{2-\alpha n} \times ((\frac{C_r}{n})^{1/2} - \bar{p}) - C_M$. For this, the optimal values of r_M and r'_M are expressed. Given the form of Π_M, they are the solutions of the system obtained by cancelling the first derivatives of the expression of Π_M, after verifying the second order conditions. The solutions are $r'_M = (\frac{C_r}{2n})^{1/2} + \bar{p} = r$, and $r_M = \frac{1}{2}\left(\left(\frac{2C_r}{n}\right)^{1/2} + \bar{p}q + p^*(2-q)\right)$. All things equal, any increase of λ' increases the profit of the 'quality goods division' of the mass-store. Suppose that $p^* = \bar{p}/$ In this case the offer of quality goods is profitable even if λ' and the demand are small. When the spread between p^* and $\bar{p}$ increases, *i.e.* when C increases, λ' must be sufficiently high to make the supply profitable. The influence of q is different. Any decrease of q increases the profitability of the 'quality goods division' but with an increase of moral hazard and bad consequences and a delayed decrease of λ' (see appendix 2 for the analytical expressions of the threshold values of λ', q, and p^*).

This proposition points out two distinct consequences of the offer of quality goods by the mass store.

- The first point is that this choice can be sustainable for the mass store. Suppose that this retailer is completely fair and reliable, *i.e.* that $q = 1$. Then, if customers trust it, *i.e* if λ' increases to λ, the supply of quality goods is not only sustainable but also profitable, given the economies of scale on fixed costs of the mass store. If C is high, *i.e.* if the gross price of quality goods is high, and if the gentrification effect is weak, one can even imagine that the mass store would become the only place where to find quality goods.

- The second point is that, the success of the mass store initiative is quite always dependent on trust. Trust can be accumulated by the reputation, but it is also challenged by the actions of the mass store around the offer of standard goods. Namely, λ' does not depend only on q, even in a dynamic stetting but also on the ways the mass store manages its offer of standard goods. Increasing trust then involves specific actions which not only increase q but also $\bar{p}$ and even C_M.

3.3.2. Satellites

All things equal, *i.e.* at the same distance, at the same price and without externalities, consumers interested in high quality products could prefer buying them in specialised stores than in mass-market retailers, as complementary currency acceptance provide them a stronger guarantee against moral hazard. Mass stores could then open smaller stores with different names close to their main store and propose under high quality products under this new name. However, when there is a complementary currency already active in the city, the mass-market retailer is not included in the network and is unable to accept it even if it creates a new name to send high quality products. It has then less interest to propose this solution which increases its expenses as soon as there is a complementary currency in circulation in the city. An alternative strategy is to encourage independent stores to propose high quality products close to it. The interest could be to attract new customers to the mass-market retailer given the externalities diffused by the high quality product store.

Reciprocally, the mass-market retailer diffuses externalities to the high quality products shops. Those cross externalities create a mutual dependency between the two stores. The complementary currency network cannot refuse the satellite to integrate the network as soon as it sells only high quality products and is able to accept the chart. If the satellite offers high quality products, the utility of consumer i expresses then as (17):

$$u_i = u + \alpha n_M - k_i + \lambda d_i - r_s \tag{17}$$

where r_s is the price of high quality products bought to the satellite. As there is no reason to suppose that fixed costs of the satellite differ from fixed costs of small stores, the profit of the satellite is given by (18):

$$\pi_s = N_s(r_s - p^*) - C_r \tag{18}$$

where N_s is the number of customers of each satellite and C_r its fixed cost

The local producer sells the high quality product to the satellite. It profit is given by expression (19):

$$\Pi = (N + 2N_s)(p^* - c) - C \tag{19}$$

The utility of consumer i who buys at the mass-market retailer is given by (20):

$$u_i = u + \alpha n_M - k_i - r_M \tag{20}$$

This expression is apparently the same than (3). It however differs from it by the amount of externalities, given that n_M increases by the number of new customers generated by the proximity of the satellite.

The profit of the mass-market retailer is given by expression (4), with the same changes on the expression of n_M.

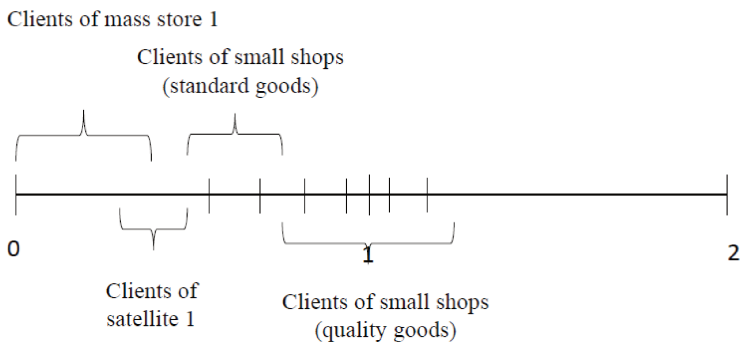

Figure 15: Mass stores, satellites, and small stores

As it is the case when the mass store sells itself quality goods, it is not possible that the threshold consumer between the group of stores made by the mass store and the satellites and the small stores buy standard goods. The satellite increases then the number of clients which diffuse positive externalities to the mass store. The point for the mass store is then

that to avoid that this advantage could be more than compensated by the transfer of clients from the mass store to the satellite concerning agricultural goods.

Proposition 4. *When a complementary currency is available, mass stores could have interest in promoting the implementation of satellites and to restrict themselves to the supply of standard goods, even if it would also be profitable to supply themselves with high quality goods.*

Proof: Consider first the threshold client among the mass store and the satellites. Given expressions (17) and (20), and the critical value of d_i, $d_i = \frac{(r_S - r_M)}{\lambda}$. Consider now the threshold consumer between the satellites and the closest small store, from which is derived $n_M = \frac{n(A-r_S)}{2(1-\lambda)-\alpha n}$, where n_M represents the total number of clients of the mass store and of the satellites (which diffuse the externalities). The profit of the satellites expresses as $\pi_s = \left(n_M - \frac{nd_i}{2}\right)(r_s - p^*) - C_r$. The profit of the mass store writes as $\Pi_M = \frac{nd_i}{2}(r_M - \bar{p}) - C_M$. The mass store plays leader in the game which determines r_M and r_s. The mass store chooses r_M which maximises its profit Π_M, given that the satellites will take this price as given to determine their own r_s which maximises π_s, and under the constraint that $\pi_s \geq 0$. This optimal value of r_M is given in appendix 2. This value is substituted in the expression of Π_M of the profit of the mass store when there are satellites. It is compared to the same profit Π_M of the mass store expressed in Proposition 3. For given values of λ, q, and p^* (or C), there exist values of λ' under which it is interesting for the mass store to encourage the development of satellites. Similarly, for given λ' and p^*, there exists a value of q from which it is interesting for the mass store to promote the implementation of satellites (see appendix 2); the same for given λ' and q, there exists a value of p^*, *i.e.* of C, such that the mass store has interest to have satellites selling quality goods close to itself.

Finally, in the most relevant cases, there are two kinds of shops selling high quality products. Small specialised stores are located in the city centre, and bigger ones are close to the mass-market retailers, inside shopping centres or malls. The use of the complementary currency has however the consequence to make more relevant a model of city where store selling quality goods and promoting short distribution channels are distinct of traditional stores. The satellite model becomes the best solution when customers can verify the origin of the products they buy. However, the complementary currency implementation provides no real solution to regulate the relation of dependency between the mass store and its satellites. The interest of the mass store is to keep the maximum of clients, then to avoid that satellites cut too much their prices. But the mass store has also interest that the satellites diffuse as muany externalities as possible, which is an incentive to make them as attractive as possible, and to cut their price. As with low prices, they attract clients also from the mass store, there could be, but not systematically, a trade-off between both effects which maintain a positive profit to the satellites.

3.4. An organic commercial belt and a versatile city centre

In the third case, the city is initially divided in two different zones. Small stores are uniformly distributed in the city and there is also a concentration of stores in a central

area devoted to culture and leisure and consumption. With the introduction of high quality products and the local currency, different effects come into play simultaneously.

Concerning proximity consumption, the effect is the same than in the previous cases. The utility of consumers is still given by expression (8) and when they are customers, they still buy only δ units of standard quality or high quality products from their local distributor. Shops located at the centre continue to answer to a different type of demand. Externalities associated to the number of shops still exert an important role. As the demand of these shops has its origin in different parts of the city, the preference for high quality products is not homogeneous but depends of the location of customers in the city. It is captured by expression (21) for agent i:

$$d_q = (1-\delta)(1+\lambda d_i + \beta \tanh m_q - r_q) \tag{21}$$

where m_q figures the number of city centre shops selling high quality products, and r_q the price of these goods. Expression (5) continues to express the demand for standard quality products to city centre shops, when m_c figures the number of these standard quality products shops. There are no cross externalities among those two categories that correspond to different styles of city centres with different associated social references, styles of leisure and modes of consumption. The profit of retailers when they choose to offer high quality products is given by expression (22):

$$\pi_q = \frac{D}{m_q}(r_q - p^*) - C_d \tag{22}$$

where D is the cumulated demand of high quality products addressed to the city centre shops.

The introduction of high quality products, and of sustainability references, tends to introduce a conflict between two different organisations of the city centre. The city centre can be occupied as initially by traditional shops selling standard quality products generating among them externalities. The same city centre could evolve toward a concentration of high quality products sellers also diffusing among them strong externalities. This situation provides then a multiple equilibrium outcome for a larger range of values of parameters, as exhibited by proposition 5:

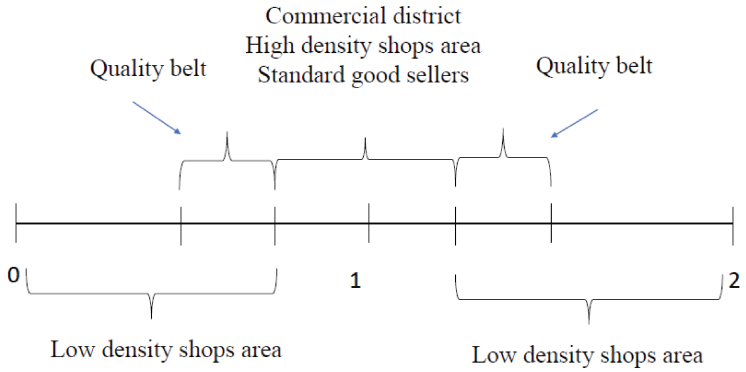

Figure 16: Traditional city centre and quality belt

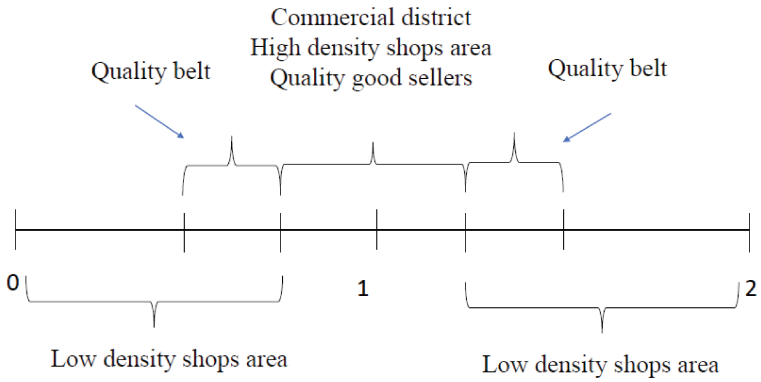

Figure 17: New norms in the city centre and quality belt

Proposition 5. *For a large range of variation of parameters, the city presents two equilibriums, the first with a city centre and the periphery occupied by stores proposing standard quality products with a belt around the centre proposing high quality products, the second with a city centre bothering retailers selling high quality products.*

Proof: Consider first the small shops outside city centre at their free entry equilibrium defined by lemma 3. Lemmas 1, 5 and Proposition 1 apply, modulo that parameter $(1-\delta)$ slightly changes numerical expressions. We conclude that, under sufficient conditions on parameters, there are high quality products shops belonging to in a 'quality belt', located as close as possible to the central commercial district. Consider now the city centre shops. Except in a limit case such that a specific number of shops of each style in the centre provides the same profit to each retailer, those last cannot have different choices for a given distribution of shops among the two styles. We deduce from that the two stable potential equilibriums which make city centre shops selling similar goods. To explore their occurrence, consider first the case where all city centre shops sell high quality products. The individual profit is given by (22), with $\pi_q = \frac{n(1-\delta)}{m_q}(1+\lambda\int_0^1 d_i di + \beta\tanh m_q - r_q)(r_q - p^*) - C_d = \frac{n(1-\delta)}{m_q}(1+\frac{\lambda}{2}+\beta\tanh m_q - r_q)(r_q-p^*) - C_d$, where m_q is given by lemma 3. The profit π_c of the benchmark and lemma 3 provide the expression of the profit when there is no quality belt: in this case, r_q is obtained after maximisation of π_q where N is given by $\frac{n(1-\delta)}{m_q}(1+\frac{\lambda}{2}+\beta\tanh m_q - r_q)$. When $m_q = 0$, there is no production of high quality products and obviously $\pi_c > \pi_q$. When $m_c = 0$, the reversed conclusion is obtained. Each equilibrium is then self-fulfilling for the same values of parameters.

