

SOUTHEAST EUROPEAN REVIEW OF BUSINESS AND ECONOMICS

Vol.4, Issue 2, 2023

*FACTORS AFFECTING CITIZENS' INTENTIONS
TO REDUCE PLASTIC WASTE*

*Emilija Gjorgjioska, Monika Angeloska - Dichovska,
Meri Boshoska, Margarita Janeska*

*HETEROGENEOUS AGENT (HA) MODELS AND
TWO ASSET HANK MODEL: REVIEW OF SOME
COMPUTATIONAL MODELS*

Dushko Josheski, Mico Apostoloov

*IMPACT OF VISUAL IDENTITY IN DIGITAL MARKETING
FOR TOURISM BASED ON EXAMPLES FROM BULGARIA*

Neviana Krasteva, Dessislava Alexova

*STRATEGIES FOR RISK MITIGATION IN THE SUPPLY
CHAIN SYSTEM*

David Saltamarski

FACULTY
OF ECONOMICS
- PRILEP

Southeast European Review of Business and Economics

SERBE

Volume 4, Issue 2, December 2023

SERBE is published twice a year (June and December)

Publisher: Faculty of Economics-Prilep

ISSN 2671-339X

DOI 10.20544/SERBE.08.02.23

e-mail address: serbe@uklo.edu.mk

<http://eccfp.edu.mk/serbe>

Editor in chief

Aneta Risteska Jankuloska, University St. Kliment Ohridski, North Macedonia

Editorial Board

Martin Dangerfield, University of Wolverhampton, UK
Sara Williams, University of Wolverhampton, UK
Dragica Odzaklieska, University St. Kliment Ohridski, North Macedonia
Jasmina Okičić, University of Tuzla, Bosnia and Herzegovina
Ali Faruk Açıkgöz, Namik Kemal University, Turkey
Slavica Rocheska, University St. Kliment Ohridski, North Macedonia
Taki Fiti, Macedonia Academy of Sciences and Art, North Macedonia
Emil Papazov, University of National and World Economy-Sofia, Bulgaria
Jerzy Kaźmierczyk, Poznan University of Economics, Poland
Laura Vasilescu, University of Craiova, Romania
Nebojša Stojcic, University of Dubrovnik, Croatia
Yulia Syaglova, Russian Presidential Academy of National Economy and Public Administration, Russian Federation
Srdjan Redzepagić, University Nice - Sophia Antipolis, France
Olivera Kostoska, University St. Kliment Ohridski, North Macedonia
Bojan Krstić, University of Niš, Serbia
Celal Demirkol, Namik Kemal University, Turkey
Dancho Petrov, University of Economics-Varna, Bulgaria
Marjan Angeleski, University St. Kliment Ohridski, North Macedonia
Vasilika Kume, Tirana University, Albania
Zoran Aralica, Institute of Economics, Croatia
Snežana Mojsoska-Salamovska, University St. Kliment Ohridski, N.Macedonia
Želko Stojanov, University of Novi Sad, Serbia
Ahmet Kubaş Namik Kemal University, Turkey
Lyudmila Mihaylova, University of Ruse, Bulgaria
Fatmir Memaj, University of Tirana, Albania
Zoran Ćirić, University of Novi Sad, Serbia
Shushma Patel, London South Bank University, UK
Rasim Yilmaz, Namik Kemal University, Turkey
Evgeniya Tonkova, University of Economics-Varna, Bulgaria
Viktorija Petrov, University of Novi Sad, Serbia
Dimitar Nikoloski, University St. Kliment Ohridski, North Macedonia
Tadija Đukić, University of Niš, Serbia

Cover design

Violeta Gligorovski, PhD

CONTENTS

EDITORIAL	7
<i>Aneta Risteska Jankuloska</i>	
FACTORS AFFECTING CITIZENS' INTENTIONS TO REDUCE PLASTIC WASTE	9
<i>Emilija Gjorgjioska, Monika Angeloska - Dichovska, Meri Boshkoska, Margarita Janeska</i>	
HETEROGENEOUS AGENT (HA) MODELS AND TWO-ASSET HANK MODEL: REVIEW OF SOME COMPUTATIONAL MODELS	32
<i>Dusko Josheski, Mico Apostolov</i>	
IMPACT OF VISUAL IDENTITY IN DIGITAL MARKETING FOR TOURISM BASED ON EXAMPLES FROM BULGARIA	67
<i>Neviana Krasteva, Dessislava Alexova</i>	
STRATEGIES FOR RISK MITIGATION IN THE SUPPLY CHAIN SYSTEM	81
<i>David Saltamarski</i>	

Open access policy

Since our intention is to popularise the work of academic researchers, we are committed to promote the dissemination of research outputs and greater global exchange of knowledge. In order to support dissemination, the Faculty of Economics - Prilep provides an unrestricted on-line access to all issues published in SERBE.

The international journal SERBE is available internationally in *EBSCO* and *CROSSREF* database.

EDITORIAL

Southeast European Review of Business and Economics (SERBE) is a peer reviewed academic journal published by the Faculty of Economics-Prilep, University “St. Kliment Ohridski”-Bitola, Macedonia. It has been founded on the rich academic and publishing heritage, including the Yearbook of the Faculty of Economics-Prilep and Proceedings from a number of international conferences. Based on this tradition, our intention is to publish original papers, which have not been previously published or submitted for reviewing to other journals.

The transition and post-transitional development in Southeast Europe is characterized by peculiar socio-economic phenomena that are interesting for research. Also, the war operations and political crises in many countries are putting substantial pressure on governments, organizations, and enterprises throughout the world to respond quickly. Hence, we encourage experienced scholars, business practitioners as well as young researchers to submit their original work on various problems in the areas of business and economics.

The eight issue of the Southeast European Review of Business and Economics (SERBE) presents papers by experienced scholars and PhD students which cover topics related digital marketing, supply chain and waste management.

DOI: 10.20544/SERBE.08.02.23.P01

FACTORS AFFECTING CITIZENS' INTENTIONS TO REDUCE PLASTIC WASTE

**Emilija Gjorgjioska¹, Monika Angeloska - Dichovska², Meri
Boshkoska³, Margarita Janeska⁴**

Abstract

The necessity of protecting the ecosystem is of crucial importance and requires immediate attention. The issues of pollution, waste, and the need to modify both individual and business practices have become dominant, especially in developing countries and disadvantaged nations. Identifying the key drivers that facilitate a shift towards circular economic processes and a significant transformation in citizens' environmentally-friendly behaviors is imperative. The aim of this study is to examine the recycling practices of residents in Bitola and Prilep, located in the Pelagonia region of the Republic of North Macedonia and to identify the main motivating factors for changing habits related to plastic recycling. Specifically, the study aims to increase plastic waste sorting practices and encourage the use of reverse vending machines (RVM). A survey was conducted, collecting data from 842 citizens to gain insights into their habits and intentions. Analyses of the study confirm that the most significant motivators for changing citizens' recycling

¹ Faculty of Economics – Prilep, st. Prilepski Braniteli No.143, Prilep, Republic of North Macedonia, e-mail: emilija.mateska@uklo.edu.mk

² Faculty of Economics – Prilep, st. Prilepski Braniteli No.143, Prilep, Republic of North Macedonia, e-mail: monika.angeloska@uklo.edu.mk

³ Faculty of Economics – Prilep, st. Prilepski Braniteli No.143, Prilep, Republic of North Macedonia, e-mail: meri.boskoska@uklo.edu.mk

⁴ Faculty of Economics – Prilep, st. Prilepski Braniteli No.143, Prilep, Republic of North Macedonia, e-mail: margarita.janeska@uklo.edu.mk

practices are financial incentives, such as rewards or discounts. Additionally, the need to increase public awareness and provide greater education on recycling remains essential elements in initiatives aimed at changing citizens' behavior.

Keywords: recycling, citizen's behavior, waste management, circular economy, ecological law.

1. Introduction

The last few decades waste management has been a crucial motive and essential part of the policies of well-developed countries' governments. Almost all of the statistical research shows that the quantity of the waste is drastically and exponentially increasing. It is estimated that the annual global waste volume will increase to 3.40 billion tons by 2050 (Kaza et al., 2018). Plastics are everywhere but a large part of it is used only once before thrown away. It ends up polluting the environment, depriving the economy of a valuable resource. According to estimates, only 5% of the value of plastic packaging material remains in the economy, the rest is lost after a very short first-use. This is a big cost for Europe, with the annual bill ranging between €70 and €105 billion. In Europe, the majority of plastic is still landfilled or incinerated rather than being recycled (European Commission, 2018).

The negative impact of litter, the issue related to air, weather and soil quality is well known; unfortunately, it may be considered that not much has been done in this field to drastically improve or stop the littering of the Earth.

Well-developed countries are a few steps ahead in how they deal with pollution and waste management compared to developing countries, especially those with low and middle-income levels. Waste management behavior is inseparably linked to the cultural background of the residents, but it is also influenced by the political and infrastructure order and organizational properties of countries and communities. The successful management and marketing of any household solid waste recycling scheme will require national and local governments to encourage high levels of public participation to ensure that the planned technology is implemented successfully (Zhang et al. 2015).

The cultural background, the legal framework, and sometimes the qualifications of certain behaviors, such as penalties or incentives for selecting, reducing, and recycling waste can be decisive factors in the acceptance of recycling such as a citizen's unconscious daily routine.

The legal framework is a necessary base for acceptance and directing some behavior as normal and acceptable by the citizens. Each country's government should strategically plan and regulate the entire process, starting from production that includes packaging, waste generation, sorting, prevention, reuse, recycling packaging waste to energy recovery.

For that purpose, in the Republic of North Macedonia, the Law on Packaging and Packaging Waste Management was enacted on September 15, 2021, as part of the legislative package in the field of waste management, in accordance with the goals for long-term environmental protection and the introduction of the concept of a circular economy. The law is aligned with the Directive 94/62/EC of the European Parliament and of the Council on packaging and packaging waste adopted on December 20, 1994. The objectives of the law are to prevent the generation of packaging waste, reduce and limit the use of harmful metals and substances in packaging, promote sorting of waste, achieve a high level of reuse, recycling, and other forms of processing, thereby reducing landfilling (Mateski et al., 2021).

According to the law, manufacturers are obligated to ensure the implementation of national targets related to the collection, recycling, and processing of packaging waste resulting from packaged products released on the market in the Republic of North Macedonia. The law specifies the following quantities of packaging waste released on the market in the Republic of North Macedonia to be collected to meet national targets: 65% by 2024, 70% by 2025, 75% by 2026, 80% by 2027, and 85% by 2028. In accordance with the law, the national targets of the Republic of North Macedonia for the collection, processing, and recycling of packaging waste by December 31, 2030, are a minimum of 65% of the weight of all packaging waste to be recycled, with a requirement to selectively collect at least 50% of plastic packaging waste. According to the Directive 94/62/EC of the European Parliament and of the Council on packaging and packaging waste and its amendments, the corresponding target for the European Union

for the same period is a minimum of 55% of plastic packaging waste to be recycled.

To gradually achieve the goals of the Law, the minister leading the environmental authority establishes annual national targets for the collection, processing, and recycling of packaging waste, in accordance with planning documents adopted in line with waste management regulations, no later than December 15 of the current year for the following year. In this regard, the Plan for Preventing Waste Generation in the Republic of North Macedonia for the period 2022-2028 was introduced. According to the Plan, aiming for "zero waste" or a sustainable circular economy requires a joint commitment from the central government, local self-governments, the business community, the education sector, the NGO sector, and citizens/consumers (Ministry of Environment and Physical Planning, 2022). "Zero waste" implies designing and managing products and processes with the intention of reducing the volume and toxicity of waste and materials, preserving and renewing all resources without incineration or landfilling (Zero Waste International Alliance). The implementation of "zero waste" will eliminate all waste that could end up in the soil, water, or air, posing a threat to human health, animals, or the planet Earth. Zero waste is a concept for minimizing waste by reducing the use of products that produce waste (Zamzam et al. 2023).

The Waste Prevention Plan encompasses numerous policies with the ultimate goal of addressing waste more quickly and efficiently, reducing waste, increasing reuse, and recycling. The objectives and vision of the plan include the development of collection and recycling systems that can be integrated into local economic activities, reducing the quantities of residual waste that need to be landfilled by removing recyclable materials and organic waste from the total waste, and more.

2. Influencing Factors for Reducing Plastic Waste

Low and middle-income countries still face major challenges in ensuring universal access to waste collection services, eliminating uncontrolled disposal and burning and moving towards environmentally sound management for all waste. Hence, there is a need for implementation of innovative and effective policies and practices to promote waste prevention

and stem the relentless increase in waste per capita as economies develop. (UNEP 2015, p.7).

Eliminating plastic waste requires wide-scale system changes and a shift from a linear to a circular plastics economy; where products are re-used, re-purposed, recycled, and recovered (Allison et al., 2022).

Reducing or eliminating plastic waste requires an active role from all stakeholders to encourage sustainable plastic use. Specifically, individuals, industry, and the government play a key role in these processes through consumer behavior, responsible production, green plastic packaging, raising public awareness, and plastic waste management for recycling and remanufacturing (Jia, Evans & Linden, 2019).

The elimination of plastic waste depends, in part, on changing human behavior. Various behaviors, such as reducing, reusing, and recycling, can be adopted by individuals to minimize plastic waste (Union, 2008 as cited in Allison et al., 2022).

Chan (1998) found that the media content of environmental news on local pollution problems may give us better understanding of the ‘public agenda’ and the ‘media agenda’ and that publicity messages from the mass media should be effective for promoting green behaviors.

Some authors highlight that for improvement and promotion of smart recycling systems, the focus should be put to promoting public intention to use and enhance their environmentally-friendly behavior in a playful way. Namely, Liu and Hsu in their study analyzed the following four factors influencing the intention of urban residents to use smart recycling systems: environmental concerns, perceived playfulness, perceived usefulness, and perceived ease of use. Perceived playfulness significantly affects intention to use. They indicated that the effect of perceived playfulness on intention to use is greater than that of environmental concern, but perceived ease of use cannot significantly affect intention to use (Allison et al., 2022).

Factors affecting recycling behavior presented in the literature are categorized as follows (Barnosky, Delmas & Huysentruyt):

1. Knowledge - Not enough awareness or knowledge about recycling and recycling initiatives
2. Inconvenience - Perceptions of recycling (in)convenience
3. Responsibility - Lack of personal responsibility.

People can be influenced, and their recycling habits can be changed through diverse, effective, and innovative incentive schemes (Gibovic & Bikfalvi, 2021). The necessary factors that can trigger a change in public behavior, as identified by Defra in 2006 (cited in Timlett & Williams, 2008), include:

- Enablers - infrastructure, education and information and removal of barriers.
- Encouragement - taxes, penalties, rewards and league tables.
- Engagement - communication, feedback, consultation, community involvement and 'bottom up' policies.
- Exemplify - leading by example.

Often, as a practice to change and initiate citizens' recycling behavior, the promotion of using green cards to collect points for waste recycling is used. The accumulated points can later be used for specific purchases or discounts at supermarkets or other places.