Variable	Scenario 2	Scenario 3	Scenario 4
β	02	0.5	0.45
$\bar{p}$	0.5	0.5	0.98
C_d	20	10	5
δ	0.7	0.7	0.2
n	2177	1333	343
m_c	4	10	3
p^*	0.7	0.6	1.1
λ	0.4	0.2	0.25

Table 6: Simulation results for π_q

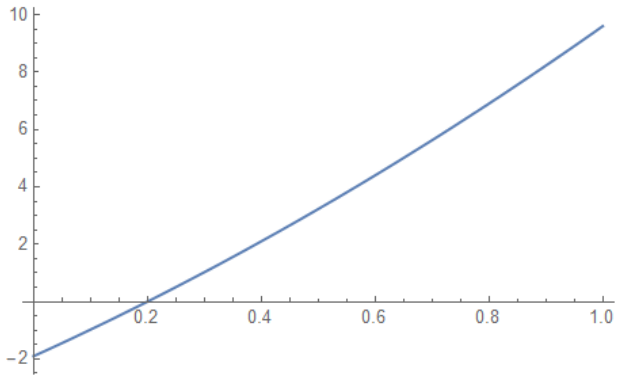

Figure 18: Scenario 2 for π_q

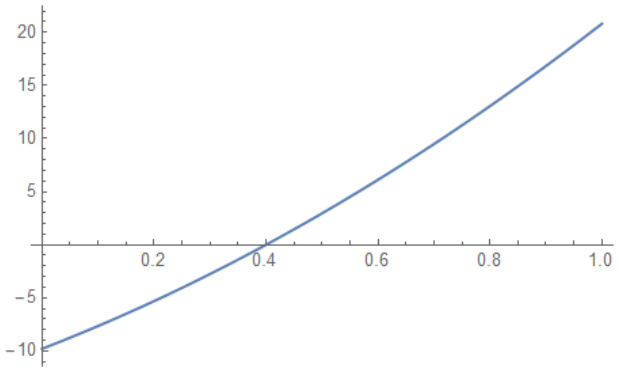

Figure 19: Scenario 3 for π_q

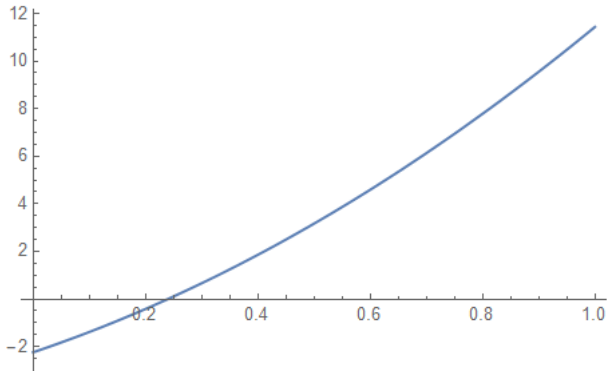

Figure 20: Scenario 4 for π_q

Proposition 5 gives an idea on the type of the indetermination associated to the transformation of city centres producing and receiving strong externalities associated to non-fundamental contents like fashion effects, crazes, and hypes. In those cases, without any possibility to precisely predict the future, the city centre commercial district can remain unchanged in its previous form, *i.e.* as a series of stores selling standard quality products, or move more or less rapidly to another model, founded on sustainability, short distribution

channels, and bio-diversity. It is also possible to compare from the point of view of shops the two situations where they provide standard or quality goods. Figures 18 to 20 provide such comparisons. We have chosen as initial conditions the long term equilibrium for city centre shops as provided by Lemma 3. In each case, the number of shops m_s corresponds to the long term equilibrium such that city centre shops profits vanishes. We recalculate the profit of the same stores when they sell quality goods. Only two values of parameters must then be defined: we fix p^*, the wholesale price of quality goods and consider the influence of the variation of λ which captures the propensity to buy quality goods, on stores profits when they sell quality goods. Without a doubt, there is generally a break-even, in term of λ from which selling quality goods is the best solution for centre district shops.

Conclusion and discussion

The objective of this chapter has been to explore the conditions of emergence and distribution of stores selling organic food that are produced locally, in different models of cities. The use of a complementary currency that is managed by an association or a local government fosters this adoption, in particular when local producers are exonerated from reconversion costs from the complementary currency to the legal tender. However, the initial location and the size of stores also matter. Whilst city centre gentrification tends to promote a central location of the stores selling high quality products, other logic compete with this generic model. Organic food can be found in the suburban areas, as a consequence of externalities generated by malls. These last could have the initiative to develop their own satellites, able to consolidate their competitive advantage in the outskirts of cities. When city centres are already occupied by a concentration of stores that also generate cross externalities, the situation evolves toward indeterminacy with the introduction of a complementary currency. Stores in the city centre could continue selling standard products and reject organic ones with the presence of sellers in a 'quality belt' around the centre, or they can also adapt themselves to a new model, with a central area dominated by sellers of organic products.

Chapter 3

EXPLORING THE INTRINSIC FACTORS INFLUENCING THE ADOPTION BEHAVIOUR OF A LOCAL CURRENCY: THE CASE OF THE RENOIR IN CAGNES-SUR-MER

In France as of 2016, there were about forty ongoing local complementary currencies projects (Blanc and Fare, 2018) and as of 2021, more than one hundred citizen-led projects according to the *Local Citizen Complementary Currencies* website (*Monnaies Locales Complémentaires Citoyennes*, 2021). With the exception of the Eusko (*Euskal Moneta*, 2021), which is the biggest local currency in Europe with over one million euros in transactions volume in 2019, local currencies are not very successful in France due to a number of reasons exposed by Blanc and Fare (2018) such as the underused potential of committed local governments, the need for more employees, for a digital version of the currency, and for more funding activities. After more than four years after its launch, one local currency in a coastal city of France is stagnating in terms of number of users and dynamic of the project, like many other local currencies. The Renoir is the local currency of the city of Cagnes-sur-Mer (hereafter referred as Cagnes) in the French Riviera (South-East of France), created mainly to help revive the city's shopping experience and foster short distribution channels. Although many studies in the literature looked into local currencies (and complementary currencies in general) issues from the perspectives of project leaders, territories, and institutions, not many have addressed the subject via the lenses of consumers (users and non-users of the local currency). We are interested in shifting the focus to consumers by exploring their determinants of adoption of a technological and social innovation that is in our case a local payment system.

The objective of this chapter is to explore the intrinsic factors that may influence the adoption behaviour of local currencies. By adoption behaviour, we refer to the act of using the local currency at least once (trial) and does not necessarily imply a regular usage as described by Rogers (2003). Instead of asking respondents directly why they use or do not use the local currency, we approach the problem by making the respondents reveal their preference and characteristics in a way that would mitigate the risk of social desirability and conformity bias in the responses. This type of studies basically include users and non-users of the product, even those who are unaware of it as mentioned by Arts et al. (2011) in their meta-analysis of consumer innovation adoption. Survey data of two hundred respondents comprised of users and non-users of the local currency are analysed in this chapter. Using statistical tools, we aim to establish a model capable of predicting the adoption or not by consumers for the Renoir. The findings and recommendations from this chapter will serve as a pathway to improvement for the Renoir and other local currencies, and will contribute to the literature of empirical studies concerning the determinants of adoption behaviour for a specific payment system like local currencies. The chapter is organised as follows. The first section provides an overview of the literature of empirical studies around technological and social innovations, the second section focuses on the case of complementary and local currencies, the third section presents the Renoir local currency project and its challenges, the fourth section describes the methodology of the chapter, the fifth section includes the statistical analyses and interpretations, and the sixth section discusses the factors influencing the adoption.

1. Consumer adoption of technological, social, and 'green' innovations

Social innovation can be perceived as a multidimensional concept and its definitions and aims vary across the spectrum of disciplines. In studies like economics, a social innovation would be an initiative that intents to incorporate social and ecological objectives in the classic agendas of businesses (Moulaert, 2005). Cajaiba-Santana (2014) describes social innovation as a driver of social change and is built via legitimated social actions. But the technological aspect cannot be completely disregarded when addressing social innovation as these two notions had always been debated together in both opposing and complementary speeches (Foucault, 1979; Hillier et al., 2004; Moulaert, 2005; Schumpeter, 1942). In this sense and bearing in mind the aims of local currencies, they can be considered as a social and technological innovation at the local level. The technological aspect is approached in this case as a continuous process driven by creativity and aimed at improving the global welfare of consumers and businesses, *e.g.* the use of bubble-wrapped features on local currency paper notes to ensure authenticity instead of special papers like traditional bank notes, or the use of smartphone applications or other technologies (such as blockchain) to instantly process transactions and manage cash-backs on purchases.

Most studies relating to the adoption of a new technology are done in the information technology (I.T.) field. Among the different approaches used in the literature, Choudrie and Dwivedi (2005) found that the survey method was primarily employed on topics of user adoption and technology usage. Williams et al. (2019) also concluded in their systematic review findings that the survey is commonly used in adoption and diffusion research.

Concerning the determinants that are usually considered in those studies, more and more authors are incorporating intrinsic determinants in their variables and their results became significantly more intriguing. Venkatesh (2000) included intrinsic motivation and emotion (playfulness) in his analysis of the determinants of perceived ease of use of a technology. In the comprehensive meta-analysis of the literature conducted by Arts et al. (2011), they found that among the 200 variables used in the 77 studies from 1970 to mid-2007, the psychographics of respondents such as innovativeness, opinion leadership, media proneness, and involvement happened to exert powerful influences on the adoption intention and behaviour while the socio-demographics only showed minor influence. The same authors also clearly distinguished adoption intention as the 'expressed desire to purchase a new product in the near future', whereas adoption behaviour is the '(trial) purchase of an innovation' (Rogers, 2003). In our case, the relevant applicable concept is the latter one.

Other determinants in adoption studies include 'community' variables such as cosmopolitanism (Lim and Park, 2013) and influences of social neighbourhood (Pénard et al., 2012), and variables pertaining to an individual's 'life experience' such as perception of innovation according to the respondent's values and their past experience and needs (Saaksjarvi, (2003). Factors relating to emotions such as mood and commitment, and prior experience with a certain movement/project were also used as variables in studies of Dietrich et al. (2016),

Djamasbi et al. (2010), and Perry et al. (2008).

For payment systems adoption, Antonides et al. (1999) found that social learning and consumer experience influence the adoption of such systems. Regarding mobile payment, a review of 94 existing academic publications by Slade et al. (2013) showed that factors like perceived ease of use, perceived usefulness, compatibility, interest in m-payments, social influence, use context, payment scenario, and trust affect positively the adoption and factors like costs, risk, and attractiveness of alternative payment systems negatively affect the adoption.

Often, complementary currencies are associated with social and economic goals and explicitly pro-ecological complementary currencies are rare. As they are not 'green' products by nature, they can be considered as green or eco-innovations fostering practices that lead to responsible and ecological behaviours as shown by Fare (2012), Michel and Hudon (2015), and Seyfang (2006). Regardless of the under-researched ecological aspect of complementary currencies, related findings on the determinants of adoption of green innovations and products may serve as a foundation for analyses in our field. Jansson et al. (2010) showed that curtailment behaviours (*e.g.* saving water, reducing car use) have an impact on habits and pro-environmental behaviour. They also found that personal values, norms, beliefs (in the form of responsibility ascription), and previous adoption experience can have effects on both the willingness to adopt an eco-innovation and to curtail. Nath et al. (2013) found that literacy and environmental awareness, consumer outreach, legal enforcement, peer groups and cultural values, and incentive tools are top enablers for the adoption of green products. The next section discusses studies pertaining specifically to complementary currencies.

2. Empirical studies on complementary currencies

The adoption behaviour of local currencies has never been studied in the literature. The only study related to the aspect of adoption is the one of Peña de Carrillo et al. (2008) who addressed the barriers and solutions to the adoption of complementary in general through perspectives of the administrator, companies, and users. They classified four types of barriers : (i) emotional, (ii) management, (iii) environmental (as of environment of the project, not in ecological sense), and (iv) technological. For consumers those barriers include among others (i) fear of the unknown and past experiences, loyalty to brand, habits, (ii) reconversion, (iii) lack of bargaining power, and (iv) low digital skills. Besides that, there are only a few studies that focus on the motivations behind the use of complementary currencies and the conditions for their success. In addition to this lack, we find no study addressing the intrinsic factors influencing the adoption behaviour of local currencies.

For local currencies in the United States (US), Collom (2005) found that cities in the U.S. that have community currencies, have populations with characteristics such as lower household incomes, higher poverty rates, higher unemployment rates, and larger self-employment sectors. Moreover, the survival of community currencies are linked to places that have younger populations, higher educational attainment, fewer married people, and less residen-

tial stability. Kim, Lough and Wu (2016) found that local currencies in the United Kingdom (UK) are more successful under certain conditions such as: in less populated areas or geographically isolated areas that may be due to a stronger sense of belonging and community support, in households with low levels of incomes, and in communities that have historical or prior experience to alternative economic movements such as local currencies and economic marginality. They also found that organisational strategies for seeking seed funding, organisational strategies for merchant engagement, operational logistics, and communication and marketing skills are implementation strategies, that are required for the success of local currencies.

For other types of complementary currencies, in a study of twenty-six LETS in the UK, Williams et al. (2001) found that 25% of people join for ideological reasons, act of resistance to various mainstream 'others' such as capitalism, materialism, globalisation and profit motive, 70% join for economic reasons (receive goods and services and use skills), and 3% join to improve their employability in labour market. In other three individual LETS systems in Australia, Williams (1996) found that 51% of users cite economic reasons, 30% social reasons, and 30.6% ideological reasons. Gran (1998) found in this study of Norvegian LETS that respondents emphasise more on short-term altruistic motives than self-centred motives. Birch and Liesch (1997) found that the primary reasons of some Australian LETS users in their study were to build a stronger community and encourage local initiatives. Caldwell (2000) established a motivational taxonomy by classifying some LETS users in the UK according to four categories of motivation: economic self-interest (16 people), economic altruism (25), ecological self-interest (25), and ecological altruism (33). Concerning time banks in the UK, Seyfang (2002) recorded in his study that 78% of users claim that they join to help others, 72% to get more involved in the community, 56% to improve their neighbourhood, 44% to meet people and/or make friends, 44% to get help for themselves, and 17% to earn time credits. Collom (2007) found in his study of time banks in the US, 7 factors (motivations) that he transformed into 7 scales: social, values, altruistic, instrumental, independence, needs, wants.