The Macedonian company Pakomak undertakes initial initiatives to change waste sorting habits. It is the first Macedonian company to introduce the global trend in sorting within the Republic of North Macedonia – reverse vending machines for collecting plastic bottles and cans (Pakomak, 2023). Citizens benefit from using these vending machines by collecting points through the Ekomak application. The application allows users to gather points and use them as vouchers in markets. It is part of a larger ecosystem where users authenticate themselves with the vending machine through the application and collect points for the disposed bottle. The green points can then be exchanged for valuable rewards and benefits, such as discount vouchers in markets and other retail outlets, discounts on public services and utility costs, donations, etc. The list of places where vouchers can be used is expanding daily and can be viewed on the mobile application itself.

Practices similar to those of Pakomak have been introduced and implemented in various parts of the world, few years before Pakomak did it in Macedonia. For example, to facilitate and encourage public participation in community recycling facilities, Hong Kong has introduced the GREEN\$ -

Greeny Coins (Hong Kong Waste Reduction Website) smart card. This card allows the public to earn GREEN\$ and exchange them for gift items. Individuals bringing no less than 2 kg of recyclables to the new community recycling network can register to receive a GREEN\$ smart card. By presenting the GREEN\$ smart card or the QR code image printed on the back of the card during subsequent submission of recyclables, the public can earn GREEN\$ for the redemption of gift items. Furthermore, Bracknell Forest Council, in the south of England, gives an opportunity to every citizen who wants to use an “e+ card” where points are accumulated. Points are awarded for each pick-up of specified bins, which are emptied if eligible by the personnel of the waste truck. The system does not employ a weight-based mechanism, and no fee reduction is offered for managing the residual waste bin. Users of the system do not receive a cashable value, but a maximum total value of GBP 26 in credits (points) per year is provided. The main rewards include leisure benefits, such as discounts or direct access to sports facilities, membership to local clubs, gyms, and pools (Plastic Smart Cities, 2023).

Additionally, Yoyo - <http://yoyo.eco> was founded in early 2017. Present in six major cities in France, including Paris, Lyon, Bordeaux, Marseille, Reims, and Mulhouse, the company is aiming to make recycling not only more convenient in France, but also more fun. Through a system of Sortersand Coaches, Yoyo participants receive points for diverting plastic bottles from landfills. The results are promising — in just two years, the community has grown to almost 400 Coaches and over 12,000 Sorters, collecting almost 3.7 million plastic bottles in France. Yoyo's approach showcases the effectiveness of combining convenience, social engagement, and incentives to promote positive recycling practices (Barnosky, Delmas & Huysentruyt).

The monetary incentive that is provided by RVMs is strong motivation to engage the general public in recycling efforts (Amantayeva et al., 2021). “Cash for trash” as a motto is well known and used worldwide for tackling litter, recycling for some money or other reward, bearing in mind that the main goal of the whole process is to keep the environment clean.

The adoption of innovative recycling practices, such as the use of green cards, reverse vending machines, and smart cards with incentives, has proven to be helpful in motivating citizens to actively participate in waste management initiatives. Initiatives such as Ekomak of Pakomak in North Macedonia, Plastic Smart Cities in Hong Kong, e+ card of Bracknell Forest Council, in the south of England and Yoyo in France have successfully implemented reward-based systems that not only promote environmentally responsible behavior but also contribute to the broader goal of keeping the environment clean. The expansion of these practices globally, as well as the incorporation of monetary incentives, as demonstrated by the strong motivation provided by RVMs, reflects a growing awareness and commitment to sustainable waste management practices on a global scale. The integration of convenient, social, and incentive-driven approaches, exemplified by these initiatives, offers a promising blueprint for fostering positive recycling habits and fostering a cleaner, more sustainable planet.

3. Research and discussion

3.1. Methodology

The primary objective of the research is to identify the awareness and motivation factors among the populations in the cities Bitola and Prilep, which are part of the Pelagonia region in the Republic of North Macedonia, regarding the recycling of plastic waste, with a particular emphasis on plastic bottles. The choice of this part of Pelagonia region was made as a result of the importance that cities have in the region due to the significant economic activity of numerous companies and its significant population. At the same time the amount of solid waste generated by the population and companies from this region continues to increase. It's noteworthy that, at the time the survey was conducted, there were no vending machines available in the above-mentioned cities. The research intends to provide valuable information that will help to develop strategies for encouraging environmentally friendly waste management practices.

The research was conducted entirely online from July 1st to August 1st 2023, using a structured, non-disguised questionnaire. The questionnaire included both closed and open-ended questions, aiming to obtain comprehensive insights. A survey link was distributed to 2000 citizens (1000 from each

city), and 842 responses were received (360 from Bitola and 482 from Prilep).

To achieve the research objective, a questionnaire was designed, consisting of three parts. The first part included questions related to the general characteristics of the respondents. The second set of questions aimed to identify the current eco-practices of the respondents. The third set was designed to collect data on the respondents' perceptions of the usage of reverse vending machines and their familiarity with their functionality.

The collected data were analyzed using survey administration software SF Google Forms and SPSS software package. The hypotheses were tested using the non-parametric Chi-square test, with the significance of results set at a 5% risk or a confidence level of 95% in statistical inference.

3.2. *Demographic Overview and Sampling Framework*

The research was carried out in North Macedonia's Pelagonia Region (with the focus on Prilep and Bitola), aimed to comprehensively explore and understand the demographic and socioeconomic characteristics of the participant pool. A total of 842 participants took part in the survey, representing a wide range of the Pelagonia Region's population. Detailed characteristics, including age, gender, educational level, and employability status, are presented in Table 1.

Upon reviewing Table 1, the distribution of respondents based on gender reveals that 68% were female, while 32% were male. Analyzing the age structure, a significant portion, comprising 34% of the participants, belong to the age group of 30 to 40 years. Subsequently, respondents aged 41 to 50 years constituted 27.4%, those in the age group of 15 to 29 years accounted for 20.4%, participants aged 51 to 64 years comprised 16%, and the least represented group consisted of respondents aged above 64 years at 2.2%.

In terms of education, the majority of respondents had completed higher education (54.28%). Following closely were individuals who had completed postgraduate or doctoral studies, constituting 22.92%. Participants with secondary education comprised 21.62%, while those with primary education represented a smaller percentage at 0.71%. Additionally, respondents with

vocational education and those without formal education made up a combined 0.5%.

In terms of employment status, the majority of respondents, numbering 701 (83.25%), were employed. A smaller percentage, 67 (7.96%), identified as students, while 44 (5.23%) were unemployed. Additionally, 27 (3.21%) respondents were retired, and a minor fraction, constituting 3 (0.36%), provided responses categorized as "other."

Table 1. Characteristics of the respondents

Characteristics of respondents	Number of respondents	%
Age	842	
15-29	172	20.4
30-40	286	34
41-50	231	27.4
51-64	134	16
over 64 years old	19	2.2
Gender		
Male	269	32
Female	573	68
Education level		
Primary education	6	0.71
Secondary education	182	21.62
Higher education	457	54.28
Postgraduate/PhD	193	22.92
Other	4	0.48
Employment status		
High school student	11	1.31
University student	56	6.65
Employed	701	83.25
Unemployed	44	5.23
Pensioner/Retire	27	3.21
Other	3	0.36

Source: own research

3.3. *Research results*

Research carried out in the Bitola and Prilep has provided important insights on waste management practices and the readiness of citizens to adopt sustainable lifestyles. The data analyzes from the conducted research confirm that, concerning waste sorting practices, 48% of the respondents consistently

participate in waste sorting. On the other hand, the remaining respondents mentioned that they engage in waste sorting either occasionally or never.

The concept that implementing focused programs and incentives can effectively promote citizens' adoption of sustainable behavior is confirmed by the analysis of the research data. The analysis of the gathered data not only confirms but also enhances the validity of the concept, showing a clear correlation between the implementation of targeted initiatives and the favorable change in people's behaviors and attitudes toward sustainable activities.

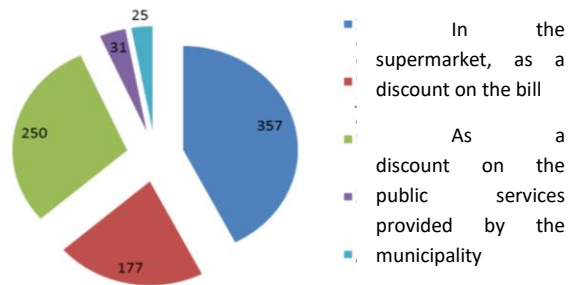
When analyzing the data regarding how many plastic bottles or cans respondents generate weekly, the majority indicated that they accumulate between 5 to 10 plastic bottles or cans per week. The analyses confirm that a substantial 89% of respondents stated that they would certainly or probably recycle more waste if there were rewards or discounts for certain products or services in exchange for a specific quantity of collected and returned plastic bottles or cans. The highest percentage of respondents believe that, for recycling, a financial reward or incentive should be provided. It is encouraging to note that a positive 94% of respondents expressed willingness to personally use reverse vending machines if installed in their city. This attitude prevails among respondents regardless of age, gender, or the municipality they reside in. The majority of respondents (42.5%) expressed a preference to use the benefits/points earned from depositing their used plastic bottles and cans into such machines for obtaining a discount in supermarkets. Approximately 30% of respondents indicated a desire to use them for donations, and around 21% for receiving discounts on public services provided by the municipality.

The respondents emphasized financial incentives as the most significant motivator for changing recycling practices. However, they also highlighted the need for greater education to increase awareness and promote the use of reverse vending machines.

To the question: "In what way would you personally like to use the benefits/points earned from depositing your used plastic bottles and cans into

reverse vending machines?”, respondents provided the following summary of responses:

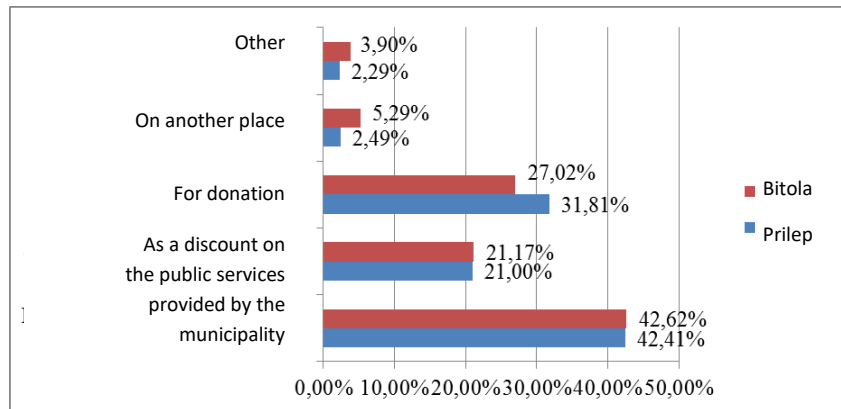
Figure 1. Desired benefits from depositing used plastic bottles and cans into reverse vending machines?



Regarding this question, the majority of respondents, approximately 42.5% (357), expressed a preference to use the benefits/points earned from depositing their used plastic bottles and cans into such machines for obtaining a discount in supermarkets. Around 30% or 250 of respondents indicated a desire to use them for donations, approximately 21% (177) for receiving discounts on public services provided by the municipality, 3.7% (31) for other places such as cafes, restaurants, tickets for sports events, etc., and about 3% or 25 respondents for other purposes (all statements refer to monetary compensation).

To visualize the difference in responses among the respondents in the two largest municipalities in the Pelagonia region, the percentages are presented on the following figure:

Figure 2. In what way would you personally like to use the benefits/points earned from depositing your used plastic bottles and cans into reverse vending machines? - Percentage breakdown by municipality



The responses to the question: “In what way would you personally like to use the benefits/points earned from depositing your used plastic bottles and cans into reverse vending machines?” indicate that there is no significant difference in the attitudes of respondents from Bitola and Prilep municipalities regarding their answers to this question. The most of them prefer to use the benefits/points earned from depositing their used plastic bottles and cans into such machines for obtaining a discount in supermarkets.

In the next part of this research, an in-depth examination will be conducted through hypothesis testing, specifically focusing on factors influencing recycling incentives. Additionally, the study will explore the cluster affiliation of citizens, aiming to discern patterns and groupings within the respondent population based on their attitudes and behaviors towards recycling practices.

3.4. Hypothesis testing

With the application of a test in the SPSS software package, as a result of input information, as well as the corresponding empirical and calculated (theoretical) values of respondents' answers, and in accordance with the subject and purpose of the research, the following general hypothesis has been tested:

H_0 - The motivation to engage more in recycling does not depend on the cluster affiliation (gender, age, education and employment status of the citizens) when there is a reward or discount for a certain number of collected and returned plastic bottles or cans, applicable to certain products or services.

Specific hypotheses derived from the general hypothesis are:

H₀₁ - The motivation to engage more in recycling does not depend on the gender of the citizens when there is a reward or discount for a certain number of collected and returned plastic bottles or cans, applicable to certain products or services.

Table 2. The empirical values of the respondents' answers by gender

	I would probably select more	I probably wouldn't select more	I would certainly select more	I would certainly not select more	I don't know	Sum
M	95	5	151	1	12	269
F	204	29	301	11	28	573
Sum	299	34	452	17	40	842

Table 3. Theoretical values of the respondents' answers by gender

	I would probably select more	I probably wouldn't select more	I would certainly select more	I would certainly not select more	I don't know	Sum
M	95,5237530	10,86223278	144,4038005	5,43111639	12,7790974	269
F	203,476247	23,13776722	307,5961995	11,5688836	27,2209026	573
Sum	299	34	452	17	40	842

Results:

Critical chi-square: 9.49
 Computed chi-square: 91.98
 Degrees of freedom 4
 $p = 0.26227$
 $\alpha = 0.05$

As the calculated test is greater than the critical (tabular) value, it can be concluded that the first specific hypothesis is rejected, meaning that the

motivation to engage more in recycling, if for a certain number of collected and returned plastic bottles or cans there is a reward or discount for certain products or services, depends on the gender of the citizens.

H₀₂ – The motivation to engage more in recycling does not depend on the age of the citizens when there is a reward or discount for a certain number of collected and returned plastic bottles or cans, applicable to certain products or services.

Table 4. The empirical values of the respondents' answers by age

	I would probably select more	I probably wouldn't select more	I would certainly select more	I would certainly not select more	I don't know	Sum
15-29	52	2	105	7	6	172
30-40	111	10	149	3	13	286
41-50	90	12	113	4	12	231
51-64	44	6	74	2	8	134
65+	2	4	11	1	1	19
Sum	299	34	452	17	40	842

Table 5. Theoretical values of the respondents' answers by age

	I would probably select more	I probably wouldn't select more	I would certainly select more	I would certainly not select more	I don't know	Sum
15-29	61,07839	6,945368	92,332541	3,4726841	8,1710213	72
30-40	101,56057	11,548693	153,52970	5,7743468	13,586698	86
41-50	82,029691	9,327800	124,00475	4,6638955	10,973872	31
51-64	47,584323	5,4109263	71,933491	2,7054632	6,3657958	34
65+	6,7470309	0,76722	10,199525	0,3836105	0,9026128	9
Sum	299	34	452	17	40	42

Results:

Critical chi-square:	26.3
Computed chi-square:	35.07
Degrees of freedom	16
$p = 0.003882$	
$\alpha = 0.05$	

As the calculated test is greater than the critical (tabular) value, it can be concluded that the second specific hypothesis is rejected, meaning that the motivation to engage more in recycling, if for a certain number of collected and returned plastic bottles or cans there is a reward or discount for certain products or services, depends on the age of the citizens.