Overall, recurrent factors associated to economic and social difficulties in the communities are present for the three types of complementary currencies. It seems that no ecological factors are linked to the use of such currency and they are more related to the economic status of the communities they are present in. Furthermore, the risk of social desirability and conformity bias is highly probable in these types of studies that focus solely on the motivations of users due to the fact that people are more likely to answer in a way that is consistent with the core values of the projects (socialisation, solidarity, altruism, ...*etc.*) even if their real intentions differ from them.

Author(s)	Year	Country(ies) studied	Type of CC	Topics of focus
Collom	2005	United States	Local currencies	Conditions for success and implementation strategies
Kim, Long & Wu	2016	United Kingdom		
Williams et *al.*	2001	United Kingdom	LETS	Motivations of users
Williams	1996	Australia		
Gran	1998	Norway		
Birch & Liesch	1997	Australia		
Caldwell	2000	United Kingdom		
Seyfang	2002	United Kingdom	Time banks	Motivations of users
Collom	2007	United States		

Table 7: Summary of studies on the motivations of users, and the success of complementary currencies (non-exhaustive)

3. The Renoir local currency

Unlike other citizen-led local currencies, the Renoir was launched in September 2016 by the Federation of Associations of Merchants and Artisans of Cagnes (hereafter referred as Federation). It is named in tribute to the famous French painter *Pierre Auguste* Renoir who spent the last moments of his life in the city. From the latest publicly available on Cagnes in 2017 by the French Institute of Economic and Statistical Studies INSEE (*Dossier complet*, 2021), the city has an ageing population with an important number of small size businesses (1 to 9 employees) creation in the wholesale and retail trade, transport, accommodation and catering sector (246 new businesses representing 27.5% in 2020). The objectives of the Renoir are the promotion and facilitation of short distribution channels and local produce, and the revitalisation of the city businesses that are under threat from the Polygone Riviera and Cap 3000; two commercial centres that sit on the outskirts of the city. It does so by providing economic and ecological incentives for users to purchase in city businesses with the Renoir.

The mission of the local currency is to 'show everyone's attachment to this same territory and help defend our local businesses' (*Le Renoir*, 2020). It is managed by the Association of the Renoir, with members from the Federation itself. The counterpart in euros that serves as the supply reserve is placed at the *Crédit Agricole* cooperative bank. There are currently eight exchange offices and sixty shops accepting the currency as of November 2020. Member shops are identified with a sticker that reads 'Welcome to the Renoir', and are mostly located in a few strategic spots of the city such as the city centre, the *Cros*, the *Béal*, and the train station. The number of users is around 275 according to the database as of February 2020. The Renoir is available in six paper notes: one, two, five, ten, twenty, and fifty-euro note. Different paintings of Auguste Renoir figure on each note, making the currency aesthetically pleasing for users.

Since the launch of the currency, an economic incentive have been made to attract and maintain users. A 10% bonus is granted to users whenever they convert euros into Renoir. The desired outcome from this extra 10% gain is to incite consumers to spend money in member shops of the city that accept the local currency, which in turn strengthens the local circuit and serves as a pedagogical tool for consumers to learn about money and their local economy. This increase in purchasing power for users is covered by the Federation. During the Covid-19 post-confinement period, the bonus was temporarily raised to 20% in June 2020 (*La Monnaie Cagnoise*, 2020). Users need to sign up to use the currency for an annual membership fee of 5 € (free for the first year). For purchases with decimal prices, user pay the integer part in Renoir and the rest in euro: for instance if a product costs 10.5 €, the user pays 10 Renoir and 50 cents in euro.

In terms of communication, the main channel of information for users is the public Facebook page *La Monnaie Cagnoise : le Renoir* (2021). There is also a page dedicated to the currency on the website of *Esprit Cagnes*, the online platform for the city's shopping experience, where we can also find the list of exchange offices and shops that accept the local currency. Previously, there were two subsequent official websites for the Renoir that were created but they are now defunct due to management issues. There is still plenty a lot of room for improvement regarding the communication aspect of the project as it is deemed insufficient by many users. The project is now working on extending its social media presence to other platforms like Instagram and LinkedIn.

In an interview with the local press, the President of the Federation claimed there were approximately 300 000€ equivalent in Renoir injected in the local economy of Cagnes in 2020, which he believes is a great achievement for the project (*Quatre après sa création*, 2021). However he still thinks that sustainable development actors in the city could take more 'actions' by adopting the Renoir, and local merchants who adopt the currency should make an effort to re-inject the money into the local circuit via B2B transactions instead of reconverting them back systematically. Besides these challenges, the project does have a value chart for its users and have also been facing other hurdles in its development such as a lack of customer relationship management tools and employees.

In 2018, the Renoir studied the possibility of a digitalisation of the currency but failed to shape in due to the high costs of the solutions considered and the departure of the then-project manager. Since then an initiative supported by the city has emerged with a electronic payment card called *Bonjour Cagnes* (2021), where people can use to pay for parking spots and in member shops of the Federation of the city. The card is linked a mobile application that acts as a payment terminal. Users would receive up to 5% cash-backs on purchases made in member shops that accept the Renoir. The 5% is funded by shops themselves (2%) and the Federation (3%). The digitalisation is set to launch in September 2021 and once it becomes effective, the inital 10% conversion bonus for paper notes will be reduced to 5% to match the cash-backs of the card. Nonetheless, the effectiveness of the card solution in attracting more users is still in question and deserves its own impact study.

4. Methodology

4.1. Theoretical framework and hypotheses

Based on the objectives of the Renoir and the findings of previous works in terms of determinants of adoption, motivations and conditions of success of local currencies, we integrate a few main variables of interest along with socio-demographics ones and pose some hypotheses that will allow us to investigate the case of Cagnes-sur-Mer. We also introduce the ecological dimension in the hypotheses since it is one of the objectives of the Renoir and also of many local currencies to promote sustainable development practices such as short distribution channels and consumption of local products. This aspect was lacking in previous studies on local currencies. Most consumers perceive local currencies at first sight as a social, economic or technological innovation, while the ecological dimension may be harder to enforce and its effects are more likely to be visible in the longer term. In fact in the case of the Renoir, the President of the Federation admits that the 'green' aspect of the project has been sort of lacking, so an absence of effect with respect to the ecological variables is expected to show up in our analyses. Drawing on all the aforementioned points, we develop the following hypotheses with specific determinants relevant to our case study.

Variables and hypotheses to be verified by the model:

1. H1: Prior experience to social and solidary economics (from French *économie sociale et solidaire*) organisations (SSEO) activities influences positively the adoption of the local currency. SSEO include cooperatives, mutuals, associations, and/or foundations according to the definition by the French Ministry of the Economy and Finance (*Qu'est-ce que l'économie sociale et solidaire ?*, 2021). This determinant is also one of the factors that came out of Kim et al.'s (2016) studies on the conditions of success of local currencies (alternative economic movements).

2. H2: Preference for high quality products influence positively the adoption of the local currency. Products from local producers and retailers are often perceived by the average consumer as made with less 'industrial' processing and thus as higher quality than those generic products from supermarkets. This determinant is in line with Arts et al.'s (2011) 'product involvement' antecedent described as 'the degree to which a consumer experiences differentiation, familiarity, importance and commitment for a specified product category, not brand'.

3. H3: Feeling/sense of solidarity in the community influences positively the adoption of the local currency. This determinant is linked to the emotion and neighbourhood dimension. As mentioned previously in the literature, good mood, a sense of belonging, and social network integration play an important role in the adoption behaviour of individuals.

4. H4: Interest in community activities influences positively the adoption of the local currency. People who have 'information seeking' and 'innovativeness' propensity characteristics as described by Arts et al. (2011) are more likely to adopt an innovation or a new products.

5. H5: Preference for local products influences positively the adoption of the local currency. This determinant is distinct from H2 and can be clearly dissociated because high quality products are not necessary local ones and vice-versa. The local aspect here reflects the sustainability dimension linked to short distribution channels and ecological footprint.

6. H6: Practice of 'virtuous gestures' influences positively the adoption of the local currency. We give the freedom to respondents to define by themselves what virtuous gestures could signify. In case they ask for clarification, we provide them some examples of both curtailment and adoption behaviours such as recycling, electricity saving, bulk purchases, ...*etc.* This determinant is also part of the sustainability variables introduced in our analyses.

7. H7: Socio-demographic characteristics influence the adoption of the local currency, either positively or negatively. Besides the traditional variables (sex, age, income, ...*etc.*) that we input based on the INSEE reference, we add the extra parents and future aspect as we are interested in exploring if the adoption of an innovation is influenced by the fact that individuals have a child or children or not. This determinant questions the eventual effect children have on the way parents think about the world in which they want their children and grandchildren to live in and thus, it affects their choice in the present.

There are thirteen independent categorical variables in our study: main variables from H1 to H6, and socio-demographic variables included in H7 are sex, age, household income, highest diploma, children, socio-professional category, and marital status. Our variable of interest (dependent variable) is the binary variable distinguishing people who use the local currency and people who do not use it. The variables are initially coded as follows (the number in parentheses represent the number of categories):

1. H1 as EXPASS (binary): 1 for 'Yes', 0 for 'No'

2. H2 as QUALPROD (3): 2 for 'Yes', 1 for 'I don't know', 0 for 'No'

3. H3 as SOLIDA (3): same as H2

4. H4 as INTCOM (3): same as H2

5. H5 as CONSOLO (3): same as H2

6. H6 as GESTEVERT (3): same as H2

7. H7 - sex as SEX (binary) : 1 for 'Woman', 0 for 'Man'

8. H7 - age as AGECAT (5):

    - 1: 15-29
    - 2: 30-44
    - 3: 45-59
    - 4: 60-74

- 5: 75+

9. H7 - socio-professional category as CSP (8):
    - 1: Farmer
    - 2: Artisan, merchant, or entrepreneur
    - 3: Executive, or superior intellectual function
    - 4: Intermediate professional
    - 5: Employee
    - 6: Factory worker
    - 7: Retired
    - 8: Unemployed, student, or seeking a job
10. H7 - child(ren) as ENF (binary): 1 for 'Yes', 0 for 'No'
11. H7 - highest diploma as EDUC (5):
    - 1: None, primary studies certificate, year 9 diploma, certificate of professional competence, or vocational studies certificate
    - 2: High school diploma, or equivalent
    - 3: 2 years of higher education
    - 4: 3 or 4 years of higher education
    - 5: 5 years or more of higher education
12. H7 - household income level as REV (6):
    - 1: <15k €
    - 2: 15-25k €
    - 3: 25-35k €
    - 4: 35-45k €
    - 5: 45-55k €
    - 6: >55k €
13. H7 - marital status as SIM (6):
    - 1: Single
    - 2: Cohabitation
    - 3: Pacsé (civil solidarity pact), a form of contractual civil union in France with fewer rights and responsibilities than a marriage
    - 4: Married
    - 5: Widow/er
    - 6: Divorced
14. Dependent variable as UT (binary): 1 for 'Yes', 0 for 'No'

4.2. Data collection and analyses

Data was collected via two methods: live interviews (face to face around the strategic shopping areas of the city, and via telephone) and survey questionnaire (email, online, and via shop owners). Initially and ideally, the collection was supposed to be done as much as possible in-person but due to the Covid-19 outbreak episode at the time of data collection, we had to adapt and collect data via other virtual methods instead. To avoid survey biases, we try to provide as many answer choices as possible to the questions (Likert-style items for our main variables) and as fewer leads as possible. One way of negating social biases is to not declare any information relating to the Renoir local currency in the beginning of the survey so that the answers of respondents do not take this aspect into consideration (as it might greatly influence their answers). The original stated purpose of the survey for respondents was simply the study of consumer preferences and characteristics. The interview version of the questionnaire is presented in Appendix 2. Responses were recorded in Microsoft Excel spread sheets, and all statistical analyses and data curation processes were done with R Studio.

5. Statistical analyses

5.1. Descriptive statistics

There are 200 observations in our sample, composed of 81 Renoir users. In terms of socio-demographic characteristics, the sample is composed mostly of respondents who are: 60 to 74 years old (36.5%), women (56%), retirees (42%), and married (45%).

Table 8 and 9 provide a brief comparison of the counts and proportions from our sample, the local currency users database, and the population of Cagnes (*Dossier complet*, 2021) based on sex and age as the other characteristics were not available for the users database.

Age category	Population		Sample		Users	
	Count	%	Count	%	Count	%
15-29	7336	16.96	23	11.5	14	5.51
30-44	9132	21.11	35	17.5	55	21.65
45-59	9843	22.76	44	22	59	23.23
60-74	9648	22.30	73	36.5	81	31.89
75+	7297	16.87	25	12.5	45	17.72
Total	43256	100	200	100	254	100

Table 8: Population, sample, and users counts and proportions by age group

Sex	Population		Sample		Users	
	Count	%	Count	%	Count	%
M	19686	45.51	88	44	94	34
F	23570	54.49	112	56	182	66
Total	43256	100	200	100	276	100

Table 9: Population, sample, and users counts and proportions by sex

The totals are different for the users database because some users did not provide their date of birth. Table 10 and 11 show the counts and proportions of our sample for all the variables in our study.

Table 12 shows the frequencies of answers to the six main questions. We observe that for only two of our factors, the majority of respondents who answered yes belong to the users group *i.e.* 51% of respondents who have a prior experience with SSEO activities, and are interested in community activities are local currency users. Conversely, for the other four remaining factors, the proportions of non-users among those who answered 'yes' to the questions are more important than those of users. This may hint at the fact that the people who have a sense of belonging or solidarity in the community, have a preference for high quality, and local products, and practice ecological gestures may not associate the local currency to these aspects. At this stage we cannot have a clear view about whether these results may or may not support our hypotheses because of the discrepancies between them.

For the socio-demographic characteristics, the highest proportion of users are women, people age 60 to 74, retirees, people who have a child/children, people who are married, people who have a household income level between 15000 and 25000 €, and people who have no diploma, primary studies certificate, year 9 diploma, certificate of professional competence, or vocational studies certificate.

In the next section, we proceed to look for specific profiles of respondents who belong to each of the users and non-users groups, if there are any. Missing data for the household income level variable are considered as MCAR (missing at random), and they were imputed using the MICE package provided by R.

Variable	Category	Count	Prop
Users	No	119	0.60
	Yes	81	0.40
Experience in SSEO activities	No	128	0.64
	Yes	72	0.36
Interest in community activities	Rather no/Absolutely no	62	0.31
	I don't know	4	0.02
	Rather yes/Absolutely yes	134	0.67
Feeling of solidarity in the community	Rather no/Absolutely no	62	0.31
	I don't know	38	0.19
	Rather yes/Absolutely yes	100	0.50
Practice of 'virtuous' gestures	Rather no/Absolutely no	18	0.09
	I don't know	1	0.01
	Rather yes/Absolutely yes	181	0.90
Preference for local products	Rather no/Absolutely no	25	0.125
	I don't know	2	0.010
	Rather yes/Absolutely yes	173	0.865
Preference for high quality products	Rather no/Absolutely no	22	0.110
	I don't know	4	0.015
	Rather yes/Absolutely yes	174	0.875
Sex	Man	88	0.44
	Woman	112	0.56
Age	15-29	23	0.115
	30-44	35	0.175
	45-59	44	0.22
	60-74	73	0.365
	>75	25	0.125
Socio-Professional Category	1	1	0.005
	2	13	0.065
	3	20	0.1
	4	25	0.125
	5	33	0.165
	6	6	0.03
	7	84	0.42
	8	18	0.09

Table 10: Sample counts and proportions - part 1

Variable	Category	Count	Prop
Child(ren)	No	48	0.24
	Yes	152	0.76
Education level	1	79	0.395
	2	33	0.165
	3	27	0.135
	4	32	0.16
	5	29	0.145
Income level	<15k	41	0.2169
	15-25k	53	0.2804
	25-35k	37	0.1958
	35-45k	31	0.1640
	45-55k	7	0.0370
	>55k	20	0.1058
Marital status	Single	54	0.27
	Cohabitation	7	0.035
	Pacsé	9	0.045
	Married	90	0.45
	Widow/er	16	0.08
	Divorced	24	0.12

Table 11: Sample counts and proportions - part 2

Variable	Category	Non-user	User
Experience in SSEO activities	No	0.66	0.34
	Yes	0.49	0.51
Preference for high quality products	Rather no/Absolutely no	0.82	0.18
	I don't know	0.50	0.50
	Rather yes/Absolutely yes	0.57	0.43
Feeling of solidarity in the community	Rather no/Absolutely no	0.71	0.29
	I don't know	0.50	0.50
	Rather yes/Absolutely yes	0.56	0.44
Interest in community activities	Rather no/Absolutely no	0.84	0.16
	I don't know	0.25	0.75
	Rather yes/Absolutely yes	0.49	0.51
Preference for local products	Rather no/Absolutely no	0.88	0.12
	I don't know	0.00	1.00
	Rather yes/Absolutely yes	0.56	0.44
Practice of 'virtuous' gestures	Rather no/Absolutely no	1.00	0.00
	I don't know	0.00	1.00
	Rather yes/Absolutely yes	0.56	0.44

Table 12: Frequencies of responses to the six main variables

Reading: 66% of respondents who answered 'No' to having any prior experience in SSEO activities have never used the local currency. 49% who answered 'Yes' to the same question are users.

Variable	Category	Non-user	User
Sex	M	0.54	0.30
	F	0.46	0.70
Age	15-29	0.17	0.04
	30-44	0.17	0.19
	45-59	0.23	0.21
	60-74	0.33	0.42
	>75	0.11	0.15
Socio-Professional Category	1	0.01	0.00
	2	0.06	0.07
	3	0.06	0.16
	4	0.16	0.07
	5	0.17	0.16
	6	0.05	0.00
	7	0.36	0.51
	8	0.13	0.02
Child/ren	No	0.29	0.16
	Yes	0.71	0.84
Education level	1	0.50	0.25
	2	0.18	0.15
	3	0.08	0.21
	4	0.15	0.17
	5	0.09	0.22
Income level	<15k	0.33	0.05
	15-25k	0.28	0.28
	25-35k	0.16	0.24
	35-45k	0.17	0.15
	45-55k	0.03	0.05
	>55k	0.03	0.22
Marital status	Single	0.37	0.12
	Cohabitation	0.03	0.04
	Pacsé	0.03	0.07
	Married	0.36	0.58
	Widow/er	0.11	0.04
	Divorced	0.10	0.15

Table 13: Frequencies of responses to socio-demographic variables

Reading: 54% of non-users are male versus only 30% in the group of users.

5.2. Multiple Correspondence Analysis

To explore whether there exist specific profiles of people belonging to the users and non-users groups, we run a Multiple Correspondence Analysis (MCA) on our data. For simplicity, only the first two dimensions will be discussed.

Figure 21 shows the individuals graph coloured by users (UT_1) and non-users (UT_0), and figure 22 the variables graph by degree of contribution (only the ten variables contributing the most are shown). There seems to be two groups forming from users and non-users, and the confidence ellipses do not cross over, which indicates that the population subgroups are significantly separated.

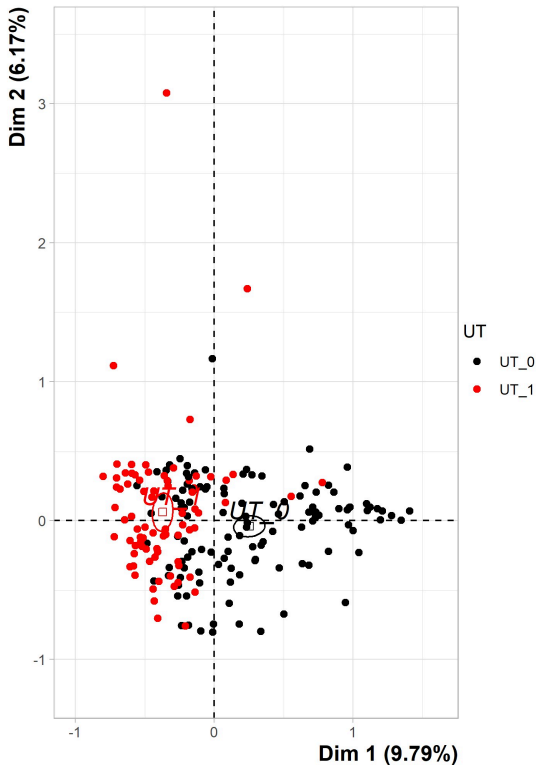

Figure 21: MCA individuals graph

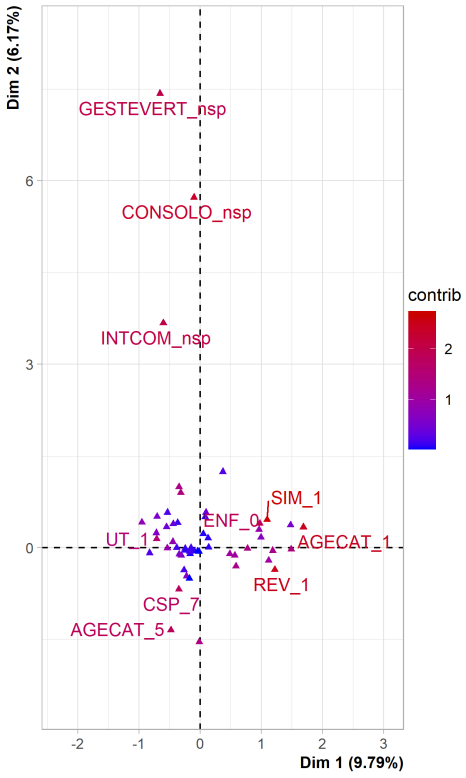

Figure 22: MCA variables graph

Figure 23 provides information on the categories contributing significantly to dimension 1 by descending order: SIM_1 (single people), REV_1 (people in the lowest household income bracket of less than 15000 € per year), AGECAT_1 (people age 15 to 29 years old), and UT_0 (non-users) with their respective contributions of 8.5%, 8.4%, 8.6%, and 3.6%. For variables, dimension 1 appears to be most significantly linked to the socio-professional category (CSP), the household income level (REV), the marital status (SIM), and the age category (AGECAT) as shown by figure 25. The same analyses can be made for dimension 2 with table 24 and 26.

	Estimate	p.value
SIM=SIM_1	5.875E-01	4.621E-27
REV=REV_1	7.491E-01	2.427E-24
AGECAT=AGECAT_1	8.017E-01	1.211E-21
UT=UT_0	3.121E-01	6.897E-20
ENF=ENF_0	3.356E-01	3.969E-17
INTCOM=INTCOM_non	4.341E-01	3.069E-15
SEX=SEX_0	2.647E-01	3.125E-14
EDU=EDU_1	4.116E-01	1.557E-12
CSP=CSP_8	6.470E-01	2.878E-12
CONSOLO=CONSOLO_non	4.605E-01	2.670E-11
QUALPROD=QUALPROD_non	3.518E-01	7.883E-09
CSP=CSP_4	3.732E-01	1.164E-07
GESTEVERT=GESTEVERT_non	4.769E-01	6.710E-06
CSP=CSP_6	6.430E-01	1.980E-04
EXPASS=EXPASS_0	9.978E-02	9.337E-03
CSP=CSP_5	-3.111E-01	2.926E-02
EDU=EDU_4	-9.407E-02	1.800E-02
AGECAT=AGECAT_3	-2.449E-01	1.762E-02
REV=REV_5	-3.196E-01	1.711E-02
AGECAT=AGECAT_4	-1.964E-01	1.670E-02
AGECAT=AGECAT_5	-3.300E-01	1.035E-02
EXPASS=EXPASS_1	-9.978E-02	9.337E-03
REV=REV_4	-1.177E-01	7.713E-03
EDU=EDU_3	-1.818E-01	1.958E-03
CSP=CSP_3	-4.968E-01	8.447E-04
GESTEVERT=GESTEVERT_oui	-9.153E-02	2.443E-05
EDU=EDU_5	-2.686E-01	2.180E-05
CSP=CSP_7	-3.120E-01	1.992E-05
REV=REV_6	-3.853E-01	2.522E-06
QUALPROD=QUALPROD_oui	-3.119E-01	1.307E-08
CONSOLO=CONSOLO_oui	-2.485E-01	1.816E-10
INTCOM=INTCOM_oui	-1.490E-01	3.096E-13
SIM=SIM_4	-2.657E-01	2.925E-13
SEX=SEX_1	-2.647E-01	3.125E-14
ENF=ENF_1	-3.356E-01	3.969E-17
UT=UT_1	-3.121E-01	6.897E-20

Figure 23: Contribution of categories to dimension 1

	Estimate	p.value
CONSOLO=CONSOLO_nsp	1.598E+00	4.799E-19
GESTEVERT=GESTEVERT_nsp	2.037E+00	1.187E-15
INTCOM=INTCOM_nsp	1.031E+00	1.552E-15
AGECAT=AGECAT_3	3.737E-01	7.029E-13
CSP=CSP_5	3.416E-01	5.152E-11
SIM=SIM_1	2.167E-01	5.592E-05
AGECAT=AGECAT_2	2.383E-01	1.481E-04
ENF=ENF_0	1.079E-01	1.563E-03
QUALPROD=QUALPROD_nsp	3.725E-01	1.187E-02
CSP=CSP_3	1.396E-01	1.632E-02
REV=REV_4	1.434E-01	1.786E-02
REV=REV_6	1.548E-01	4.304E-02
INTCOM=INTCOM_oui	-5.349E-01	3.495E-02
CONSOLO=CONSOLO_oui	-8.015E-01	3.318E-02
GESTEVERT=GESTEVERT_oui	-1.065E+00	1.153E-02
REV=REV_1	-1.672E-01	7.798E-03
ENF=ENF_1	-1.079E-01	1.563E-03
EDU=EDU_1	-1.663E-01	5.597E-04

Figure 24: Contribution of categories to dimension 2

	R2	p.value
CSP	5.099E-01	9.947E-27
REV	4.853E-01	2.656E-26
SIM	4.758E-01	1.510E-25
AGECAT	3.980E-01	1.297E-20
UT	3.442E-01	6.897E-20
ENF	3.012E-01	3.969E-17
INTCOM	2.716E-01	2.795E-14
SEX	2.532E-01	3.125E-14
EDU	2.747E-01	6.964E-13
CONSOLO	2.014E-01	2.398E-10
QUALPROD	1.605E-01	3.292E-08
GESTEVERT	9.913E-02	3.420E-05
EXPASS	3.363E-02	9.337E-03

Figure 25: Contribution of variables to dimension 1

	R2	p.value
AGECAT	5.551E-01	2.771E-33
CSP	4.112E-01	2.655E-19
CONSOLO	3.314E-01	6.007E-18
GESTEVERT	2.813E-01	7.417E-15
INTCOM	2.771E-01	1.324E-14
SIM	2.869E-01	6.698E-13
ENF	4.939E-02	1.563E-03
EDU	6.801E-02	7.950E-03

Figure 26: Contribution of categories to dimension 2

The variables graph in figure 22 seems to indicate a discrimination on axis 1 between users on the left side and non-users on the right side. Leading factors of non-users are their young age, the fact that they live alone and have no child, and their low level of income. Axis 2 does not provide a relevant discrimination of categories although those who have no opinion (_nsp is the category for 'I don't know') appear to be apart from the rest. The interpretations of these results do not seem to clearly emphasise the specific role of our variable of interest UT, but they suggest the existence of a specific group of profiles pertaining to the non-users respondents.