H₀₃ – The motivation to engage more in recycling does not depend on the education of the citizens when there is a reward or discount for a certain number of collected and returned plastic bottles or cans, applicable to certain products or services.

Table 6. The empirical values of the respondents' answers by education

	I would probably select more	I probably wouldn't select more	I would certainly select more	I would certainly not select more	I don't know	Sum
without f.e.	2	0	1	0	0	3
higher e.	161	16	250	9	21	457
2 years h.e.	0	0	0	0	1	1
master/PhD	72	13	97	5	6	193
primary	1	0	5	0	0	6
secondary	63	5	99	3	12	182
Sum	299	34	452	17	40	842

Table 7. Theoretical values of the respondents' answers by education

	I would probably select more	I probably wouldn't select more	I would certainly select more	I would certainly not select more	I don't know	Sum
without f.e.	1,0653207	0,1211401	1,6104513	0,0605701	0,142517	3
higher e.	162,28385	18,453682	245,32542	9,2268409	21,71021	457
2 years h.e.	0,3551069	0,0403801	0,5368171	0,0201900	0,047506	1
master/PhD	68,535630	7,7933492	103,60570	3,8966746	9,168647	193
Primary	2,130641	0,2422803	3,2209026	0,1211401	0,285036	6
secondary	64,629454	7,3491686	97,700713	3,6745843	8,64608	182
Sum	299	34	452	17	40	842

Results:

Critical chi-square: 31.41

Computed chi-square: 31.83

Degrees of freedom 20

 $p = 0.045171$ $\alpha = 0.05$

As the calculated test is greater than the critical (tabular) value, it can be concluded that the third specific hypothesis is rejected, meaning that the motivation to engage more in recycling, if for a certain number of collected and returned plastic bottles or cans there is a reward or discount for certain products or services, depends on the education of the citizens.

H₀₄ – The motivation to engage more in recycling does not depend on the employment status of the citizens when there is a reward or discount for a certain number of collected and returned plastic bottles or cans, applicable to certain products or services.

Table 8. The empirical values of the respondents' answers by employment status

	I would probably select more	I probably wouldn't select more	I would certainly select more	I would certainly not select more	I don't know	Sum
employee	255	29	375	14	28	701
unemployed	14	0	22	1	7	44
retiree	6	4	13	2	2	27
high school student	23	1	30	0	2	56
middle school student	0	0	10	0	1	11
other	1	0	2	0	0	3
Sum	299	34	452	17	40	842

Table 9. Theoretical values of the respondents' answers by employment status

	I would probably select more	I probably wouldn't select more	I would certainly select more	I would certainly not select more	I don't know	Sum
employee	248,92992	28,30641	376,30879	14,153207	33,30166	701
unemployed	15,624703	1,776722	23,619952	0,8883610	2,090261	44
retiree	9,5878860	1,0902613	14,494061	0,5451306	1,282660	27
high school student	19,885986	2,261283	30,061758	1,1306413	2,660332	56
middle school student	3,9061758	0,4441805	5,9049881	0,2220902	0,522565	11
other	1,0653207	0,1211401	1,6104513	0,0605700	0,142518	3
Sum	299	34	452	17	40	842

Results:

Critical chi-square:	31.41
Computed chi-square:	2409.25
Degrees of freedom	20
p = 0.006819	
$\alpha = 0.05$	

As the calculated test is greater than the critical (tabular) value, it can be concluded that the fourth specific hypothesis is rejected, meaning that the motivation to engage more in recycling, if for a certain number of collected and returned plastic bottles or cans there is a reward or discount for certain products or services, depends on the employment status of the citizens.

From the hypothesis testing, a general conclusion can be drawn that the general hypothesis, H_0 - The motivation to engage more in recycling does not depend on the cluster affiliation (gender, age, education and employment status of the citizens) when there is a reward or discount for a certain number of collected and returned plastic bottles or cans, applicable to certain products or services, is rejected.

4. Conclusion

Raising awareness and educating the general population about the usefulness of reverse vending machines and the associated benefits are crucial initiatives. These initiatives should focus on clarifying the ease of use, environmental advantages, and the positive impact on sustainable waste management that reverse vending machines can contribute.

In addition to educational campaigns, it is also necessary to implement supplementary programs with financial incentives. These programs should be carefully designed to motivate and reward individuals for adopting stronger recycling practices. Financial incentives can include discounts on products or services, loyalty programs, or other tangible rewards that serve as a compelling incentive to actively participate in recycling efforts.

Analyses have confirmed that the motivation for increased waste sorting in the Pelagonia largest cities (Bitola and Prilep) depends on cluster affiliation, including gender, age, educational background, and employment status of the citizens. Therefore, when designing programs, it is necessary to consider and tailor them to the cluster characteristics of the citizens. Beyond the educational framework aimed at raising awareness among residents, given that bad behaviors and habits are contagious like a virus, there is a need for

greater activity from state and inspection authorities to monitor the consistent implementation of laws and other legal acts.

The country is shaped not only by the bureaucracy represented by elected individuals and government institutions but also by its population, their attitudes, actions, and collective contributions. Through their active engagement in sustainable practices and adoption of a responsible waste management approach, people make significant contributions to the general welfare of their communities and, consequently, the country as a whole. Therefore, creating an adaptable and ecologically conscious society requires that everyone be encouraged to consider themselves responsible for the environment.

Only through consistent, professional, and responsible behavior, aligned with domestic and European legal regulations and the best global practices, can the negative impact of waste on the environment be minimized. To achieve this goal precise waste management, implementation of environmentally friendly disposal methods, and promotion of recycling and circular economy practices are necessary.

References

Allison, A.L., Baird, H.M., Lorencatto, F., Webb, T.L, Michie, S. (2022). Reducing plastic waste: A meta-analysis of influences on behavior and interventions. *Journal of Cleaner Production*, 380. <https://www.sciencedirect.com/science/article/pii/S095965262204433X>. (Accessed Nov 5, 2023).

Amantayeva, A., Alkuatova, A., Kanafn, I., Tokbolat, S., Shehab, E. (2021). A system engineering study of integration reverse vending machines into the waste management system of Kazakhstan, *Journal of Material Cycles and Waste Management*, 23 (3).

Barnosky, E., Delmas, M.A. & Huysentruyt, M. The Circular Economy: Motivating Recycling Behavior for a More Effective System Available from

https://escholarship.org/content/qt4h20v1w5/qt4h20v1w5_noSplash_d61b868a755d256a1a658e70dd7167c0.pdf . (Accessed Nov 5, 2023).

Chan, K. (1998). Mass communication and pro environmental behaviour: Waste recycling in Hong Kong, 1998, *Journal of Environmental Management*. 52(4), pp.317–325.

European Commission, (2018). Available from: https://ec.europa.eu/commission/presscorner/detail/sv/MEMO_18_6. (Accessed Nov 20, 2023).

European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste, *Official Journal L 365* , 31/12/1994 P. 0010 – 0023.

Gibovic, D. & Bikfalvi, A. (2021). Incentives for Plastic Recycling: How to Engage Citizens in Active Collection. Empirical Evidence from Spain. *Recycling*. 6(2), 29. Available from: <https://www.mdpi.com/2313-4321/6/2/29> (Accessed Nov 30, 2023).

Hong Kong Waste Reduction Website, GREEN@COMMUNITY. Available from: <https://www.wastereduction.gov.hk/en-hk/waste-reduction-programme/greencommunity> (Accessed Nov 20, 2023).

Jia, L., Evans, S. & Linden, S. (2019). Motivating actions to mitigate plastic pollution, *Nature Communications*. 10 (1):1-3. Available from: https://www.researchgate.net/publication/336322238_Motivating_actions_to_mitigate_plastic_pollution (Accessed Nov 1, 2023).

Kaza, Silpa; Yao, Lisa C.; Bhada-Tata, Perinaz; Van Woerden, Frank. (2018). *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. Urban Development; Washington, DC: World Bank.

Liu, L., & Hsu, Y., (2022). Motivators factors behind the public’s use of smart recycling systems: perceived playfulness and environmental concern, *Humanities and Social Sciences Communications*. Available from: https://www.researchgate.net/publication/363764878_Motivators_factors_be

hind_the_public's_use_of_smart_recycling_systems_perceived_playfulness_and_environmental_concern (Accessed Nov 10, 2023).

Матески, А., Ѓорѓиоска, Е., Бундалеска, Е. (2021). *Водич за практична примена на Законот за пакување и управување со отпад од пакување и Законот за проширена одговорност на производителот за управување со посебни текови*, Скопје: Пакомак ДОО Скопје.

Министерство за животна средина и просторно планирање, (2022). План за спречување на создавање на отпад на Република Северна Македонија за периодот од 2022-2028 / Ministry of Environment and Physical Planning, (2022). Plan for Preventing Waste Generation in the Republic of North Macedonia for the period 2022-2028 available from: ПСЗО-2022-2028.pdf (moep.gov.mk) (Accessed Nov 15, 2023).

Pakomak (2023), Available from: https://pakomak.mk/Pages/Index/povratni_vending_masini?selectPage=info_za_vending_masini_2 (Accessed Nov 10, 2023).

Plastic Smart Cities (2023). Recycling Incentive Scheme. Available from: <https://plasticsmartcities.org/recycling-incentive-scheme/> . (Accessed Nov 4 , 2023).

Singh, A.S. & Masuku, M.B., (2014). Sampling Techniques & Determination of Sample Size in Applied Statistics Research: an Overview, *International Journal of Economics, Commerce and Management*, United Kingdom Vol. II, Issue 11, Nov 2014. Available from: <https://ijecm.co.uk/wp-content/uploads/2014/11/21131.pdf> (Accessed Nov 08, 2023). Timlett, R.E. & Williams, I.D. (2008). Public participation and recycling performance in England: A comparison of tools for behaviour change. *Resources, Conservation and Recycling*. 52(4) pp. 622-634. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0921344907001723> (Accessed Nov 11, 2023).

UNEP, (2015). Global Waste Management Outlook, United Nations Environment programme. Available from:

<https://www.unep.org/resources/report/global-waste-management-outlook>
(Accessed Nov 1, 2023).

Zamzam, R., Kusmawati, A., Ichsan I.Z., Puspitasari, P.R (2023). Zero Waste Knowledge and Behavior of Early Childhood Pre-Service Teacher in Science Education, *Jurnal Penelitian Pendidikan IPA Journal of Research in Science Education*. 9(12), pp. 10590-10595.

Zhang, D., Xiaoling Yin, G.H., and Gong, Q. (2015) Residents' Waste Separation Behaviors at the Source: Using SEM with the Theory of Planned Behavior in Guangzhou, China. *International Journal of Environmental Research and Public Health*, 12(8), pp.9475-9491.

HETEROGENEOUS AGENT (HA) MODELS AND TWO - ASSET HANK MODEL: REVIEW OF SOME COMPUTATIONAL MODELS

Dushko Josheski¹, Mico Apostolov²,

Abstract

These are Heterogeneous Agent HA models with continuum of agents in discrete and continuous time with aggregate uncertainty i.e. these are Krusell-Smith (1997) (1998) types of models. The two asset HANK (Heterogeneous Agent New Keynesian) model uses discrete cosine transform (DCT) technique and sequential equilibrium with recursive individual planning as a sequence of discretized Bellman equations. Some of the models are placed in a two-sector economy as Kiyotaki, Moore (1997) and one sector growth model studied by Huggett (1997). Huggett (1993) is a HACT (heterogeneous agent model in continuous time) model that describes solution for a simple continuous time heterogeneous agent economy. Some of the models are computed with MIT shock which is an unexpected shock that hits an economy at its steady state, leading to a transition path back towards the economy's steady state. Heterogeneous Agent New Keynesian (HANK) models are emerging as leading frameworks to study the impact of monetary and fiscal policy on the macroeconomy. Central idea of this paper is the notion that representative agent models were wrong turn for modern macroeconomics especially for general equilibrium model (some individuals are some are not liquidity constrained) and that central problems of

¹ Faculty of Tourism and Business Logistics, Goce Delcev University, Stip, North Macedonia; e-mail: dusko.josevski@ugd.edu.mk

² Faculty of Tourism and Business Logistics, Goce Delcev University, Stip, North Macedonia; e-mail mico.apostolov@ugd.edu.mk

macroeconomics cannot arise in representative agent models (debt, bankruptcy, asymmetric information). Results from models prove the importance of distributions of household income, wealth, savings decisions in order HA and HANK models to construct optimal monetary policy as opposed to RANK (Representative Agent New Keynesian) model “lean against the wind “ monetary policy response.

Keywords: HANK model, MIT shock, Huggett economy, sequential equilibrium

1. Introduction

Heterogeneity is pervasive in macroeconomic data, for instance households vary in their income, wealth, and consumption while firms vary in productivity, and investment, see Winberry (2018). The heterogeneity of agents is relevant, and it could provide answers for the welfare questions that are crucial in macroeconomics. In a way it is a critique of representative agents’ models³. Models with heterogenous agents (HA) have become dominant workhorse in macroeconomics since seminal works by: Bewley (1986), Hopenhayn (1992), Huggett (1993), Aiyagari (1994)⁴. Lucas (1987) showed that for standard preferences, aggregate fluctuations have a very small impact on the welfare of a representative consumer. Lucas (1987) estimates that magnitude of the costs of business cycles on total consumption to be remarkably small 0.1%. And this estimation is based on a assumption that of a perfect insurance of idiosyncratic risk. Lucas (1987) instigated growing literature and studies such as Imrohoroğlu (1989) was to “examine whether the magnitude of the costs of business cycles in economies with incomplete insurance differs significantly from the cost estimates found in an environment with perfect insurance”. A rapidly growing literature has

³ Arrow (1951) and Arrow, Debreu (1954), proved that competitive equilibrium in Arrow-Debreu economy is Pareto optimal and discovered class of convex Arrow-Debreu economies for which competitive equilibria always exist. In the case of incomplete, see Geanakoplos (1990) markets this equilibrium may (will) not be efficient see Geanakoplos (1986) or the will be suboptimal constrained.