The coordinates, quality of representations (square cosines), percentage of contributions, and the test values of all the categories for dimension 1 and 2, and the variables graph are shown respectively in figure 29 and 30 in appendix 2.

5.3. Correlation analysis

Goodman-Kruskal's τ (Pearson, 2020) is used to measure the association between many categorical variables, and is perfectly suitable in our case for exploratory data analysis as it is an asymmetric measure. This rather odd characteristic of the measure is useful in depicting associations that are not commonly captured by other measures like Spearman's rank correlation or Kendall's τ. Reflecting on the author's example, Goodman-Kruskal's τ allow to detect asymmetric associations between the origin and the manufacturer of a car: knowing the manufacturer (for instance BMW), we can easily associate it with its country origin (Germany) but the opposite association is not that easy to establish. Similarly, given

the number of our categorical variables and their categories, it is of our interest to explore the asymmetric associations, if there are any, prior to conducting our regression estimations.

Figure 27 shows the degrees of association for each of our variable pairs. UT can be slightly more predictable from INTCOM, EDU, CSP, SIM, and REV than other variables (respectively 0.12, 0.1, 0.11, 0.11, and 0.19). However, the opposite associations are not true except for INTCOM (0.1). Moreover, UT does not seem to explain much of the variability for other variables. Although the degrees of association are weak, in practical terms, the results suggest that whether a person uses or not the local currency, it provides no information whatsoever about the characteristics of that person (except very little about his/her interest in community activities). The fact that EDU, CSP, SIM, and REV possess five or more categories should be taken into account to explain non-true reverse associations between these variables and UT.

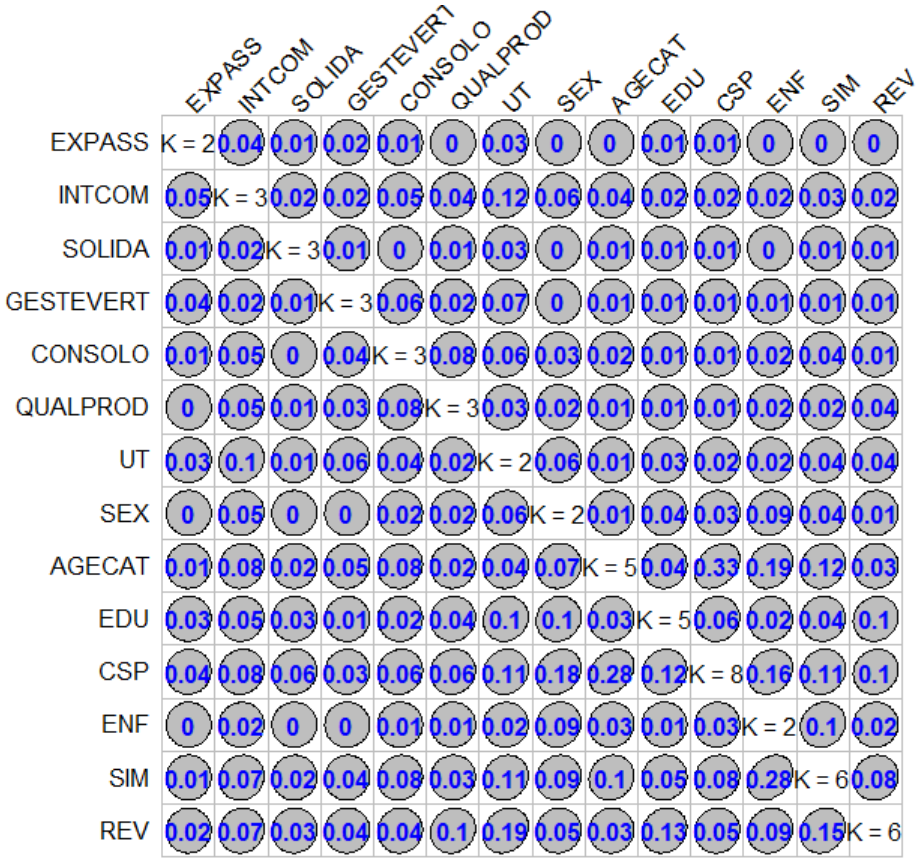

Figure 27: Goodman-Kruskal correlation matrix

5.4. Econometric analyses

5.4.1. Model specification

To establish a binary choice model that is capable of predicting the outcome of adoption behaviour or not of consumers, we must estimate the probability P_i associated to the events (adoption) and non-events (non adoption) of the local currency. To model P_i, we decide to use a Logit model where the error distribution function follows the logistic law distribution function. As an exploratory approach, we take into consideration every variable of our study

(13 independent variables composed of 6 main variables 7 control variables). The full model (M) is expressed as:

$$\textbf{M: } \mathrm{UT}_i = a_0 + a_1\mathrm{EXPASS}_i + a_2\mathrm{INTCOM}_i + a_3\mathrm{SOLIDA}_i + a_4\mathrm{GESTEVERT}_i + a_5\mathrm{CONSOLO}_i + a_6\mathrm{QUALPROD}_i + a_7\mathrm{SEX}_i + a_8\mathrm{AGECAT}_i + a_9\mathrm{EDU}_i + a_{10}\mathrm{CSP}_i + a_{11}\mathrm{ENF}_i + a_{12}\mathrm{SIM}_i + a_{13}\mathrm{REV}_i + \varepsilon_i$$

Where the dependent dichotomous variable UT_i is defined by the following decision model :

$$\begin{cases} \mathrm{UT}_i = 1 & \text{if } \mathrm{UT}_i^* > 0 \\ \mathrm{UT}_i = 0 & \text{if } \mathrm{UT}_i^* < 0 \end{cases} \tag{23}$$

Given the considerable number of categories and variables in our model, we will use the stepwise (M2), forward (M3), and backward (M4) variables selection methods from R to estimate our model.

The regrouping of variable categories were simplified in this part of our analyses to avoid over-complications. We regrouped our variable categories based on duality assumptions (yes or no, under average or above average, living alone or not alone, ...*etc.*) for most of the variables except for the level of diploma, socio-professional category, and sense of solidarity in the community. We argue that the categories of these three last variables cannot be divided into simply two groups. It would not be possible to test for equality of the categories for each variable because the number of combinations would be too large to do so. Categories of REV, INTCOM, SIM, EDU, and CSP were recoded as follows:

- REV: two categories - we calibrate approximately to income levels below the national average for category 1, 2, and 3, and those above average for category 4, 5, and 6 according to the latest publicly available data from the INSEE (*Revenus salariaux*, 2021) . The first category above average is coded as REV1, and the other as REV2.
- INTCOM: two categories - one that regroups those who are not interested in community activities or don't know (*non* and *nsp*), and the other one for people who are interested. The first category is coded as INTCOM1, and the second as INTCOM2.
- SIM: two categories of people who live alone and those who don't - one that regroups people who are widow(er)s, single or divorced (category 1, 5, and 6), and the other one for the remaining statuses. The first category is coded as SIM1, and the second as SIM2.
- EDU: three categories - one that regroups people belonging to category 1 (no diploma, primary studies certificate, year 9 diploma, certificate of professional competence, or vocational studies certificate), one that regroups category 2, 3 and 4 (high school diploma or equivalent, 2, 3, 4 years of higher education), and the last one that regroups category 5 (5 years or more of higher education). The three new categories are respectively coded as EDU1, EDU2, and EDU3.
- CSP: three categories - one that regroups people who have a job (category 1 to 6), one that regroups retirees (category 7), and the last one regroups for students and

unemployed people. The three new categories are respectively coded as CSP1, CSP2, and CSP3.

5.4.2. Estimation results

Results obtained from the first estimations with the three variable selection methods (M2, M3, and M4) are identical. They are summarised in table 14:

	Estimate	Std.Error	z value	P($>\|z\|$)	
(Intercept)	-21.38	1327.30	-0.02	0.99	
GESTEVERTnsp	37.65	6656.32	0.01	1.00	
GESTEVERToui	18.30	1327.30	0.01	0.99	
INTCOM2	1.05	0.41	2.59	0.01	**
SIM2	0.76	0.37	2.06	0.04	*
SEX1	0.89	0.36	2.46	0.01	*
SOLIDAnsp	0.78	0.51	1.53	0.13	
SOLIDAoui	0.99	0.42	2.38	0.02	*
EXPASS1	0.55	0.35	1.56	0.12	
REV2	0.85	0.40	2.13	0.03	*
N° of observations	200				
Significance codes	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

Table 14: First estimation results for M2, M3, and M4

We then ran the regression again with every variable suggested by the stepwise method (since they are the same as those from forward and backward method) except GESTEVERT, due to its high standard error and non-significance in the model. The results from the second estimation are summarised in table 15.

For the next steps, we proceed as follows.

1. We look for observations that might influence the estimation results, and remove them if there are any: it is considered that an observation influences the results if the associated residual is not comprised in the [-2, 2] interval.

2. We ran another estimation of the model with the new data without the influential observations, and assess if there is an improvement in the overall quality of the model (adjustment, predictive, and information quality).

3. We compare the models according to the different quality criteria.

	Estimate	Std.Error	z value	P($>|z|$)	
(Intercept)	-3.11	0.54	-5.78	0.00	$***$
INTCOM2	0.93	0.39	2.40	0.02	$*$
SEX1	0.84	0.34	2.45	0.01	$*$
REV2	0.87	0.38	2.31	0.02	$*$
SOLIDAnsp	0.89	0.50	1.79	0.07	$*$
SOLIDAoui	0.84	0.40	2.10	0.04	$*$
EXPASS1	0.80	0.34	2.34	0.02	$*$
SIM2	0.67	0.35	1.91	0.06	.
N° of observations	200				
Significance codes	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

Table 15: Second estimation results for M2

Figure 28 shows the residuals plot for second estimation of M2: two observations seem to be greatly influencing the results as their residuals are substantially greater than 2. We then sort the residuals in ascending or descending order to identity the two observations: they are ranked at number 140 and 116, with residuals respectively of 2.21 and 2.22 (see appendix 2 for the sorting of residuals). Observation 116 is a user of the local currency who is a single man between the age of 60 and 74, is an artisan or has a job in the sector of agriculture, has a child or children, has a high school or an equivalent diploma, has an yearly household fiscal income level between 15000 and 25000 €, has no prior experience in SSEO activities, is not interested community activities, does not feel a sense of solidarity in the community, practices 'virtuous gestures', and looks for local, and high quality products. Observation 140 is also a user who is a single man with no child, has a high school or an equivalent diploma, has an yearly household fiscal income level of under 15000 €, has no experience in SSEO activities, is not interested community activities, doesn't know if there is a sense of solidarity in the community, practices 'virtuous gestures', does not look for local products, but looks for high quality products. We proceed to do another estimation by removing the two observations and check if there is an improvement in the quality of the model.

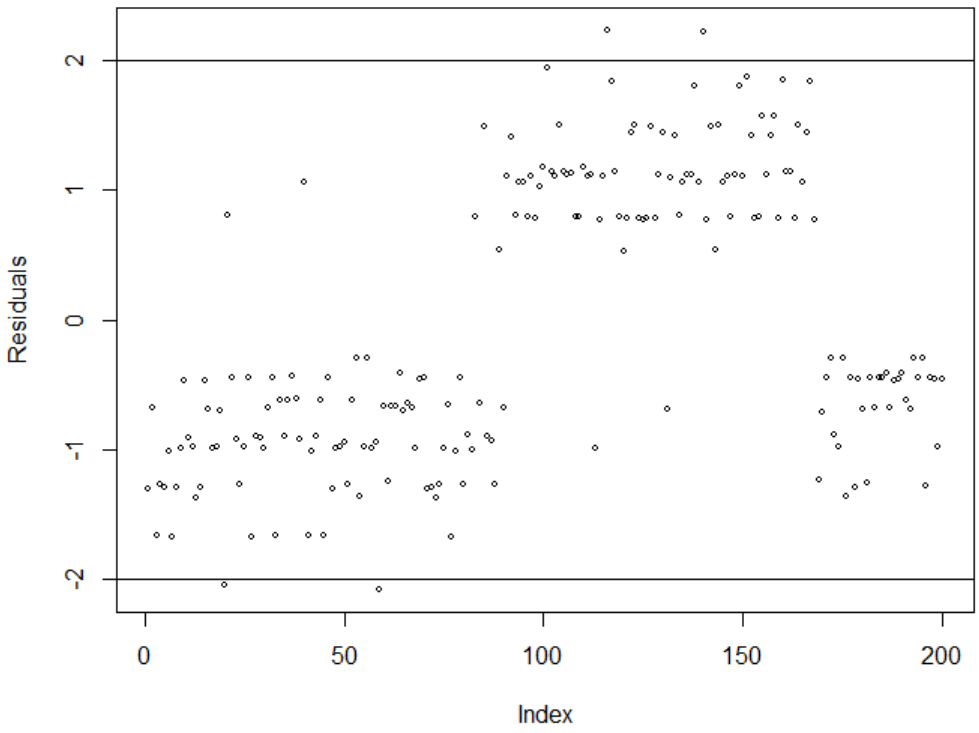

Figure 28: Residuals plot for the second estimation of M2

	Estimate	Std.Error	z value	P($>\|z\|$)	
(Intercept)	-3.56	0.59	-5.98	0.00	$***$
INTCOM2	1.13	0.41	2.76	0.01	$**$
SEX1	0.98	0.36	2.75	0.01	$**$
REV2	0.81	0.39	2.10	0.04	$*$
SOLIDAnsp	0.83	0.51	1.61	0.11	
SOLIDAoui	0.95	0.42	2.28	0.02	$*$
EXPASS1	0.92	0.35	2.60	0.01	$**$
SIM2	0.82	0.36	2.25	0.02	$*$
N° of observations	198				
Significance codes	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

Table 16: Third estimation results for M2 after removing influential residuals

By comparing table 15 and table 16, we see that INTCOM2, SEX1, and EXPASS1 are now statistically significant over the 99% confidence level, and SIM2 is now significant over the 95% level. REV2's significance remains unchanged and SIMnsp is not significant anymore.

We compare the quality of the two models based on three criteria.

1. Quality of prediction:
   - Error rate: proportion of correctly predicted events and non-events over the total number of observations
   - Sensibility indicator: capacity to predict an event ($y_i = 1$)
   - Specificity indicator: capacity to predict a non-event ($y_i = 0$)
   - Precision indicator: proportion of correctly predicted events over the total number of predicted events
   - False positives rate: proportion of correctly predicted non-events over the total number of predicted non-events
2. Quality of adjustment: McFadden's R^2
3. Information criteria: Akaike's 'An Information Criterion' (AIC) and Schwarz's Bayesian Information Criterion (BIC)

The prediction matrix used as reference is shown below in table 17, and accordingly the prediction matrices for the two estimations are shown in table 18:

Observed probability(sample)	Estimated probability		Total
	0	1	
0	a	b	a + b
1	c	d	c + d
Total	a + c	b + d	N = a + b + c + d

Table 17: Prediction matrix as reference

		0	1
Second estimation	0	88	31
	1	25	56

		0	1
Third estimation	0	89	30
	1	27	52

Table 18: Prediction matrices for estimations

Error rate	(b+c)/N
Sensibility	d/(c+d)
Specificity	a/(a+b)
Precision	d/(b+d)
False positives	b/(a+b)

Table 19: Calculation of quality indicators

From table 18 and estimations results, we build a comparative table with the aforementioned quality criteria.

		Second estimation	Third estimation
Prediction quality	Error	**0.28**	0.29
	Sensibility	**0.69**	0.66
	Specifity	0.74	**0.75**
	Precision	**0.64**	0.63
	False positive	0.26	**0.25**
Ajustment quality	R^2	0.17	**0.2**
Information criterion	AIC	238.76	**228.54**
	BIC	265.15	**254.85**
	N° observations	200	198

Table 20: Comparison of model quality between the two estimations

Table 20 shows a slight improvement in the overall quality of the model obtained from the third estimation, *i.e.* after removing the two influential observations. The numbers in bold represent the 'best' results among the two models. However, it is worth noting that this slight improvement in the results from the third estimation can appear subtle and ambiguous to interpret because it comes at the cost of losing some percentage point in some criteria to the second estimation: a .01 point difference in the error rate, a .03 point difference in the sensibility indicator, and a .01 point difference in the precision indicator. If we consider these trade-offs as negligible, then the third estimation can be considered as the best fit for our model.

We ran two final tests for the model : the Variance Inflation Factor (VIF) test that measures for multicollinearity, and the interest of the model that tests for nullity of the coefficients. The tests results provided respectively in table 21 and 22 show that there is no issue of multicollinearity, and we refuse the hypothesis of nullity of the overall coefficients of our model, which means there is an interest in estimating this model at the associated risk level. To add another layer of robustness check for our results, we aso ran a full VIF test of the complete model and again, no risk of multicollinearity was detected. The results of this full VIF is shown in table 27 of appendix 2.

5.4.3. Odds ratio and marginal effects

The parameter estimates of our model only indicate if a variable plays a positive or negative role in the adoption of the local currency. Because the value of the estimates in themselves do not tell us much about the importance of the variables, we need to calculate the Odds Ratio (OR) estimates and the average marginal effects (AME) of the variables.

Variable	GVIF	Df	$GVIF^{\frac{1}{2Df}}$
INTCOM	1.02	1	1.01
SEX	1.06	1	1.03
REV	1.18	1	1.09
SOLIDA	1.13	2	1.03
EXPASS	1.08	1	1.04
SIM	1.14	1	1.07

Table 21: VIF test results for our model

χ^2	Df	p.value
107.61	7	0.00

Table 22: Interest of the model test results

Estimate	OR	Std.Error	z value	P($>\|z\|$)	95% Confidence limits		
INTCOM2	3.0807	1.2538	2.7646	0.0057	1.4176	7.0773	**
SEX1	2.6687	0.9543	2.7450	0.0060	1.3391	5.4760	**
REV2	2.2455	0.8665	2.0965	0.0360	1.0591	4.8384	*
SOLIDAnsp	2.2890	1.1762	1.6115	0.1070	0.8417	6.3763	
SOLIDAoui	2.5738	1.0693	2.2755	0.0228	1.1602	5.9608	*
EXPASS1	2.5036	0.8846	2.5974	0.0093	1.2640	5.0776	**
SIM2	2.2675	0.8256	2.2483	0.0245	1.1161	4.6803	*
Significance codes	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1						

Table 23: Odds ratio results

Estimate	AME	Std.Error	z value	P($>\|z\|$)	95% Confidence limits		
INTCOM2	0.2077	0.0711	2.9217	0.0035	0.0684	0.3470	**
SEX1	0.1820	0.0641	2.8388	0.0045	0.0564	0.3077	**
REV2	0.1532	0.0736	2.0799	0.0375	0.0088	0.2975	*
SOLIDAnsp	0.1472	0.0915	1.6082	0.1078	-0.0322	0.3265	
SOLIDAoui	0.1692	0.0703	2.4087	0.0160	0.0315	0.3069	*
EXPASS1	0.1692	0.0634	2.6672	0.0076	0.0449	0.2935	**
SIM2	0.1547	0.0689	2.2439	0.0248	0.0196	0.2898	*
Significance codes	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1						

Table 24: Average marginal effects results

If we look at the odds ratio results generated in table 23, we can see that the relative chances of adopting the local currency for a respondent who has the category compared to the reference category are rather high since they are greater than two for every estimate. For instance, people who have an interest in community activities are 3 times more likely to use the local currency compared to those who are not interested or answered 'I don't know'.

For the average marginal effects presented in table 24, the predicted probability of using a local currency is .2077 greater for an individual who is interested in community activities than for one who is not interested or answered 'I don't know'. The same interpretations can be done for the rest of the factors.

However these results should be interpreted with great caution especially when the confidence limits are considerably important due to the small sample size. Although we are not able to measure the precise amplitude of the factors or classify them, we can be certain that the relative chances in overall that the people who possess these characteristics have a higher chance than 1 in adopting the local currency (if we consider the lower bound of the confidence limits), conditionally to all the factors present in our model.

6. Factors influencing the adoption

Results from the statistical analyses of our sample suggest that there could be a few factors that influence the adoption of a local currency. Among the six factors used in our model, only three seem to have a significant and positive role in influencing the adoption: the interest in community activities, the feeling of solidarity in the community, and the past experience in SSO activities. One way of explaining this result is the fact that people who possess the aforementioned characteristics are more likely to seek for information concerning opportunities and news in where they live than the 'reference' people who do not have those characteristics. Therefore they are also more likely to stumble upon the Renoir local currency and adopt them. These results concurred with those of Arts et al. (2011) who posited that the antecedent 'information seeking (the extent to which one seeks information about innovations (or new developments, trends, ...*etc.*)' has a positive effect on consumer innovation adoption.

The adoption in this case may be an economically-driven decision (for the 10% bonus in purchasing power) or simply stems from pure goodwill for the community aspect of the project. Sustainability factors such as preference for local and high quality products, and the practice of ecologically responsible actions do not seem to come in play here just like we anticipated. Respondents may have not perceived the sustainability dimension of the project well enough for it to influence their choice, and this result can suggest two things: either they radically do not believe that the local currency ensures this function, or there were not enough communication or pedagogical tools put forward by the project team to promote the ecological aspect of the local currency.

For the socio-demographic aspect, women, people who do not live alone, and people with household income levels higher than the average are more likely to be users of the local currency than respectively men, people who live alone, and people with household income levels lower than the average. One of the reasons women are be more likely to use the local currency could be the fact that they come or are more often present in the city centre or where there are shops accepting the local currency than men, and in consequence

this increases their chance in adopting the local currency. This result may not come as a surprise since we know for a fact that around 66% of users are women. For the household income level, this result may on the contrary come as a surprise since one of the incentives for users of the Renoir is of economic nature. This seemingly odd result could be explained by the fact that the income is taken into account at a household level, therefore it does not necessarily reflect the level for each individual. Interestingly, this result coincides with the proportion of people who live alone and those who do not by level of household income and adoption. Table 25 and 26 show these proportions.

	SIM1	SIM2
REV1	0.52	0.27
REV2	0.06	0.15

Table 25: Proportion of respondents' household income level by marital status when UT=0

	SIM1	SIM2
REV1	0.23	0.32
REV2	0.05	0.37

Table 26: Proportion of respondents' household income level by marital status when UT=1

If we reason in terms of conditions of success of local currencies according to characteristics specific to a community based on findings of Kim et al. (2016), our results seem to validate the empirical evidence in which the adoption is fostered when users have a sense of belonging and community support, and prior experience with alternative economic movements. In our case, socio-demographic determinants such as sex, level of household income, and marital status seem to be new factors of adoption that should merit more consideration in future studies.

Conclusion and discussion

The aim of this chapter was to explore the determinants of adoption behaviour of a local currency. The end goal was to help the project identify potential adopters and contribute to the literature of technological and social innovation regarding a specific payment system, which is the local complementary currency. We delve into the subject by studying the case of a real local currency that launched 4 years ago in the French Riviera. The adjustment and predictive quality of our model hint at a possibility of targeting the right people to increase adoption and foster the development of such project. The implications of our study for the project managers are twofold: knowing the characteristics of people who are most likely to use the local currency, we can put forth strategies to specifically look for and target people who have these characteristics, or taking into account the current target population, the project team can look for ways to improve their communication and marketing tools to attract potential users who do not possess those characteristics yet *e.g.* instil a sense of solidarity and promote/educate about alternative economic movements to the population. This result is in accordance with the findings of Antonides et al. (1999) who recommended managers to foster social learning (making people aware of the existence of a project) by 'making use of social reference groups and stimulating word-of-mouth' methods, *e.g.* engaging a public discussion on the features of the technology.

Our work contributes to the literature of empirical studies on local currencies by being the first study of its kind that uses statistical tools applied to survey data and by addressing the topic from the perspective of consumers with a novel adoption approach. When comparing our results with those from existing literature, we find some converging points and a few novel ones. We were also able to contribute to the theoretical claims and results from the literature that social currencies rely on prior or simultaneous communities construction by Orzi (2021), and on the main effects of some adopter characteristics as antecedents of consumer innovation adoption by Arts et al. (2011). Even if the Renoir does not stem purely from a citizen-led initiative, we still observe that community-type determinants play a role in the adoption of such project, which leads us to think that what triggers such project in the first place may not always play a substantial role in its development nor success. For upcoming projects, we highly recommend thorough consumer and territory studies to be done before and after the launch of a local currency to mitigate common problems that may occur such as barriers to adoption, and more importantly to measure the impact of the project which is crucial for its sustainability. We encourage future research of the subject to focus more on the user and adoption dimension of local currencies rather than solely on their management dimension.

GENERAL

CONCLUSION

The objective of this thesis was to study local complementary currencies through different economic and innovation perspectives and provide a more in-depth cognisance of the subject in its potential in addressing important issues related to sustainability.

The digitalisation of local currencies goes in line with the evolution trajectory of a payment system in our fast-moving and technologically advanced era preconised by many of the researchers that we mentioned earlier in our study. In chapter one, we un-ravelled how the governance of a local currency via blockchain may roll out and formalised this setting with a theoretical model. We showed that such configuration is possible under certain conditions and for many different stages of development of a local currency. Whether it is at the start of the project or at its maturity stage - *e.g.* a network of multiple local currencies from different cities - our analytical results show that it is feasible to deploy a management of local currencies via a blockchain consensus protocol, namely the Proof of Work in our case. Adoption of the blockchain by a few real-world projects affirms the legitimacy and potential of the technology in filling the gaps of traditional digital solutions in terms of costs, security, and scalability.

The example of the MonedaPAR, although not a local currency *per se* but rather a peer-to-peer mutual credit system for prosumers (therefore with the presence of overdraft unlike classic local currencies), shows that the decision to switch to a blockchain solution stemmed from mainly 3 reasons learned from past projects according to its co-founders Mario Cafiero and Sebastián Valdecantos: (i) technological solutions impeding the scalability of the project, (ii) incapacity in preventing malicious actors from counterfeiting paper notes for example, and (iii) difficulty in monitoring the performance of the network (*How a blockchain credit system helps Argentina's marginalized*, 2019). The system runs on the Bitshares blockchain which is consistent at this stage of the project with a rather low number of users (less than 1000 prosumers) but might be problematic when the network becomes much larger because everything depends on a tier blockchain, which they have no control over it at all.