⁴ More complete review of this literature could be read in Heathcote et al.(2009)

emerged which studies how this micro heterogeneity shapes⁵ our understanding of business cycle fluctuations, see (Auclert (2017), Berger and Vavra (2015), Kaplan, Moll and Violante (2016), and on the firm side: Bachmann, Caballero and Engel (2013), Clementi and Palazzo (2016), Ottonello and Winberry (2017)). Although a neoclassical synthesis dominated quantitative macroeconomics for many decades, heterogeneous agent models were always present and taken seriously as early as the multiple class models of Kalecki (2016) that emphasized heterogeneous marginal propensities to consume and their implications for fiscal policy. Important components of Friedman (1956) were his empirical and theoretical analyses of differences in marginal propensities to consume across classes of consumers who faced stochastic processes of non-financial income with different mixtures of permanent and temporary components, see Sargent (2023). The DSGE (Dynamic stochastic general equilibrium) model proposed by Christiano, Eichenbaum, and Evans (2005) and later estimated by Smets and Wouters (2003) using Bayesian techniques, is currently considered to be a benchmark richly specified DSGE model for a closed economy, see Kolasa et al. (2012). These models may be called Friedmanite DSGE models, since they assume that monetary policy has no effect on real variables such as: output and real interest rate in the long run. But due to sticky prices and wages, monetary policy matters in the short run. The name HANK model was coined by Kaplan et al. (2018). They developed HANK model on the household side with Aiyagari-Huggett-Imrohoroglu incomplete market model, with one important modification: as in Kaplan, Violante (2014), households can save in two assets, a low-return liquid asset and a high-return illiquid asset that is subject to a transaction cost. The most important lesson we have learned from HANK models is about the transmission mechanism of monetary policy. If we start from canonical representative agent model, there, a cut in the nominal rate induces a rise in consumption expenditures through intertemporal substitution through the aggregate Euler equation. Such rise in expenditures, in turn, leads to an expansion in the demand for labor and, because of nominal rigidities, to an additional round of increase in

⁵ Models of heterogeneous agents have become widespread in macroeconomics, at least since [Krusell and Smith \(1997\)](#), [Krusell and Smith \(1998\)](#) developed the first widely applicable algorithm to solve them in an environment of aggregate risk.

expenditures. The size of these indirect general equilibrium effects linked to the Keynesian multiplier are proportional to the magnitude of the aggregate marginal propensity to consume which, in RANK models, is tiny (equal to the discount rate), see Violante (2021)⁶. From the RANK prospect in order to understand the impact of a change in the policy rate on aggregate consumption, all CB needs are two ingredients: expected inflation to convert the nominal rate under control into the real one, and the aggregate intertemporal elasticity of substitution which measures the sensitivity of aggregate consumption to the real rate. From the HANK perspective in order to estimate the aggregate consumption response, one needs a full picture of the joint distribution of marginal propensities to consume, income composition, and the various elements of household balance sheets. In general, households are unequally exposed to aggregate shocks. In HANK models, this heterogeneous sensitivity is a source of amplification of shocks to the extent that income is redistributed from low MPC to high MPC households ((Auclert, 2017); (Bilbiie, 2020), (Patterson, 2021), Slacalek, Tristani, Violante (2020)). The importance of indirect equilibrium channels means that the transmission of monetary policy is crucially mediated by all those mechanisms that contribute to price formation in goods, inputs, credit, housing and financial markets. It is then essential for a central bank to have a deep comprehension of market structure, market frictions as well as of those institutions, see Violante (2020). Household heterogeneity and market incompleteness also alter the strength of their propagation through the macroeconomy⁷. CGE models were also suffering critique for their reliance

⁶ Thus, somewhat paradoxically, the channel by which monetary policy affects aggregate output in the standard New Keynesian model differs markedly from the ideas typically associated with John Maynard Keynes i.e. the equilibrium spending multiplier see [Keynes \(1936\)](#). Most undergraduate macroeconomics textbooks argue that the multiplier effect of government purchases is larger than that of transfers, see [Keynes \(1936\)](#), [Mankiw \(2006\)](#). In the standard Keynesian framework, government spending on useless public works has a larger multiplier effect than spending on government transfer payments does, see [Ono, Y. \(2011\)](#).

⁷ First, through redistribution channel: exposure to aggregate fluctuations is highest at the extremes of the distribution, second in HANK models, this precautionary saving channel amplifies the negative aggregate shock because the cut in expenditures to build the additional buffer stock of saving piles up onto the initial reduction of aggregate demand, see [Acharya and Dogra \(2020\)](#). And the fiscal policy channel. When the monetary authority cuts

of “representative agent” and aggregation procedures. If the representative agents’ model is estimated with data from heterogeneous agents’ economy under different policy regimes important parameters vary considerably. For instance, the aggregate labor supply elasticity, which was/is often recognized as a crucial parameter for fiscal policy analysis, depends on cross-sectional distribution of reservation wages, which distribution is in turn a function of fiscal policy regime, see Auerbach, Kotlikof (1987); and Judd (1987); Prescott (2004), and Chang, Kim, Schorfheide (2013). As per Bernanke (2015), monetary policy is a blunt tool which certainly affects the distribution of income and wealth, although whether its net effect is to increase or reduce inequality is not clear, see Violante (2020). HANK models are useful because they offer a structure to shed light on the interplay between stabilization and redistribution. For instance, in case of positive mark-up shock HANK models propose rise in the nominal rate to cut aggregate demand and tame inflation. An increase in mark-ups reduces the labor share in favor of the owners of capital. A rise in the policy rate which stifles aggregate demand would further hurt workers. HANK model in such a case prescribes opposite i.e. toward a cut in the nominal rate in order to foster the aggregate demand for labor and redistribute income back to workers. This paper will review and solve following HA-DSGE models: Winberry (2018), Huggett (1997), Huggett (1993), Kiyotaki and Moore (1997), and Two-asset HANK model: Bayer, Lueticke (2020). Last model uses sequential equilibrium by Reiter (2002). These models will be solved in MATLAB or Python programming languages.

the interest rate, borrowers gain. Governments are net borrowers and, as a result, they have extra resources in their budget. The extent of this inflow depends largely on the maturity structure of debt and on how rates at other horizons respond to a change in the short rate, see [Auclert, Rognlie and Straub, \(2020\)](#). The magnitude of fiscal policy effect depends on the cross-sectional covariance between the change in income and the marginal propensity to consume.

2. Toolbox for Solving and Estimating Heterogeneous Agent Macro Models Winberry (2018)

Firms $j \in [0, 1]$ produce output y_{jt} according to production function:

$$y_{jt} = e^{z_t} e^{\varepsilon_{jt}} k_{jt}^{\theta} n_{jt}^{\nu}; \theta + \nu < 1 \quad (1)$$

Where in previous z_t is an aggregate productivity shock, ε_{jt} is an idiosyncratic productivity shock, k_{jt} is capital, n_{jt} is labor, θ is the elasticity of output with respect to capital, and ν with respect to labor. Aggregate productivity shock is same for all firms and follows AR(1) process:

$$z_{t+1} = \rho_z z_t + \sigma_z \omega_{t+1}^z; \omega_{t+1}^z \sim \mathcal{N}(0, 1) \quad (2)$$

Gross investment i_{jt} yields:

$$k_{jt+1} = (1 - \delta)k_{jt} + i_{jt}, \wedge \frac{i_{jt}}{k_{jt}} \notin [-a, a] \quad (3)$$

Where parameter a is around zero investment within which firms do not incur fixed costs but if $\frac{i_{jt}}{k_{jt}} \notin [-a, a]$ the firms must pay fixed adjustment costs⁸ ξ_{jt} in units of labor. Households do have utility function:

$$\mathbb{E} \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t^{1-\sigma} - 1}{1-\sigma} - \chi \frac{N_t^{1+\alpha}}{1+\alpha} \right] \quad (4)$$

Where β is a discount factor, σ is relative risk aversion parameter, N_t is labor supply, χ is disutility of labor supply, and α is the Frisch elasticity of labor supply⁹. Alternatively :

⁸ A common model assumption used by economists to explain this 'lumpy' firm behaviour is that adjustment comes with a fixed cost; a cost that does not depend on the size of the change, but must be paid for any level of adjustment, however small.

$$u(c_t(j), h_t(j)) = \frac{c_t(j)^{1-\sigma^c}}{1-\sigma^c} \cdot \frac{h_t(j)^{1+\frac{1}{\sigma^L}}}{1+\frac{1}{\sigma^L}} \quad (5)$$

Where σ^c is the risk aversion, and σ^L is the Frisch elasticity of labor supply. $u(\cdot)$ represents the utility increasing from consumption $c_t(j)$, and decreasing from hours worked $h_t(j)$. Welfare is the sum of current and expected utilities: $w_t(j) = \sum_{\tau=0}^{+\infty} \beta^\tau u(c_{t+\tau}(j), h_{t+\tau}(j))$. Following Khan, A., Thomas, J. K. (2008), implications of household optimizations are incorporated into the firm's optimization problem by approximating the transformed value function:

$$\hat{v}(\varepsilon, k; s) = \lambda(s) \max_n \{ e^z e^\varepsilon k^\theta n^v - w(s)n \} + E_\xi [\max \{ v^a(\varepsilon, k; s) - \xi \lambda(s) w(s), v^n(\varepsilon, k, s) \}] \quad (6)$$

Where s is the state vector and $\lambda(s) = C(s)^{-\sigma}$ is the marginal utility of consumption in equilibrium and also:

$$v^a(\varepsilon, k, s) = \max_{k' \in \mathbb{R}} -\lambda(s)(k' - (1 - \delta)k) + \beta E[\hat{v}(\varepsilon', k'; s'(z'; s)|\varepsilon)]$$

$$v^n(\varepsilon, k, s) = \max_{k' \in [(1-\delta-\alpha)k, (1-\delta+\alpha)k]} -\lambda(s)(k' - (1 - \delta)k) + \beta E[\hat{v}(\varepsilon', k'; s'(z'; s)|\varepsilon, k, s)] \quad (7)$$

unconstrained capital choice is $k^a(\varepsilon, k, s)$ and constrained is $k^n(\varepsilon, k, s)$, firms will pay fixed costs if $v^a(\varepsilon, k, s) - \xi \lambda(s) w(s) \geq v^n(\varepsilon, k, s)$, there is a unique threshold between these two options:

$$\tilde{\xi}(\varepsilon, k, s) = \frac{v^a(\varepsilon, k, s) - v^n(\varepsilon, k, s)}{\lambda(s) w(s)} \quad (8)$$

Where $\hat{\xi}(\varepsilon, k, s)$ is the threshold with a bounded support: $\hat{\xi}(\varepsilon, k, s) = \min[\max\{0, \tilde{\xi}(\varepsilon, k, s), \bar{\xi}\}]$. As for the equilibrium:

Definition 1: A recursive competitive equilibrium for the model is a set $\hat{v}(\varepsilon, k, s), n(\varepsilon, k, s), k^a(\varepsilon, k, s); \hat{\xi}(\varepsilon, k, s), \lambda(s), w(s); s'(z'; s) = (z'; \mu'(z\mu))$ such that :

- i. Firm optimization takes $\lambda(s), w(s); s'(z'; s)$ as given
- $\hat{v}(\varepsilon, k, s), n(\varepsilon, k, s), k^a(\varepsilon, k, s), k^n(\varepsilon, k, s); \hat{\xi}(\varepsilon, k, s)$ to solve optimization

⁹ The Frisch elasticity measures the relative change of working hours to a one-percent increase in real wage, given the marginal utility of wealth λ . In the steady-state benchmark model is given as: $\frac{dh/h}{dw/w} = \frac{1-h}{h} \left(\frac{1-\eta}{\eta} \theta - 1 \right)^{-1}$

problem

$$\begin{aligned} \hat{v}(\varepsilon, k, s) &= \lambda(s) \max_n \{ e^z e^\varepsilon k^\theta n^v - w(s)n \} + E_\xi [\max \{ v^a(\varepsilon, k, s) - \\ &\xi \lambda(s) w(s), v^n(\varepsilon, k, s) \}] \\ \text{and } \tilde{\xi}(\varepsilon, k, s) &= \frac{v^a(\varepsilon, k, s) - v^n(\varepsilon, k, s)}{\lambda(s) w(s)}. \end{aligned}$$

ii. Household optimization $\lambda(s) = C(s)^{-\sigma}$

$$\begin{aligned} ; C(s) &= \int \left[e^z e^\varepsilon k^\theta n(\varepsilon, k, s)^v + (1 - \delta)k - \left(\frac{\tilde{\xi}(\varepsilon, k, s)}{\bar{\xi}} \right) k^a(\varepsilon, k, s) - \right. \\ &\left. \left(1 - \frac{\tilde{\xi}(\varepsilon, k, s)}{\bar{\xi}} \right) k^n(\varepsilon, k, s) \right] d\mu(\varepsilon, k) \\ \text{and } \int \left(n(\varepsilon, k, s) + \frac{\tilde{\xi}(\varepsilon, k, s)^2}{2\bar{\xi}} \right) d\mu(\varepsilon, k) &= \left(\frac{w(s)\lambda(s)}{\chi} \right)^{\frac{1}{\alpha}} \end{aligned}$$

iii. Law of motion for all feasible sets

$$\begin{aligned} \Delta_\varepsilon; \Delta_k \text{ is} \\ \mu'(z, \mu)(\Delta_\varepsilon \times \Delta_k) &= \int \int p(\rho_\varepsilon \varepsilon + \sigma_\varepsilon \omega^\varepsilon \in \Delta_\varepsilon) d\omega^\varepsilon \times \left[\frac{\tilde{\xi}(\varepsilon, k, s)}{\bar{\xi}} \right] \{ k^a(\varepsilon, k, s) \in \\ \Delta_k \} &+ \left(1 - \frac{\tilde{\xi}(\varepsilon, k, s)}{\bar{\xi}} \right) \{ k^n(\varepsilon, k, s) \in \Delta_k \} d\mu(\varepsilon, k) \end{aligned}$$

iv. Law of motion for aggregate shocks is

$$z' = \rho_z z + \omega'_z; \omega'_z \sim \mathcal{N}(0, \sigma_z)$$

The PDF of the distribution of firms is given as:

$$g(\varepsilon, k) \cong g_0 \exp \left\{ g_1^1 (\varepsilon - m_1^1) + g_1^2 (k - m_1^2) + \sum_{i=2}^{n_g} \sum_{j=0}^i g_i^j [(\varepsilon - m_1^1)^{i-j} (k - m_1^2) - m_i^j] \right\} \quad (9)$$

Previous is following Algan et al. (2008) and n_g indexes the degree of approximation and $g_0, g_1^1, g_1^2; \{g_i^j\}_{i,j=2,0}^{n_g,i}$ are parameters and $m_1^1, m_1^2; \{m_i^j\}_{i,j=2,0}^{n_g,i}$ are centralized moments of distribution. And the moments¹⁰ are implied by the parameters :

¹⁰Normalization is done by

$$g(\varepsilon, k) \cong g_0 \exp \left\{ g_1^1 (\varepsilon - m_1^1) + g_1^2 (k - m_1^2) + \sum_{i=2}^{n_g} \sum_{j=0}^i g_i^j [(\varepsilon - m_1^1)^{i-j} (k - m_1^2) - m_i^j] \right\} = 1$$

$$\begin{aligned}
 m_1^1 &= \int \int \varepsilon g(\varepsilon, k) d\varepsilon dk \\
 m_1^2 &= \int \int k g(\varepsilon, k) d\varepsilon dk \\
 m_i^j &= \int \int (i-j)^{i-j} (k - m_1^2)^j g(\varepsilon, k) d\varepsilon dk ; i = 2, \dots, n_g, j = 0, \dots, i
 \end{aligned}
 \tag{10}$$