The theoretical setting from chapter 2 allowed us to show that the initial distribution of consumers, their wealth, the nature, and initial location of different categories of stores, have significant consequences on the initial, final location and size of food stores that offer organic (high quality) products in different models of cities. Reconversion mechanics of local currencies to legal tender play a substantial role in guaranteeing product quality since the conditions and costs of reconversion ensure the function of signalling effect in our model. The objective of this chapter was to demonstrate the interest of the use of local currencies as a signal for product quality. Although the presence of signals is crucial for the decision-making process, a signal is not an end in itself since its quality is as essential as its presence (Akerlof, 1978).

Our original design of an exploratory study with empirical data for the case of a real local currency shed lights on some interesting and hidden aspects of the determinants of adoption of a specific payment system. The specific case of the Renoir local currency of the city of Cagnes in France allows us to develop a model capable of predicting the adoption or

not of the currency based on some intrinsic and socio-demographic factors. Learning from our results, we can reconciliate with some findings in the literature regarding the adoption behaviour, issues, and conditions of success of a local currency project. The community, solidarity, and experience with alternative economic movements aspects seem to constitute an essential foundation without which they would become inevitable hurdles sooner or later for the development of a local currency project, be it having sustainable or social objectives. These determinants seem to be important drivers for the adoption of a local currency as confirmed in the literature. Unfortunately, ecological determinants still lack the influence that they are supposed to exert on the adoption behaviour of consumers, so this dimension merits more attention in future research. In fact, more pedagogical and marketing effort from the project must be put forth to fill this gap as it may prove to drastically boost the interest and adoption of local currencies, especially in our current world context of sustainability transition and concerns.

Even if each project is different and unique in its own way, it is necessary that a common solution must be found to address the two plaguing issues of impact measurement inconsistency and lack of fitting preliminary market studies references before launching a local currency. The first problem could be fathomed through more transparency and monitoring with the help of a technological solution like the blockchain but the second problem is more difficult to tackle due to the intricacies of complementary currencies as a whole. The latter issue should nevertheless be encompassed in the scope of future investigations. Until then, the legitimacy and credibility of local currencies might still be constantly questioned, and this greatly impedes the involvement of major partners and stakeholders like committed local governments for instance, who have power to make substantial regulatory and institutional changes for the development of local currencies (Blanc and Fare, 2018).

Reflecting on the results from the three chapters of this thesis and for future work on the subject, some promising extensions can be mentioned.

Concerning the economic modelling of a blockchain consensus protocol in the case of a local payment system, the PoS may be used in the future instead of the PoW or any other protocol. The main reasons behind this stem from the growing popularity of the PoS protocol in the last year, its non-energy consuming design, and its rewards system for holders. This calls for obviously more complex modelling and solid real cases for reference. The latter was not present at the time of writing of this thesis; thus, this option was not feasible, so we had to rule it out. The landscape of blockchain consensus protocols is evolving at a fast pace and keeping things consistent and on track is sometimes a considerable challenge, even for the most influential actors in the field. For instance, CoinMarketCap, the biggest and most-referenced price-tracking website for crypto-assets did not show Polkadot (ranked 9th in market capitalisation at the time of writing), which uses Nominated PoS protocol (NPoS), on its list of PoS-based crypto-currencies but shows other crypto-currencies like Bitshares that uses a DPoS protocol (*Top PoS Tokens by Market Capitalization*, 2021). This inconsistency shows that general agreement on the definition of a consensus protocol still requires additional work and global coordination effort, especially in the case of the PoS protocol where there exist many variants.

As for commercial centres and consumer behaviour, we observe in the last decade an accentuated diminishing trend in indoor and suburban malls in many big cities especially in the U.S. at first (David Uberti, 2014; Dokoupil, 2008; Hudson and O'Connell, 2009) but also in other developed countries like France (Guillemot and Grasnier, 2011; Soumagne et al., 2011) and Portugal (Ferreira and Paiva, 2017; Teixeira, 2014). There are a few factors that could be attributed to this phenomenon such as the development of *big-box* stores like Walmart and Home Depot in North America (Parlette and Cowen, 2011), the effects of e-commerce on consumer behaviour (Hernández et al., 2010) and the rapid increase in consumer spending on e-commerce platforms (Ali, 2021). The Covid-19 pandemic episodes since 2020 have been drastically exacerbating the situation. However, in this highly competitive segment, malls have also adapted to fight back through different strategies that work more or less like blending the mall space in the urban fabric of cities and the adoption of more of an open space-like setting (Al, 2017). Examples include the Oculus hub in New York and the Polygone Riviera in Cagnes-sur-Mer. This in turn would greatly affect the evolution of city spatial distribution in the next few years. Accordingly, concerning the theoretical modelling aspect, one dimension that can be altered for testing is the endogenisation of the population to shops, workplace, security, transport, and other factors specific to a city. This calls obviously for a much more sophisticated modelling attempt, but it could be relevant in the case of a more atypical or context-specific city configuration for example.

In terms of potential future studies combining the three approaches addressed in this thesis, it would be insightful for instance to incorporate a theoretical modelling of a blockchain consensus protocol (preferably one of the PoS variants) to a city with specific configuration settings that envisages to develop a local currency project. A study of the city's features such as population characteristics (socio-demographics, mental and community well-being, ...*etc.*) and main indicators (number, nature, and size of businesses, employment rate, ...*etc.*) would be conducted prior to the modelling analyses. Ultimately, provided the results from our theoretical models, an application to a large-scale local currency project like the Eusko would be ideal to provide empirical evidence to support our argument and most importantly extend the literature on the determinants of local payment systems adoption.

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APPENDICES

Appendix 1: Threshold values of λ', q, and p^* in Proposition 3

Mathematica transcription of variables and parameters: l for λ', L for λ, P for $\bar{p}$, p for p^*, a for α.

- Value of λ' from which the mass store has interest in selling quality goods:

$$\{l \to \frac{1}{4\,(-2+an)\,n\,(p-P)^2\,q^2}\left(-16\,Cr+16\sqrt{\frac{Cr}{n}}\,n\,P-(-2+an)\,n\,(-2+a\,n)\,(p-P)^2\,q^2+\sqrt{\left(\left(16\,Cr-16\sqrt{\frac{Cr}{n}}\,n\,P+(-2+an)\,n\,(-2+a\,n)\,(p-P)^2\,q^2\right)^2+16\,(-2+an)\,n\,(p-P)^2\,q^2\left(2\,Cr\,(2+an-2\,a\,n)+n\left((-2+an)\,P^2\,q^2+(-2+an)\,p\,q\left(-2\sqrt{2}\sqrt{\frac{Cr}{n}}+p\,q\right)+2\,P\left(-4\sqrt{\frac{Cr}{n}}+2\,a\sqrt{\frac{Cr}{n}}\,n+(-2+an)\,q\left(\sqrt{2}\sqrt{\frac{Cr}{n}}-p\,q\right)\right)\right)\right)\right)\right)\}\}$$

- Value of q under which the mass store has interest in selling quality goods:

$$\{q \to \left(2\left(2\,(-1+l)\sqrt{\left(\left(n\,(p-P)^2\left(Cr\,(4+l\,(2+an-4\,l-2\,a\,n))+2\sqrt{\frac{Cr}{n}}\,n\,(-2+l\,(-2+2\,l+a\,n))\,P\right)\right)\Big/\left((-2+an)\,(-2+2\,l+a\,n)\right)\right)}+n\left(\sqrt{2}\sqrt{\frac{Cr}{n}}\,(-p+P)+a\sqrt{\left(\left(n\,(p-P)^2\left(Cr\,(4+l\,(2+an-4\,l-2\,a\,n))+2\sqrt{\frac{Cr}{n}}\,n\,(-2+l\,(-2+2\,l+a\,n))\,P\right)\right)\Big/\left((-2+an)\,(-2+2\,l+a\,n)\right)\right)}\right)\right)\Big/\left(n\,(-2+l\,(-2+2\,l+a\,n))\,(p-P)^2\right)\}\}$$

- Value of p^* under which the mass store has interest in selling quality goods:

$$\{p \to \left(a\,l\,n^2\,P\,q^2+4\,(-1+l)\sqrt{\frac{n\left(Cr\,(4+l\,(2+an-4\,l-2\,a\,n))+2\sqrt{\frac{Cr}{n}}\,n\,(-2+l\,(-2+2\,l+a\,n))\,P\right)q^2}{(-2+an)\,(-2+2\,l+a\,n)}}+2\,n\left(-\sqrt{2}\sqrt{\frac{Cr}{n}}\,q+(-1+(-1+l)\,l)\,P\,q^2+a\sqrt{\frac{n\left(Cr\,(4+l\,(2+an-4\,l-2\,a\,n))+2\sqrt{\frac{Cr}{n}}\,n\,(-2+l\,(-2+2\,l+a\,n))\,P\right)q^2}{(-2+an)\,(-2+2\,l+a\,n)}}\right)\right)\Big/\left(n\,(-2+l\,(-2+2\,l+a\,n))\,q^2\right)\}\}$$

Appendix 2: Values of r_M of the mass store profit when satellites sell quality goods, and threshold values of λ', q ,and p^* in Proposition 4

- Value of r_M maximising the profit of the mass store in Proposition 4:

$$\begin{aligned}
&\mathbf{rm} \to \tfrac{1}{n(-2+2L+an)} \\
&(n(-2+an)p+ \\
&2L\left(2\sqrt{2}\sqrt{\tfrac{Crn(-2+2L+an)}{L(-2+an)}}+\right. \\
&\left.n\left(\sqrt{2}\sqrt{\tfrac{Cr}{n}}-\sqrt{2}a\sqrt{\tfrac{Crn(-2+2L+an)}{L(-2+an)}}+P\right)\right))
\end{aligned}$$

- Value of q under which the mass store has interest in encouraging the implementation of satellites instead of supplying itself quality goods:

$$\begin{aligned}
&\{q \to \frac{1}{n\,(-2+l\,(-2+2\,l+a\,n))\,(p-P)^2}2\,(-2+2\,l+a\,n) \\
&\left(\frac{\sqrt{2}\,\sqrt{\frac{Cr}{n}}\,n\,(-p+P)}{-2+2\,l+a\,n}+\right. \\
&\sqrt{\left(\frac{1}{(-2+2\,l+a\,n)\,(-2+2\,L+a\,n)^2}\right.} \\
&n\,(p-P)^2\left(Cr\,\left(8\,\left(2\,L-4\,L^2+(-2+a\,n)^2\right)-8\,l^2\,\left(2\,L-4\,L^2+(-2+a\,n)^2\right)+\right.\right. \\
&\left.l\,(2+2\,L-a\,n)\,((-2+a\,n)\,(-9+4\,a\,n)+2\,L\,(-7+4\,a\,n))\right)+ \\
&(-2+l\,(-2+2\,l+a\,n))\left(-8\,L^2\,\sqrt{\frac{Cr}{n}}\,\sqrt{\frac{Cr\,n\,(-2+2\,L+a\,n)}{L\,(-2+a\,n)}}+\right. \\
&(-2+a\,n)\,(p-P)\left(-2\,\sqrt{2}\,\sqrt{\frac{Cr\,n\,(-2+2\,L+a\,n)}{L\,(-2+a\,n)}}+\right. \\
&\left.\left.n\left(\sqrt{2}\,a\,\sqrt{\frac{Cr\,n\,(-2+2\,L+a\,n)}{L\,(-2+a\,n)}}-2\left(\sqrt{2}\,\sqrt{\frac{Cr}{n}}-p+P\right)\right)\right)+2\,L\left(3\,a\,n\right. \\
&\sqrt{\frac{Cr\,n\,(-2+2\,L+a\,n)}{L\,(-2+a\,n)}}\left(2\,\sqrt{\frac{Cr}{n}}+\sqrt{2}\,(-p+P)\right)+2\left(\sqrt{2}\,\sqrt{\frac{Cr}{n}}\,n\,(p-\right. \\
&\left.\left.\left.\left.\left.\left.P)-3\,\sqrt{\frac{Cr\,n\,(-2+2\,L+a\,n)}{L\,(-2+a\,n)}}\left(2\,\sqrt{\frac{Cr}{n}}+\sqrt{2}\,(-p+P)\right)\right)\right)\right)\right)\right)\}\}
\end{aligned}$$

The analytical expressions of the threshold values of λ' and p^* are too long and not yet sufficiently simplified to be reproduced. They are available in their current form on demand.

Appendix 3: Questionnaire

This is a translation of the questionnaire from French.

1. Are / were you a member of an organisation of the social and solidary economics : cooperatives, mutuals, associations, and/or foundations?
   a. Yes
   b. No

	Absolutely yes	Rather yes	I don't know	Rather no	Absolutely no
2. Are you interested in events organized by the city, the Federation of associations of merchants, or any local events close to your home?					
3. Do you believe there is a strong feeling of solidarity between people and a good atmosphere in Cagnes?					
4. Do you practice 'virtuous gestures' in your daily life? (recycling, bulk purchases, energy savings, *...etc.*) ?					
5. Do you look to consume local products?					
6. Are you concerned about the quality of products that you consume, do you look for quality products?					