Firms value function is given as:

$$v(\varepsilon, k, z, m) \cong \sum_{i=1}^{n_\varepsilon} \sum_{j=1}^{n_k} \theta_{ij}(z, m) T_i(\varepsilon) T_j(k) \tag{11}$$

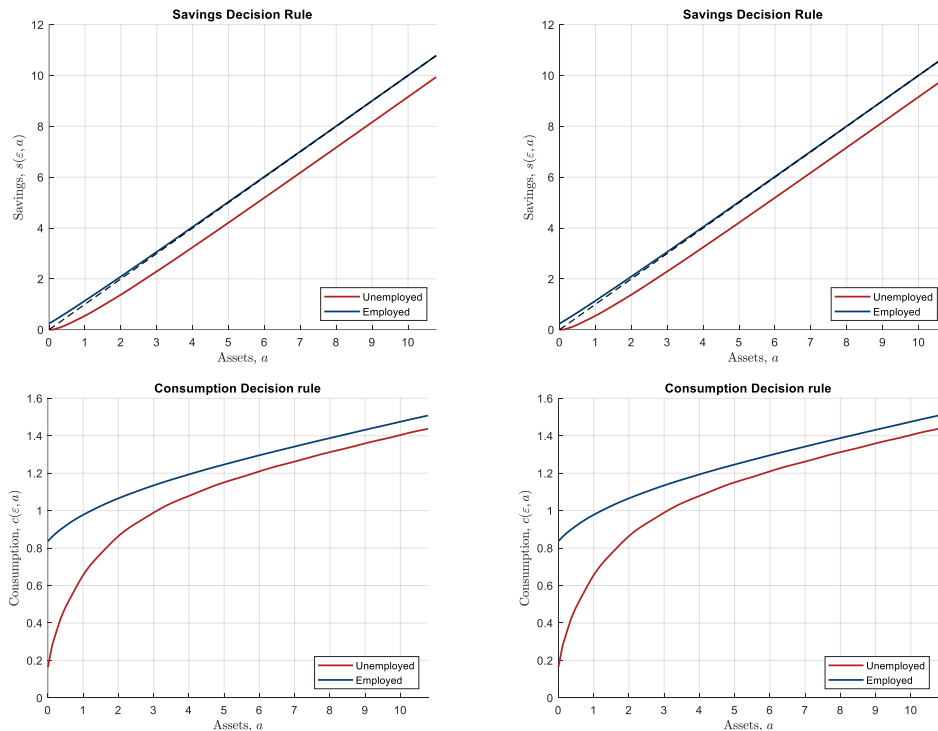
Where $T_i(\varepsilon), T_j(k)$ are Chebyshev polynomials. Chebyshev nodes can be computed as: $x_t = \cos\left[\frac{\pi(t-1)}{T}\right], t = 1, \dots, T$. The points $\{v_t\}_t^T = \mathbf{1}$ are found via transformation like this: $v_t = \frac{\bar{b} + \omega_L + (\bar{b} - \omega_L)x_t}{2}$. Chebyshev polynomials can be defined recursively as $T_0(x) = 1, T_1(x) = x, T_{n+1}(x) = 2xT_n(x) + T_{n-1}(x)$. The coefficients of these polynomials for a function $f(x)$ can be obtained by the following integral: $a_n = \frac{2}{\pi} \int_{-1}^1 \frac{f(x)T_n(x)}{(1-x^2)^{\frac{1}{2}}} dx$. Hubbard, Kirkegaard and Paarsch imposed 5 in/equality constraints on the equilibrium bid functions¹¹, that are approximated by the Chebyshev polynomials of order K (Hubbard, Kirkegaard et al. 2013). Bellman equation for this problem is given as:

$$\begin{aligned}
 \hat{v}(\varepsilon, k_j; z, m) &= \lambda(z, m) \max_n \{ e^z e^\varepsilon k^\theta n^v - w(z, m)n \} + \lambda(z, m)(1 - \delta)k + \\
 &\left(\frac{\hat{\xi}(\varepsilon_i, k_j, z, m)}{\xi} \right) \\
 &\left(\begin{aligned} & -\lambda(z, m)k^\alpha(\varepsilon_i, k_j, z, m) - w(z, m) \frac{\hat{\xi}(\varepsilon_i, k_j, z, m)}{2} \\ & + \beta E_{(z'|z)} \left[\int \hat{v}(\rho_\varepsilon \varepsilon_i + \sigma_\varepsilon \omega'_\varepsilon k^\alpha(\varepsilon_i, k_j, z, m); z', m'(z, m)) p(\omega'_\varepsilon) d\omega'_\varepsilon \right] \end{aligned} \right) \\
 &(1 - \\
 &\frac{\xi(\varepsilon_i, k_j, z, m)}{\xi}) \left(\begin{aligned} & -\lambda(z, m)k^n(\varepsilon_i, k_j, z, m) \\ & + \beta E_{(z'|z)} \left[\int \hat{v}(\rho_\varepsilon \varepsilon_i + \sigma_\varepsilon \omega'_\varepsilon k^n(\varepsilon_i, k_j, z, m); z', m'(z, m)) p(\omega'_\varepsilon) d\omega'_\varepsilon \right] \end{aligned} \right)
 \end{aligned}
 \tag{12}$$

¹¹ 1. $\varphi_n(v) = \omega_L$,2. $\varphi_n(\bar{b}) = \omega_H$ 3. $\sum_{m \neq n} (\bar{b} - \bar{v}) f_m(\bar{b}) \varphi'_m(v) = 1$,4. $\varphi(\omega_L) = \frac{N-1}{N}$,5. $\varphi_n(v_j - 1) \leq \varphi_n(v_j)$, for some uniform array $j = 2, \dots, J$.

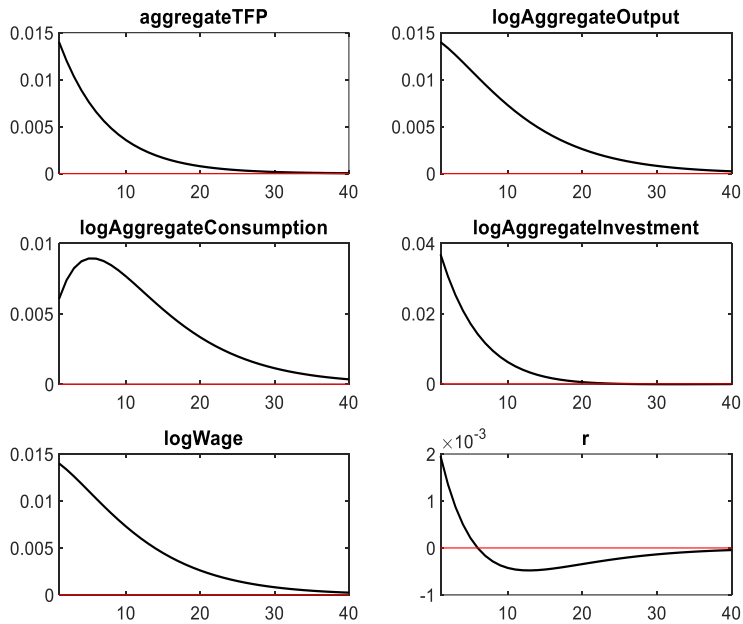
Parametrization follows A.,Thomas, J. K. (2008) and : $\beta = 0.96$ (discount factor), $\sigma = 1$ (utility curvature), $\alpha = \lim \alpha \rightarrow 0$ (inverse Frisch), χ (labor disutility) $\chi = \frac{1}{3}N$, $v = 0.64$ (labor share), $\theta = 0.256$ (capital share), $\delta = 0.085$ (capital depreciation), $\rho_z = 0.859$ (Aggregate TFP AR(1)), $\sigma_z = 0.859$ (Aggregate TFP AR(1)), $\bar{\xi} = 0.083$ (fixed cost), $a = 0.011$ (no fixed cost region), $\rho_\varepsilon = 0.859$ (Idiosyncratic TFP AR(1)), $\sigma_\varepsilon = 0.859$ (Idiosyncratic TFP AR(1)).Next follows computation results of previous model.

Figure 1. Computes and analyzes steady state with no aggregate shocks.



Source: Authors own calculations based on a code available at: <https://github.com/JohannesPfeifer/winberryAlgorithmCodes>

Figure 2 first order approximation of aggregate dynamics



*Source: Authors own calculations based on a code available at:
<https://github.com/JohannesPfeifer/winberryAlgorithmCodes>*

3. G(Global)DSGE: A Toolbox for Solving DSGE Models with Global Methods: Steady States and Transition Paths in Heterogeneous Agent Models as per Huggett (1997)

This model draws on a seminal work by Huggett (1997). This model is included in GDSGE toolbox that solves non-linear Dynamic Stochastic General Equilibrium (DSGE) models with a global method based on the Simultaneous Transition and Policy Function Iteration (STPFI) algorithm

introduced in Cao, Luo, and Nie (2023). Decision problem is characterized by and Euler equation:

$$u'(c_t) = \beta \mathbb{E}_t[(1 + r_{t+1})u'(c_{t+1})] + \lambda_t \quad (13)$$

Where λ_t is Lagrange multiplier on the borrowing constraint, and the complementary-slackness condition, $\lambda_t k_{t+1} = \mathbf{0}$ with state transition functions. For the one sector growth model studied by Huggett (1997), steady state equilibrium object is aggregate capital stock and the transition path aggregate equilibrium object is the time sequence of the aggregate capital stock. Now about Euler equation here.

3.1 Euler equation

Here following lemma applies (see Achdou et al., 2022)

Lemma 2: The consumption and savings policy functions $c_j(\mathbf{a})$ and $s_j(\mathbf{a})$ for $j = 1, 2..$ corresponding to HJB equation : $\rho v_j(\mathbf{a}) = \max_c u(c) + v'_j(\mathbf{a})(y_j + r\mathbf{a} - c) + \lambda_j (v_{-j}(\mathbf{a}) - v_j(\mathbf{a}))$ which is maximized at : $\mathbf{0} = -\frac{d}{da} [s_j(\mathbf{a})g_j(\mathbf{a})] - \lambda_j g_j(\mathbf{a}) + \lambda_{-j}g_{-j}(\mathbf{a})$ is given as:

$$\begin{aligned} (\rho - r)u'(c_j(\mathbf{a})) &= u''(c_j(\mathbf{a}))c'_j(\mathbf{a})s_j(\mathbf{a}) + \lambda_j(u'(c_{-j}(\mathbf{a})) - u'(c_j(\mathbf{a}))) \\ s_j(\mathbf{a}) &= y_j + r\mathbf{a} - c_j(\mathbf{a}) \end{aligned}$$

(14)

Proof:

differentiate $\rho v_j(\mathbf{a}) = \max_c u(c) + v'_j(\mathbf{a})(y_j + r\mathbf{a} - c) + \lambda_j (v_{-j}(\mathbf{a}) - v_j(\mathbf{a}))$ with respect to \mathbf{a} and use that $v'_j(\mathbf{a}) = u'(c_j(\mathbf{a}))$ and hence $v''_j(\mathbf{a}) = u''(c_j(\mathbf{a}))c'_j(\mathbf{a})$ ■

The differential equation:

$$\begin{aligned} (\rho - r)u'(c_j(\mathbf{a})) &= u''(c_j(\mathbf{a}))c'_j(\mathbf{a})s_j(\mathbf{a}) + \lambda_j(u'(c_{-j}(\mathbf{a})) - u'(c_j(\mathbf{a}))) \\ s_j(\mathbf{a}) &= y_j + r\mathbf{a} - c_j(\mathbf{a}) \end{aligned}$$

is and Euler equation, the right hand side $(\rho - r)u'(c_j(\mathbf{a}))$ is expected change of marginal utility of consumption $\frac{\mathbb{E}_t[du'(c_j(a_t))]}{dt}$. This uses Ito's formula to Poisson process:

$$\mathbb{E}_t[du'(c_j(a_t))] = \left[u''(c_j(a_t))c'_j(a_t)s_j(a_t) + \lambda_j \left(u'(c_{-j}(a_t)) - u'(c_j(a_t)) \right) \right] dt \quad (15)$$

So, this equation

$$(\rho - r)u'(c_j(a)) = u''(c_j(a))c'_j(a)s_j(a) + \lambda_j(u'(c_{-j}(a)) - u'(c_j(a)))$$

$$s_j(a) = y_j + ra - c_j(a)$$

can be written in more standard form:

$$\frac{\mathbb{E}_t[du'(c_j(a_t))]}{dt} = (\rho - r)dt \quad (16)$$

Generalized Euler equations when W is defined recursively $W_{t+1} = R(W_t - c_t)$ previously we should define that $\sum_{t=1}^{\infty} R^{-t+1}c_t \leq W_1$ and gross interest rate $R = r + 1$; are given in the following form:

$$u'(c_t) = R \left[\beta \delta \left(\frac{\partial c_{t+1}(W_{t+1})}{\partial W_{t+1}} \right) + \delta \left(1 - \frac{\partial c_{t+1}(W_{t+1})}{\partial W_{t+1}} \right) \right] u'(c_{t+1}) \quad (17)$$

Where $\left[\beta \delta \left(\frac{\partial c_{t+1}(W_{t+1})}{\partial W_{t+1}} \right) + \delta \left(1 - \frac{\partial c_{t+1}(W_{t+1})}{\partial W_{t+1}} \right) \right]$ is the effective discount factor, also $c_{t+1}(W_{t+1})$ represents the optimal consumption choice. With uncertainty Euler equation will become:

$$u'(c_t) = \beta R \widehat{E} [u'(c_{t+1}) | I_t]$$

Where $\widehat{E} [u'(c_{t+1}) | I_t]$ represents the agents, expectation given the information set I_t . Now, taking 2nd order approx. to marginal utility in $t + 1$ around c_t gives:

$$\widehat{E} \left[\frac{c_{t+1} - c_t}{c_t} | I_t \right] = \sigma_t (1 - (\beta R)^{-1}) + \frac{1}{2} \phi_t \widehat{E} [(c_{t+1} - c_t)^2 | I_t] \quad (18)$$

Where $\phi_t = -\frac{c_t u'''(c_t)}{u''(c_t)}$ is a coefficient of relative prudence (see Dynan (1991), expected consumption growth that rises with the real interest rate and falls with impatience. In continuous time previous would be:

$$\frac{\dot{c}_t}{c_t} = \sigma_t (r - \rho) \quad (19)$$

Where $\sigma_t = -\frac{u'(c_t)}{c_t u''(c_t)}$; and $c_{t+\Delta t} = c_t + \Delta c_t$, $\beta = 1 - \rho \Delta t$; $\Delta t \rightarrow 0$. Now, let's consider that $\varepsilon_{t+1} = u'(c_{t+1}) - (\beta R)^{-1} u'(c_t)$ as in Hall (1978). It was pointed by Hall (1978) that this equation $u'(c_t) = \beta R \widehat{E} [u'(c_{t+1}) | I_t]$ implies that $\widehat{E} [\varepsilon_{t+1} z_t | I_t] = z_t \widehat{E} [\varepsilon_{t+1} | I_t]$ for any $z_t \in I_t$.

3.2 Back to Huggett (1997): sequential equilibrium

This sequence is sequential equilibrium: $c_t(k, e), \lambda_t(k, e), k'_t(k, e)$

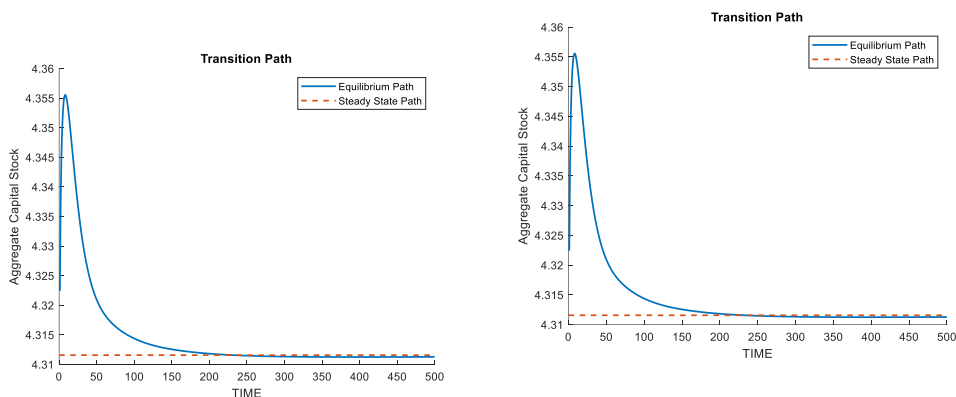
$$\begin{aligned} c_t(k, e)^{-\sigma} &= \beta(1 + r_{t+1})E[c_{t+1}(k'_t(k, e), e')^{-\sigma}|e] + \lambda(k, e) \\ k'_t(k, e)\lambda_t(k, e) &= \mathbf{0}, \lambda_t(k, e) \geq \mathbf{0}; k'_t(k, e) \geq \mathbf{0} \\ c_t(k, e) + k'_t(k, e) &= k(1 + r_t) + w_t e \end{aligned} \tag{20}$$

Market clearing conditions are:

$$\begin{aligned} r_t &= \alpha k_t^{\alpha-1} - \delta \\ w_t &= (1 - \alpha)K_t^\alpha \\ K_t &= \int k\phi_t(dk, de) \end{aligned} \tag{21}$$

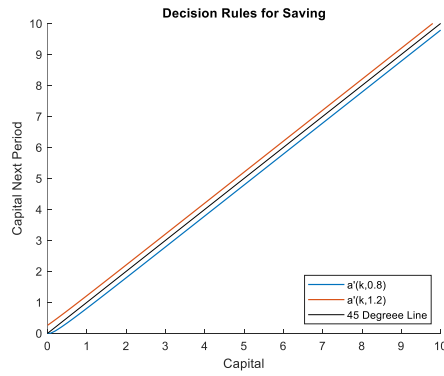
ϕ_t are consistent with the transitions implied by policy functions and exogenous shocks¹². The first feature of this model is that there is a continuum of agents in the economy experiencing idiosyncratic labor endowment shocks. The endowment uncertainty is such that there is uncertainty for individual agents but no uncertainty over the aggregate labor endowment. Next on three plots we will presents the results for this model.

Figure 3 Huggett model transition path Figure 4 Transition path Huggett model (GDSGE)



¹² A steady-state equilibrium is a sequential equilibrium with time-invariant equilibrium objects.

Figure 5 Huggett model savings decision



4. Huggett (1993) economy and credit crunch in Huggett economy per (Gustavo Mellior)

As in Achdou et al.(2022), two functions v_1, v_2 at I discrete points in the space dimension a_i , $i = 1, \dots, I$. Equispaced grids are denoted by Δa_i as the distance by the grid points, and shot hand notation used is $v_{i,j} \equiv v_j(a_i)$ and so on. Backward difference approximation is given as:

$$\begin{cases} v'_j(a_i) \approx \frac{v_{i+1,j} - v_{i,j}}{\Delta a} \equiv v'_{i,j,F} \\ v'_j(a_i) \approx \frac{v_{i+1,j} - v_{i-1,j}}{\Delta a} \equiv v'_{i,j,B} \end{cases} \quad (22)$$

Two basic equations to explain Huggett economy are :

$$\begin{cases} \rho v_1(a) = \max_c u(c) + v'_1(a)(z_1 + ra - c) + \lambda_1(v_2(a) - v_1(a)) \\ \rho v_2(a) = \max_c u(c) + v'_2(a)(z_2 + ra - c) + \lambda_2(v_1(a) - v_2(a)) \end{cases} \quad (23)$$

Where $\rho \geq 0$ represents the discount factor for the future consumption c_t (Individuals have standard preferences over utility flows), a represents wealth in form of bonds that evolve according to : $\dot{a} = y_t + r_t a_t - c_t$ where

y_t is the income of individual, which is endowment of economy's final good, and r_t represents the interest rate. Equilibrium in this Huggett (1993) economy is given as:

$$\int_{\underline{a}}^{\infty} a g_1(a, t) da + \int_{\underline{a}}^{\infty} a g_2(a, t) da = B \quad (24)$$

Where in previous expression $0 \leq B \leq \infty$ and when $B = 0$ that means that bonds are zero net supply. So the finite difference method approx. to

$$\left(\begin{array}{l} \rho v_1(a) = \max_c u(c) + v'_1(a)(z_1 + ra - c) + \lambda_1(v_2(a) - v_1(a)) \\ \rho v_2(a) = \max_c u(c) + v'_2(a)(z_2 + ra - c) + \lambda_2(v_1(a) - v_2(a)) \end{array} \right)$$
 is given as:

$$\begin{aligned} \rho v_{i,j} &= u(c_{i,j}) + v'_{i,j}(z_j + ra_i + c_{i,j}) + \lambda_j(v_{i,-j} - v_{i,j}), j = 1, 2 \\ c_{i,j} &= (u')^{-1}(v'_{i,j}) \end{aligned} \quad (25)$$

Here will be presented two main approaches for solving Huggett (1993) model and problem numerically. This part is based on : Rouwenhorst (1995) and also in Kopecky ,Suen (2010).Now, e_t is a two-state Markov process $e_t \in \{e_l, e_h\}$ and that transition probabilities are given as following:

$$\Gamma = \begin{bmatrix} \gamma & 1 - \gamma \\ 1 - \gamma & \gamma \end{bmatrix} \quad (26)$$

Where in previous autocorrelation is given as: $2\gamma - 1$. Now about the two-state Euler equation process:

1. In the low earnings state:

$$\begin{aligned} (e_l + ra - h(a, e_l))^{-\sigma} &= \beta r \{ \gamma [e_l + rh(a, e_l) - h(h(a, e_l), e_l)]^{-\sigma} + \\ & (1 - \gamma) [e_h + rh(a, e_l) - h(h(a, e_l), e_h)]^{-\sigma} \} \end{aligned} \quad (27)$$

2. In the high earning state:

$$\begin{aligned} (e_h + ra - h(a, e_h))^{-\sigma} &= \beta r \{ \gamma [e_h + rh(a, e_h) - h(h(a, e_h), e_h)]^{-\sigma} + \\ & (1 - \gamma) [e_l + rh(a, e_h) - h(h(a, e_h), e_l)]^{-\sigma} \} \end{aligned} \quad (28)$$

With exogenous grid savings function is approximated as:

$$[e_l + r a_k - y]^{-\sigma} = \beta r \left\{ \gamma [e_l + r y - \hat{h}(y, \theta^{l,0})]^{-\sigma} + (1 - \gamma) [e_h + r y - \hat{h}(y, \theta^{h,0})] \right\} \quad (29)$$

Where in previous: $\theta^0 = [\theta^{l,0}, \theta^{h,0}]$ these are vectors, and $\hat{h}(a^k, \theta) = \theta_k, \forall k$ and $\theta^l, \theta^h \in \mathbb{R}^N$. This MATLAB code and its algorithm explanation are due to Gustavo Mellior (Kent Uni.2016) and those files can be found at Benjamin Moll web site: <https://benjaminmoll.com/codes/>¹³. To solve for y we have:

$$y = \frac{a^m f_k^l(a^{m+1}, \theta^0) - a^{m+1} f_k^l(a^m, \theta^0)}{f_k^l(a^{m+1}, \theta^0) - f_k^l(a^m, \theta^0)} \quad (30)$$

Now:

$$f_k^l(y, \theta^0) = [e^l + r a - y]^{-\sigma} = \beta r \left\{ \gamma [e^l + r y - \hat{h}(y; \theta^{l,0})]^{-\sigma} + (1 - \gamma) [e_h + r y - \hat{h}(y, \theta^{h,0})]^{-\sigma} \right\} \quad (31)$$

Where $f_k^l(y, \theta^0)$ is the FOC function at $a = a^k; e = e^l$. With the method of endogenous grid we have:

$$a = \frac{[A^l(y, \theta^0)]^{-\frac{1}{\sigma} - e^l + y}}{r} \quad (32)$$

Savings grid is $y = \{y^1, y^2, \dots, y^n\}$ and $y^1 = \underline{a}; y^n = \bar{a}$. We can define here:

$$A^l(y; \theta^0) = \beta r \left\{ \gamma [e^l + r y - \hat{h}(y; \theta^{l,0})]^{-\sigma} + (1 - \gamma) [e_h + r y - \hat{h}(y, \theta^{h,0})]^{-\sigma} \right\} = 0 \quad (33)$$

¹³ In [Bernanke et al.\(1991\)](#) credit crunch is defined as:“..We define a bank credit crunch as a significant leftward shift in the supply curve for bank loans, holding constant both the safe real interest rate and the quality of potential borrower..”A credit crunch (credit squeeze, credit tightening; credit crisis) is a sudden reduction in the general availability of loans or a sudden tightening of the conditions required to obtain a loan from banks. A credit crunch generally involves a reduction in the availability of credit independent of a rise in official interest rates.

And for $A^l(y; \theta^0)$ we have:

$$A^h(y; \theta^0) = \beta r \left\{ \gamma [e^h + ry - \hat{h}(y; \theta^{h,0})]^{-\sigma} + (1 - \gamma) [e_l + ry - \hat{h}(y, \theta^{l,0})]^{-\sigma} \right\} = \mathbf{0} \quad (34)$$

Now, the density function can be discretized:

$$\begin{aligned} f_{i,j}^1 &= f_{i,j}^1 + \pi(\lambda^j | \lambda^k) \frac{a_{i+1} - h(a_l, \lambda^k)}{a_{i+1} - a^i} f_{l,k}^0 \\ f_{i+1,j}^1 &= f_{i+1,j}^1 + \pi(\lambda^j | \lambda^k) \frac{h(a_l, \lambda^k) - a^i}{a_{i+1} - a^i} f_{l,k}^0 \\ \sum_{i=1}^n \sum_{j=1}^m f_{i,j}^1 &= \mathbf{1} \end{aligned} \quad (35)$$

Economy is described in the text as before, and when credit crunch occurs a household with assets \underline{a}_{t_0} will find itself below the new borrowing limit, and it will reduce consumption by Δa and it moves closer to \underline{a}_T . And in this example $\underline{a}_{t_0} + 3\Delta a = \underline{a}_T$

$$\begin{aligned} \Delta a &= s_1(\underline{a}_{t_0}) = z_1 + r(\underline{a}_T - 3\Delta a) - c_1(\underline{a}_{t_0}); \\ \Delta a &= s_1(\underline{a}_{t_0} + \Delta a) = z_1 + r(\underline{a}_T - 2\Delta a) - c_1(\underline{a}_{t_0} + \Delta a); \\ \Delta a &= s_1(\underline{a}_{t_0} + 2\Delta a) = z_1 + r(\underline{a}_T - \Delta a) - c_1(\underline{a}_{t_0} + 2\Delta a); \\ \mathbf{0} &= s_1(\underline{a}_{t_0} + 3\Delta a) = z_1 + r(\underline{a}_T) - c_1(\underline{a}_{t_0} + 3\Delta a) \quad (36) \end{aligned}$$

When credit crunch occurs previous will be modified to reduce borrowing limit by $3\Delta a$

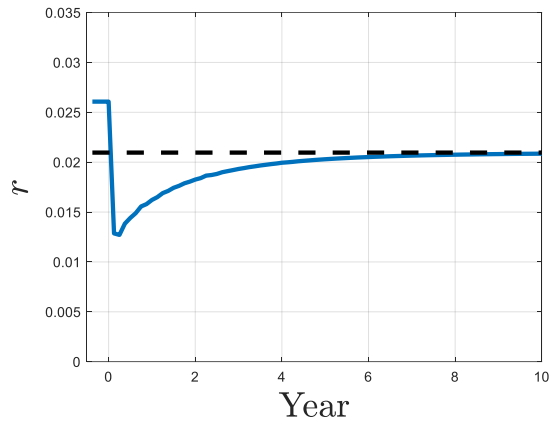
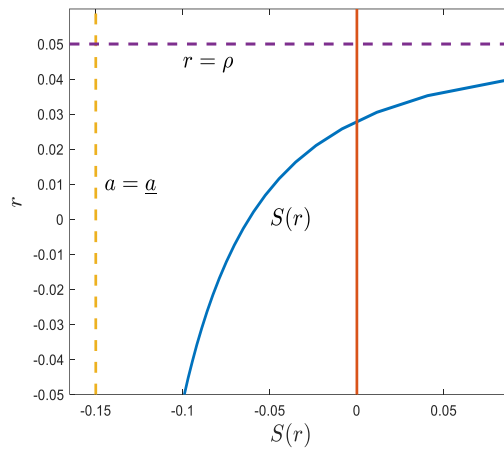
$$\begin{aligned} \bar{c}_{1,1} &= z_1 + r\underline{a}_{t_0} - \Delta a; & \bar{c}_{2,1} &= z_1 + r(\underline{a}_{t_0} + \Delta a) - \Delta a; \\ \bar{c}_{3,1} &= z_1 + r(\underline{a}_{t_0} + 2\Delta a) - \Delta a; & \bar{c}_{\underline{a}_T, \mathbf{1}} &= z_1 + r\underline{a}_T; & \bar{v}'_{i,j} &= u'(\bar{c}'_{i,j}); \\ v_{i,j} &= v'_{i,j} \mathbb{1}_{S_F > 0} + \mathbf{v}'_{i,j} \mathbb{1}_{(S_B < 0)} + \bar{v}'_{i,j} \mathbb{1}_{S_B > 0 > S_F} \end{aligned} \quad (37)$$

In this example parameters of the model are :

$$\begin{aligned} s &= 2; \rho = 0.05; \\ z_1 &= 0.12; z_2 = 0.25; z = [z_1, z_2]; la_1 = 1.15; la_2 = 1, \\ la &= [la_1, la_2]; r_0 = 0.03; r_{min} = 0.001; r_{max} = 0.045; \end{aligned}$$