7. Do / did you use the local currency Renoir?
   a. Yes
   b. No

8. You are a:
   a. Woman
   b. Man

9. How old are you?

10. What is your occupation?
    a. Unemployed, student, seeking a job
    b. Retired
    c. Factory worker
    d. Employee
    e. Intermediate professional

f. Farmer
g. Artisan, merchant, or entrepreneur
h. Executive, or superior intellectual function

11. Do you have a child / children?
    a. Yes
    b. No

12. What is your highest level of diploma?
    a. None, or primary studies certificate
    b. Year 9 diploma, certificate of professional competence, or vocational studies certificate
    c. High school diploma, or equivalent
    d. 2 years of higher education
    e. 3 or 4 years of higher education
    f. 5 years or more of higher education

13. What is your level of annual household income?
    a. Less than 15k €?
    b. Between 15k and 25k €?
    c. Between 25k and 35k €?
    d. Between 35k and 45k €?
    e. Between 45k and 55k €?
    f. More than 55k €?

14. What is your marital status?
    a. Single
    b. Cohabitation
    c. Pacsé
    d. Married
    e. Widow/er
    f. Divorced

Appendix 4

	Dim.1	ctr	cos2	v.test	Dim.2	ctr	cos2	v.test
EXPASS_0	0.138	0.317	0.034	2.587	0.008	0.002	0.000	0.142
EXPASS_1	-0.245	0.564	0.034	-2.587	-0.013	0.003	0.000	-0.142
INTCOM_non	0.776	4.882	0.270	7.333	-0.011	0.001	0.000	-0.100
INTCOM_nsp	-0.602	0.190	0.007	-1.212	3.672	11.208	0.275	7.400
INTCOM_oui	-0.341	2.039	0.236	-6.852	-0.105	0.305	0.022	-2.105
SOLIDA_non	0.130	0.138	0.008	1.232	0.160	0.329	0.011	1.510
SOLIDA_nsp	-0.163	0.133	0.006	-1.116	-0.098	0.076	0.002	-0.672
SOLIDA_oui	-0.019	0.005	0.000	-0.264	-0.062	0.079	0.004	-0.870
GESTEVERT_non	0.993	2.325	0.098	4.406	0.168	0.106	0.003	0.747
GESTEVERT_nsp	-0.658	0.057	0.002	-0.658	7.426	11.460	0.277	7.426
GESTEVERT_oui	-0.095	0.214	0.086	-4.142	-0.058	0.126	0.032	-2.515
CONSOLO_non	1.187	4.613	0.201	6.330	-0.046	0.011	0.000	-0.247
CONSOLO_nsp	-0.101	0.003	0.000	-0.143	5.728	13.636	0.331	8.121
CONSOLO_oui	-0.170	0.658	0.186	-6.084	-0.060	0.127	0.023	-2.126
QUALPROD_non	1.120	3.616	0.155	5.557	-0.207	0.195	0.005	-1.025
QUALPROD_nsp	0.371	0.072	0.003	0.747	1.243	1.285	0.032	2.505
QUALPROD_oui	-0.150	0.514	0.151	-5.481	-0.002	0.000	0.000	-0.090
UT_0	0.484	3.651	0.344	8.277	-0.100	0.249	0.015	-1.716
UT_1	-0.711	5.363	0.344	-8.277	0.147	0.366	0.015	1.716
SEX_0	0.568	3.712	0.253	7.098	-0.125	0.288	0.012	-1.569
SEX_1	-0.446	2.917	0.253	-7.098	0.099	0.226	0.012	1.569
AGECAT_1	1.688	8.580	0.370	8.584	0.337	0.541	0.015	1.711
AGECAT_2	0.095	0.041	0.002	0.616	0.576	2.410	0.070	3.740
AGECAT_3	-0.316	0.574	0.028	-2.366	0.902	7.445	0.230	6.760
AGECAT_4	-0.223	0.475	0.029	-2.385	-0.466	3.288	0.125	-4.979
AGECAT_5	-0.479	0.750	0.033	-2.552	-1.344	9.388	0.258	-7.167
EDU_1	0.585	3.541	0.224	6.670	-0.299	1.471	0.058	-3.412
EDU_2	0.052	0.012	0.001	0.324	0.226	0.350	0.010	1.416
EDU_3	-0.551	1.073	0.047	-3.071	0.340	0.648	0.018	1.894
EDU_4	-0.383	0.615	0.028	-2.358	-0.001	0.000	0.000	-0.009
EDU_5	-0.717	1.953	0.087	-4.166	0.244	0.358	0.010	1.415
CSP_1	-0.176	0.004	0.000	-0.176	-0.502	0.052	0.001	-0.502
CSP_2	-0.367	0.229	0.009	-1.365	0.411	0.455	0.012	1.527
CSP_3	-0.703	1.292	0.055	-3.304	0.509	1.077	0.029	2.393
CSP_4	0.963	3.036	0.133	5.135	0.297	0.459	0.013	1.585
CSP_5	-0.347	0.520	0.024	-2.175	0.996	6.807	0.196	6.247
CSP_6	1.480	1.720	0.068	3.671	0.374	0.174	0.004	0.927
CSP_7	-0.349	1.337	0.088	-4.185	-0.680	8.062	0.334	-8.158
CSP_8	1.487	5.214	0.219	6.599	-0.027	0.003	0.000	-0.119
ENF_0	0.977	5.994	0.301	7.742	0.395	1.560	0.049	3.135
ENF_1	-0.308	1.893	0.301	-7.742	-0.125	0.493	0.049	-3.135
SIM_1	1.096	8.493	0.444	9.403	0.462	2.394	0.079	3.963
SIM_2	0.081	0.006	0.000	0.219	0.502	0.367	0.009	1.349
SIM_3	-0.534	0.336	0.013	-1.635	0.576	0.621	0.016	1.765
SIM_4	-0.537	3.404	0.236	-6.858	-0.003	0.000	0.000	-0.044
SIM_5	-0.015	0.000	0.000	-0.061	-1.540	7.884	0.206	-6.406
SIM_6	-0.264	0.219	0.010	-1.377	-0.362	0.655	0.018	-1.888
REV_1	1.221	8.392	0.408	9.014	-0.359	1.149	0.035	-2.647
REV_2	-0.041	0.012	0.001	-0.360	-0.055	0.035	0.001	-0.480
REV_3	-0.245	0.322	0.015	-1.754	-0.043	0.015	0.000	-0.305
REV_4	-0.439	0.781	0.035	-2.651	0.391	0.984	0.028	2.361
REV_5	-0.825	0.713	0.028	-2.376	-0.084	0.012	0.000	-0.242
REV_6	-0.951	2.486	0.106	-4.595	0.418	0.763	0.021	2.021

Figure 29: Coordinates, square cosines, percentage of contributions, and test values for dimension 1 and 2

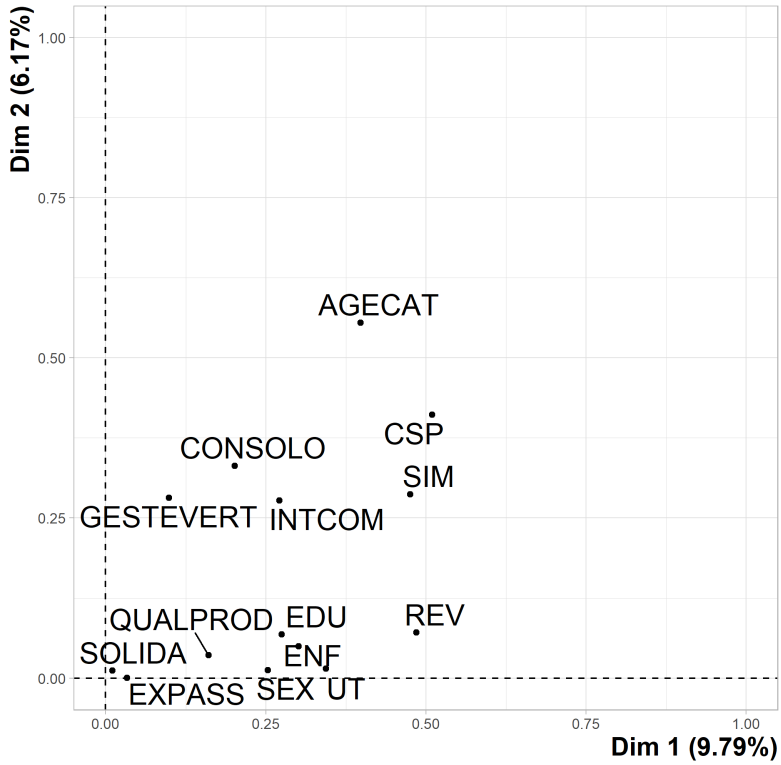

Figure 30: MCA variables graph

Appendix 5

```
       59        20        77         7        27         3        33        41        45        13        73       176
-2.0724000 -2.0384759 -1.6751856 -1.6671393 -1.6671393 -1.6588338 -1.6588338 -1.6588338 -1.6572555 -1.3650236 -1.3650236 -1.3581128
       54         1        47        71         8        14        72         5       178       196        24        51
-1.3576378 -1.2996143 -1.2996143 -1.2996143 -1.2879280 -1.2879280 -1.2879280 -1.2848038 -1.2848038 -1.2751069 -1.2668023 -1.2668023
       74        88         4        80       181        61       169        42        78         6        82         9
-1.2668023 -1.2668023 -1.2612609 -1.2612609 -1.2574539 -1.2465539 -1.2303366 -1.0119380 -1.0119380 -1.0071236 -0.9999039 -0.9849049
       17        30        48        57        68        75       113        18        25        49        12        55
-0.9849049 -0.9849049 -0.9849049 -0.9849049 -0.9849049 -0.9849049 -0.9849049 -0.9739325 -0.9739325 -0.9739325 -0.9709058 -0.9709058
      174       199        50        58        87        23        39        29        11        28        35        43
-0.9709058 -0.9709058 -0.9471877 -0.9450992 -0.9244873 -0.9198646 -0.9198646 -0.9050899 -0.9029784 -0.8907490 -0.8907490 -0.8907490
       86        81       173       170        19        65        16       131       180       192        67       183
-0.8907490 -0.8816574 -0.8792426 -0.7062626 -0.7001947 -0.6929990 -0.6864702 -0.6864702 -0.6864702 -0.6864702 -0.6769521 -0.6769521
      187        90        31         2        60        62        63        76        66        84       191        34
-0.6769521 -0.6751893 -0.6736042 -0.6698154 -0.6626250 -0.6626250 -0.6626250 -0.6525652 -0.6392708 -0.6392708 -0.6218969 -0.6143907
       44        52        36        38        10        15       188        69       179       189       198       200
-0.6143907 -0.6143907 -0.6122029 -0.6038556 -0.4650309 -0.4650309 -0.4650309 -0.4576441 -0.4576441 -0.4576441 -0.4576441 -0.4576441
       22        26        79        32        46        70       171       177       182       184       185       194
-0.4467011 -0.4467011 -0.4467011 -0.4454175 -0.4454175 -0.4454175 -0.4454175 -0.4454175 -0.4454175 -0.4454175 -0.4454175 -0.4454175
      197        37        64       186       190        53        56       172       175       193       195       120
-0.4454175 -0.4379831 -0.4114132 -0.4114132 -0.4114132 -0.2960365 -0.2960365 -0.2960365 -0.2960365 -0.2960365 -0.2960365  0.5329990
       89       143       114       125       141       168        98       121       124       126       128       159
 0.5447096  0.5447096  0.7693059  0.7693059  0.7693059  0.7693059  0.7835343  0.7835343  0.7835343  0.7835343  0.7835343  0.7835343
      163       153        83        96       119       147       154       108       109        21        93       134
 0.7835343  0.7875197  0.7932414  0.7932414  0.7932414  0.7932414  0.7932414  0.7985275  0.7985275  0.8069848  0.8069848  0.8069848
       99        40        94        95       135       145       165       139       132       150        91       111
 1.0310217  1.0647263  1.0647263  1.0647263  1.0647263  1.0647263  1.0647263  1.0647343  1.0988623  1.1029626  1.1105138  1.1105138
      115        97       103       146       106       112       129       136       137       148       156       107
 1.1105138  1.1108220  1.1108220  1.1108220  1.1161850  1.1161850  1.1161850  1.1161850  1.1161850  1.1161850  1.1161850  1.1325964
      105       161       118       162       102       110       100        92       133       152       157       130
 1.1410527  1.1410527  1.1411779  1.1411779  1.1414077  1.1753726  1.1790792  1.4037794  1.4143009  1.4143009  1.4143009  1.4390939
      166       122       127        85       142       123       104       144       164       155       158       138
 1.4390939  1.4400391  1.4896966  1.4902918  1.4929220  1.4963522  1.4984908  1.4984908  1.4984908  1.5717805  1.5717805  1.8044697
      149       117       167       160       151       101       140       116
 1.8044697  1.8335351  1.8335351  1.8504505  1.8754534  1.9376396  2.2188457  2.2280439
```

Figure 31: Sorting of residuals in ascending order

Appendix 6

Variable	GVIF	Df	$GVIF^{\frac{1}{2Df}}$
EXPASS	1.30	1.00	1.14
INTCOM	1.77	2.00	1.15
SOLIDA	2.08	2.00	1.20
GESTEVERT	2.00	2.00	1.19
CONSOLO	2.80	2.00	1.29
QUALPROD	2.03	2.00	1.19
SEX	1.52	1.00	1.23
AGECAT	20.20	4.00	1.46
EDU	5.07	4.00	1.22
CSP	33.44	7.00	1.28
ENF	1.96	1.00	1.40
SIM	8.07	5.00	1.23
REV	6.69	5.00	1.21

Table 27: VIF test results for the full model with all variables