$I = 800$; Equilibrium Found, Interest rate = 0.0261. In the next photo equilibrium interest rate and supply of borrowings (loans) priced by that rate are depicted (Huggett model Credit crunch interest rate Response of $r(t)$ after a credit crunch from $\underline{a}_{t_0} = -0.1692$ to $\underline{a}_T = -0.15$):

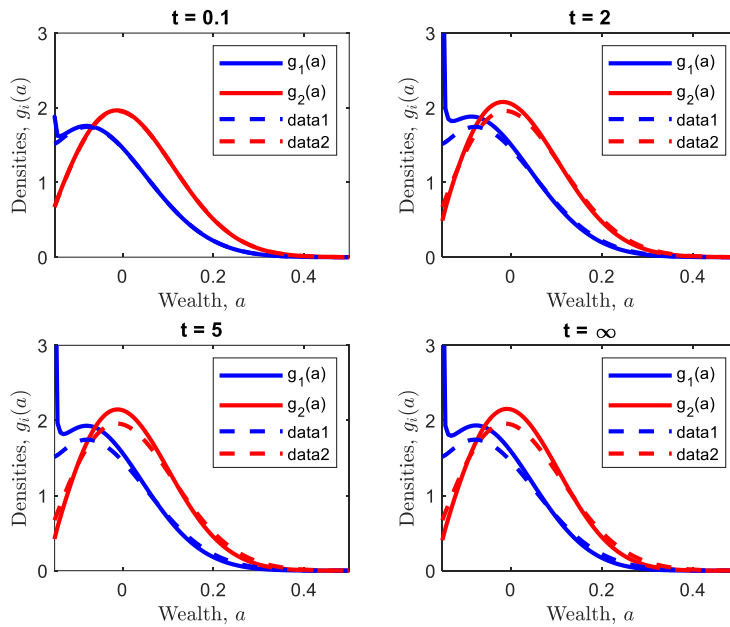
Figure 6 equilibrium interest rate



*Source: Author's calculations based on code available at:
<https://benjaminmoll.com/codes/>*

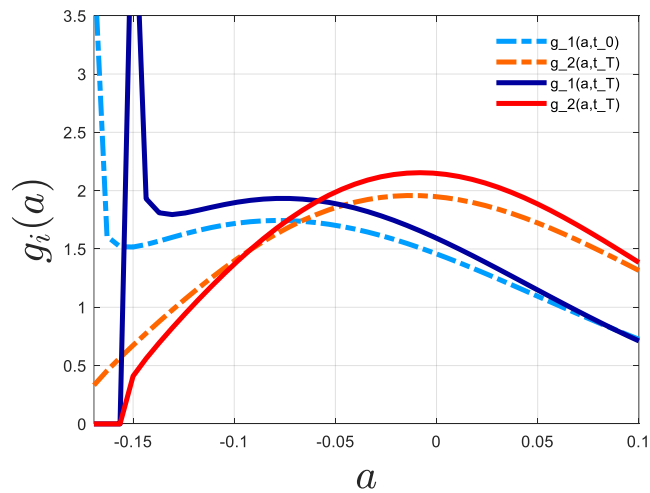
Next we will plot Huggett transitional model of credit crunch and distribution of wealth in this economy.

Figure 7 Huggett model credit crunch transition model



Source: Author's calculations based on code available at: <https://benjaminmoll.com/codes/>

Figure 8. Initial and terminal distributions of wealth



Source: Author's calculations based on code available at: <https://benjaminmoll.com/codes/>

5. G (Global) DSGE: A toolbox for Solving DSGE Models with Global Methods: Kiyotaki and Moore (1997), Credit Cycles

This is a model due to Kiyotaki and Moore (1997) paper simply entitled credit cycles. In their seminal, Kiyotaki and Moore (1997) put forth a model of credit cycles in which movements in asset prices interacts with the real side of the economy and produce amplified and persistent effects of shocks to the economy. The original model is relatively simple with risk-neutral agents and one-time unanticipated MIT shocks. Next, we will explain MIT shock.

5.1 MIT shock

Boppart et al. (2018) writes that “MIT shock” is defined as: “An “MIT shock” is an unexpected shock that hits an economy at its steady state, leading to a transition path back towards the economy’s steady state.....”.Mukoyama (2021) also follows Boppart et al. (2018) definition:”.... the probability of the shock is considered zero, and no prior (contingent) arrangement is possible for the occurrence of the MIT shock”.....The dynamic analysis that was using exogenous shocks or policy changes has been used in the literature with the earlier examples including: Abel, Blanchard (1983), Auerbach, Kotlikoff (1983), and Judd (1985).And more recent examples being: Boppart et al. (2018), Kaplan et al. (2018), Boar ,Midrigan (2020), Guerrieri et al. (2020).

5.2 Back to Kiyotaki, Moore (1997)

Here the economy consists of two production sectors, farming and gathering, with the population of each sector normalized to one. The farmers are more productive but are less patient than the gatherers and thus they tend to borrow from the gatherers in equilibrium. Farmers now maximize:

$$\max_{\{x_t, k_t, b_t\}} \mathbb{E}_0 \left[\sum_t \beta^t \frac{(x_t)^{1-\sigma}}{1-\sigma} \right] \quad (38)$$

Subject to budget constraint: $x_t + q_t k_t + \frac{b_t}{R_t} = y_t + q_t k_{t-1} + b_{t-1}$ and the production function is $y_t = A_t(a + c)k_{t-1}$.The value of land holding in previous is: $q_t k_{t-1}$ and the bond holding is: b_{t-1} . The aggregate TFP

shock A_t follows a Markov process. Resources are allocated among consumption x_t , as well as land and bond holdings in the next period. Portion c of the output is non-tradable and must be consumed: $x_t \geq A_t c k_{t-1}$, only remaining portion a is tradable. Collateral constraint for the agent is given as:

$$b_t + \theta q_{1-t} k_t \geq 0 \quad (39)$$

Where q_{1-t} is the lowest possible land price in the next period. And $\theta \leq 1$. Gatherer solves:

$$\max_{\{x'_t, k'_t, b'_t\}} \mathbb{E}_0 \left[\sum_t \beta'^t \frac{(x'_t)^{1-\sigma}}{1-\sigma} \right] \quad (40)$$

Subject to budget constraint: $x'_t + q'_t k'_t + \frac{b'_t}{R_t} = y'_t + q'_t k'_{t-1} + b'_{t-1}$ and concave production function: $y'_t = \underline{A}_t (k'_{t-1})^\alpha$. We assume here that: $\underline{A}_t = \delta A_t$; $\delta \leq 1$. The multiplier on farmer's budget constraint is $\beta^t \lambda_t$ and on the tradability constraint $\beta^t \eta_t$ and on the collateral constraint $\beta^t \mu_t$ the following first order conditions and complementary-slackness conditions are necessary and sufficient for optimality:

$$\begin{aligned} (x_t)^{-\sigma} - \lambda_t + \eta_t &= 0 \\ \eta_t (x_t - c k_{t-1}) &= 0 \\ -q_t \lambda_t + \theta q_{1-t} \mu_t + \beta \mathbb{E}[(q_{t+1} + a + c) \lambda_{t+1} - c \eta_{t+1}] &= 0 \\ -\frac{1}{R_t} \lambda_t + \mu_t + \beta \mathbb{E}[\lambda_{t+1}] &= 0 \\ \mu_t (q \theta q_{1-t} k_t + b_t) &= 0 \\ \beta' \mathbb{E} \left[\left(\frac{q_{t+1} + a + c (k'_t)^{\alpha-1}}{q_t} \right) \left(\frac{x'_{t+1}}{x'_t} \right)^{-\sigma} \right] &= 1 \\ \beta' R_t \mathbb{E}_t \left[\left(\frac{x'_{t+1}}{x'_t} \right)^{-\sigma} \right] &= 1 \end{aligned} \quad (41)$$

The total land supply is fixed \bar{K} and the market clearing conditions are given as:

$$\begin{aligned} b_t + b'_t &= 0 \\ k_t + k'_t &= \bar{K} \\ x_t + x'_t = Y_t = A_t (a + c) k_{t-1} + \underline{A}_t (k'_{t-1})^\alpha & \end{aligned} \quad (42)$$

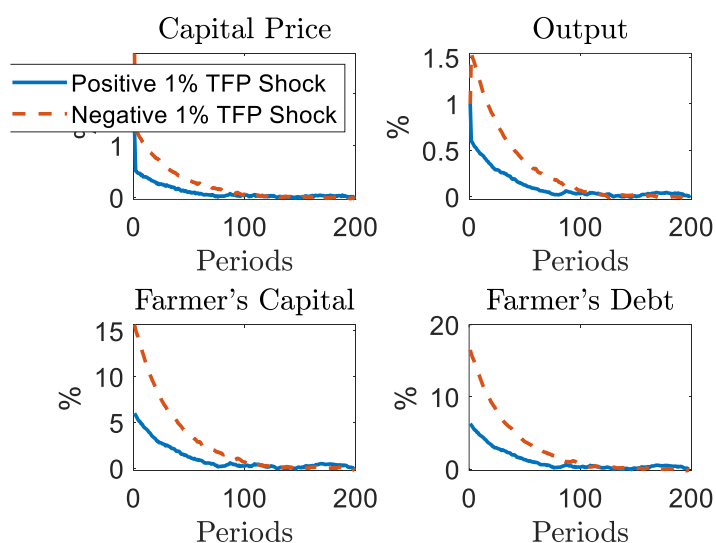
We define recursive equilibrium¹⁴ over two endogenous state variables. The first-one is the farmers' land-holding k_{t-1} . The second one is the farmers' financial wealth share defined as:

$$\omega_t = \frac{q_t k_{t-1} + b_{t-1}}{q_t \bar{K}} \quad (43)$$

In the numerical exercise TFP is i.i.d and $A_t \in \{0.99, 1.0, 1.01\}$ with probability of 1/3 for each state.

In the ergodic distribution, the probabilities for binding collateral constraint conditional on the three values of $A_t \in \{0.92, 0.80, 0.77\}$. Next =, results of simulation of Kiyotaki, Morre (1997) are graphically presented.

Figure 9 Kiyotaki-Moore (1997) The IRFs after positive and negative 1 percent TFP shocks



*Source: Author's own calculations based on code available at:
<https://www.gdsge.com/example/KM1997/KM1997.html#equation-eq-budget-farmer>*

¹⁴ It has been widely used in exploring a wide variety of economic issues including business-cycle fluctuations, monetary and fiscal policy, trade related phenomena, and regularities in asset price co-movements. This is the equilibrium associated with dynamic programs that represent the decision problem when agents must distinguish between aggregate and individual state variables.

6. Two-asset HANK model: Bayer,Luetticke (2020) method for solving Heterogenous DSGE

Bayer, Luetticke (2020) propose a method for solving Heterogeneous Agent DSGE models that uses fast tools originally employed for image and video compression to speed up a variant of the solution methods proposed by Michael Reiter, see (Perturbation with our reduction for HANK models¹⁵). Bayer, Luetticke (2020) method has the following broad characteristics: The model is formulated and solved in discrete time. Solution begins by calculation of the steady-state equilibrium with no aggregate shocks. Both the representation of the consumer's problem and the description of the distribution are subjected to a form of "dimensionality reduction". This means finding a way to represent these objects efficiently using fewer points. "Dimensionality reduction" of the consumer's decision problem is performed before any further analysis is done. This involves finding a representation of the policy functions using some class of "basis functions". Dimensional reduction of the joint distribution is accomplished using a "copula". The method approximates the business-cycle-induced deviations of the individual policy functions from those that characterize the riskless steady-state. This is done using the same basis functions originally optimized to match the steady-state individual (micro) policy function. Now will set up the dynamic recursive problem here. Consider a household problem in presence of aggregate and idiosyncratic risk S_t measures the (exogenous) aggregate state (e.g., levels of productivity and unemployment), s_{it} records agent i 's idiosyncratic state (exogenous and endogenous, e.g. employment or assets). μ_t is the distribution over s at date t (e.g., the wealth distribution). P_t is the pricing kernel. It captures the info about the aggregate state that the consumer needs to know in order to behave optimally. Γ defines the budget set. This delimits the set of feasible choices x that the agent can make. The Bellman equation for this problem is:

$$v(s_{it}, S_t, \mu_t) = \max_{x \in \Gamma(s_a, P_t)} u(s_{it}, x) + \beta E v(s_{it+1}(x, s_{it}), S_{t+1}, \mu_{t+1}) \quad (44)$$

And the corresponding Euler equation is:

¹⁵ code available at: <https://github.com/econ-ark/BayerLuetticke>

$$u'(s_{it}, x(s_{it}, S_t, \mu_t)) = \beta E_t R(S_t, S_{t+1}, \mu_t, \mu_{t+1} | u'(s_{i,t+1}, S_{t+1}, \mu_{t+1})) \quad (45)$$

Now when solving for steady state, first we need to discretize the state space by representing the nodes of the discretization in a set of vectors. Such vectors will be represented by an overbar: \bar{s}_{it} ; \bar{c}_{it} . The optimal policy $c(s_{it}; P(\mu))$ induces flow utility u_c whose discretization is a vector \bar{u}_c . Π is like an expectation operator. In steady-state discretized Bellman equation is given as:

$$\begin{aligned} \bar{v} &= \bar{u} + \beta \Pi_{\bar{c}} \bar{v} \\ \bar{\mu} &= \bar{\mu} \Pi_{\bar{c}} \\ d\bar{\mu} &= d\bar{\mu} \Pi_{\bar{c}} \end{aligned} \quad (46)$$

We will define an approximate equilibrium in which: \bar{c} is the vector that defines a linear interpolating policy function c at the state nodes given P and v , v is a linear interpolation of \bar{v} , \bar{v} ; $d\bar{\mu}$ solve the approximated Bellman equation subject to the steady-state constraint Markets clear joint requirement on \bar{c} , μ , and P ; denoted as $\Phi(\bar{c}, \mu, P) = 0$.

6.1 Sequential equilibrium (Reiter (2002))

A 'sequential equilibrium with recursive individual planning' is: A sequence of discretized Bellman equations, such that

$$v_t = \bar{u}_{P_t} + \beta \Pi_{c_t} v_{t+1} \quad (47)$$

Previous holds for policy c_t which optimizes with respect to v_{t+1} and P_t and a sequence of "histograms" $d\mu$ (discretized distributions), such that: $d\mu_{t+1} = d\mu_t \Pi_{c_t}$ which holds given the policy h_t , that is optimal given P_t , v_{t+1} . That is, given a histogram describing the distribution in period t , $d\mu_t$, next period's histogram is determined by the transition matrix. Prices, distribution, and policies lead to market clearing. The large system above can be transformed into much smaller system:

$$F(\{d\mu_t^1, \dots, d\mu_t^n\}, S_t, \{d\mu_{t+1}^1, \dots, d\mu_{t+1}^n\}, S_{t+1}, \theta_t, P_t, \theta_{(t+1)}, P_{t+1}) =$$

$$\left[\begin{array}{c} d\bar{C}(\mu_t^1, \dots, \bar{\mu}_t^n) - d\bar{C}(\mu_t^1, \dots, \bar{\mu}_t^n) \Pi_{c_t} \\ d\text{ct} \left[\text{idct}(\tilde{\theta}(\theta_t)) - (\bar{u}_{c_t} + \beta \Pi_{c_t} \text{idct}(\tilde{\theta}(\theta_{t+1}))) \right] \\ S_{t+1} - c(S_t, d\mu_t) \\ \Phi(c_t, d\mu_t, P_t, S_t) \end{array} \right] \quad (48)$$

6.2 Back to Bayer, Luetticke (2020)

Let $\bar{\theta} = \text{dct}(\bar{v})$ be the coefficients obtained from the DCT¹⁶ of the value function in steady-state. Define an index set I that contains the x percent largest (i.e. most important) elements from $\bar{\theta}$. Let θ be a sparse vector with non-zero entries only for elements $i \in I$. Define:

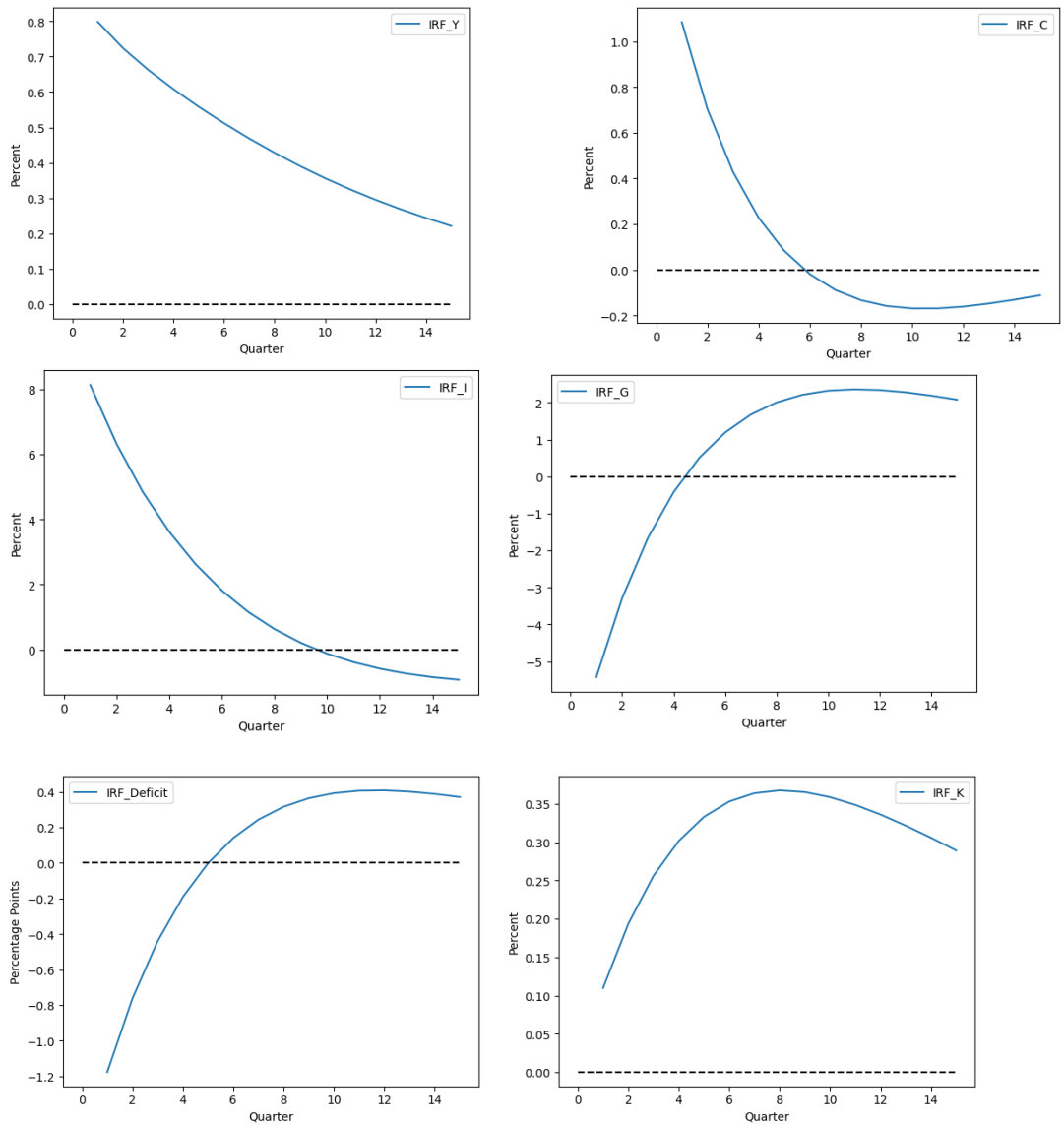
$$\tilde{\theta}(\theta_t, t) = \begin{cases} \bar{\theta}(i) + \theta_t t(i), & i \in I \\ \bar{\theta}(i), & \text{else} \end{cases} \quad (49)$$

This assumes that the basic functions with least contribution to representation of the function in levels, make no contribution at all to its changes over time. For the two asset HANK model we have: consumption c , CRRA parameter ξ , CES consumption bundles η , Frisch elasticity γ , and two assets: liquid bonds b , and lower bound \underline{b} . Borrowing constraint: $R_b(b < 0) = R^B(b > 0) + \bar{R}$.

Idiosyncratic productivity shock is h , if $h = 0$ entrepreneur receives profits Π , otherwise $h = 1$; $h \sim AR(1)$, ρ_h persistence parameter, c^h idiosyncratic risk, wage W cost of capital $r + \delta$, Rotemberg price setting: quadratic adjustment cost scaled by $\frac{\eta}{2\kappa}$; discount factor β , Investment subject to Tobin's q adjustment cost ϕ , Government spending G , ρ_G intensity of repaying government debt: $\rho_G = 1$ implies roll-over, and tax T . results from simulation are presented in following page.

¹⁶ A discrete cosine transform (DCT) expresses a finite sequence of data points in terms of a sum of cosine functions oscillating at different frequencies.

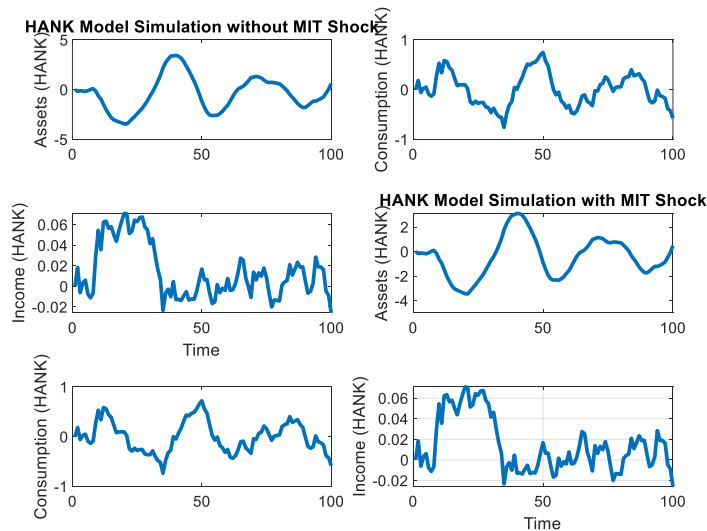
Figure 10 HANK IRF'S.



Source: Authors' calculations based on a code available at:
<https://github.com/econ-ark/BayerLuetticke>

On the next page we will present HANK model with and without MIT shock.

Figure 11. HANK model in discrete time with MIT and without MIT shock.



Source: Authors' calculations

7. Conclusion

When savings and assets are plotted one against in Winberry (2018), there is a positive association between savings and assets for employed and unemployed. Same goes when consumption is plotted against agents assets except now this association is concave. When comes to distribution of assets (wealth) and mass of households in the economy there is not much difference between histogram and parametric family¹⁷In contrast to most existing work, Winberry (2018) method does not rely on the dynamics of the distribution being well-approximated by a small number of moments, substantially expanding the class of models which can be feasibly computed. In Huggett (1997) steady states and transition paths in heterogeneous Agent converge in

¹⁷ Parametric family or a parameterized family is a family of objects (a set of related objects) whose differences depend only on the chosen values for a set of parameters.

around 200-250 periods. In credit crunch model for Huggett (1993), interest rate converges to equilibrium in 4-6 years after the shock. In Kiyotaki, Moore (1997) capital price, output, farmers' capital and farmers debt are transitioning to steady-state for about 100-200 periods after positive or negative TFP shock. The two-asset HANK (Heterogeneous Agent New Keynesian) model by Bayer, Lueticke (2020), proposed an extension of Reiter's method to solve heterogeneous agent models with aggregate risk by perturbation. This method does not rely on the dynamics of the distribution being well-approximated by a small number of moments, substantially expanding the class of models which can be feasibly computed.

References

Abel, A. B., Blanchard, O. J. (1983). An Intertemporal Model of Saving and Investment. *Econometrica* 51, pp. 675–692.

Acharya, S., and Dogra, K. (2020), Understanding HANK: Insights from a PRANK, *Econometrica*, vo. 88(3), pp. 1113-1158.

Achdou, Y., Han, J., Lasry, J.-M., Lions, P.-L., Moll, B. (2022). Income and Wealth Distribution in Macroeconomics: A Continuous-Time Approach, *The Review of Economic Studies*, Volume 89, Issue 1, pp. 45-86

Aiyagari, S. Rao (1994). Uninsured Idiosyncratic Risk and Aggregate Saving, *The Quarterly Journal of Economics*, Volume 109, Issue 3, pp. 659–684, <https://doi.org/10.2307/2118417>

Algan, Y., Allais, O., Den Haan, W. J. (2008). Solving heterogeneous-agent models with parameterized cross-sectional distributions, *Journal of Economic Dynamics and Control*, Volume 32, Issue 3, pp. 875-908,

Arrow, J. (1951). An Extension of the Basic Theorems of Classical Welfare Economics. In J. Neyman (ed.), *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability* (p./pp. 507--532), : University of California Press.

- Arrow, K. J.; Debreu, G. (1954). Existence of an equilibrium for a competitive economy. *Econometrica*. 22 (3),pp.265–290.
- Auclert, A. (2017). Monetary Policy and the Redistribution Channel, Discussion paper.
- Auclert, A., Rognlie, M., and Straub, L. (2020). Micro Jumps, Macro Humps: Monetary Policy and Business Cycles in an Estimated HANK Model, Mimeo Harvard University.
- Auerbach, A. J. Kotlikoff, L. J. (1983). National Savings, Economic Welfare, and the Structure of Taxation. In M. Feldstein (Ed.), *Behavioral Simulation Methods in Tax Policy Analysis*, pp. 459–498. University of Chicago Press.
- Auerbach, Alan J. Laurence J. Kotlikoff. (1987). *Dynamic Fiscal Policy*, Cambridge: Cambridge University Press
- Bachmann, R., R. Caballero, and E. Engel (2013). Aggregate Implications of Lumpy Investment: New Evidence and a DSGE Model. *American Economic Journals: Macroeconomics*, 5, pp. 29–67.
- Bayer, C. Luetticke, R. (2020). Solving heterogeneous agent models in discrete time with many idiosyncratic states by perturbation methods *Quant. Econom.*, 11, pp. 1253-1288
- Berger, D., and J. Vavra (2015). Consumption Dynamics During Recessions. *Econometrica*, 83, pp. 101–154.
- Bernanke, B. (2015). Monetary Policy and Inequality. *Brookings Blog*, June 1.
- Bernanke, B. S., Lown, C. S., & Friedman, B. M. (1991). The Credit Crunch. *Brookings Papers on Economic Activity*, 1991(2), 205–247. <https://doi.org/10.2307/2534592>

Bewley, T.F. (1986). Stationary monetary equilibrium with a continuum of independently fluctuating consumers. In "Contributions to Mathematical Economics in Honor of Gerard Debreu" (W. Hildenbrand and A. Mas-Colell (eds.), North Holland

Bilbiie, F., and Monacelli, T., and Perotti, R. (2020), Stabilization vs. Redistribution: The Optimal Monetary-Fiscal Mix, CEPR DP 15199.

Boar, C. V. Midrigan (2020). Efficient Redistribution. mimeo. New York University.

Boppart, T., Krusell, P., Mitman, K. (2018). Exploiting MIT shocks in heterogeneous-agent economies: the impulse response as a numerical derivative. *Journal of Economic Dynamics and Control*, Volume 89, pp. 68-92

Cao, D. Luo, W. Nie, G. (2023). Global DSGE models, *Review of Economic Dynamics*, ISSN 1094-2025

Chang, Y., Kim, S.-B., Schorfheide, F. (2013). Labor-market heterogeneity, aggregation, and policy (in)variance of DSGE model parameters. *Journal of the European Economic Association*, 11, 193–220. <http://www.jstor.org/stable/23355064>

Christiano, L. J., M. Eichenbaum, C. L. Evans 2005: Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy, *Journal of Political Economy*, 113(1), 1-45

Clementi, G. L., and B. Palazzo (2016). Entry, Exit, Firm Dynamics, and Aggregate Fluctuations, *American Economic Journals: Macroeconomics*, 8, pp.1–41

Friedman, M. (1956). *A Theory of the Consumption Function*. Princeton University Press.

Geanakoplos, J.D.; (1990). An introduction to general equilibrium with incomplete asset markets. *Journal of Mathematical Economics*, 19(1-2), pp. 1–38.

Geanakoplos, J.D.; Polemarchakis, H.M. (1986). Existence, regularity and constrained suboptimality of competitive allocations when the asset structure is incomplete. In Hell, W.P.; Starr, R.M.; Starrett, D.A. (eds.). *Uncertainty, information and communication: Essays in honor of K.J. Arrow*. Vol. 3. Cambridge University Press. pp. 65–95. ISBN 9780521327046.

Guerrieri, V., G. Lorenzoni, L. Straub, and I. Werning (2020). *Macroeconomic Implications of COVID-19: Can Negative Supply Shocks Cause Demand Shortages?* NBER Working Paper 26918.

Hall, R.E. (1978). Stochastic Implications of the Life Cycle-Permanent Income Hypothesis: Theory and Evidence. *The Journal of Political Economy*, 86(6), 971-987.

Heathcote, J., Storesletten, K., Violante, G. L. (2009). Quantitative Macroeconomics with Heterogeneous Households. *Annual Review of Economics*, 1(1), pp.319–354. doi: 10.1146/annurev.economics.05

Hopenhayn, H. A. (1992). Entry, Exit, and firm Dynamics in Long Run Equilibrium. *Econometrica*, 60(5), pp.1127–1150. <https://doi.org/10.2307/2951541>

Hubbard, T. P., et al. (2013). Using Economic Theory to Guide Numerical Analysis: Solving for Equilibria in Models of Asymmetric First-Price Auctions. *Computational Economics* 42(2): 241-266.

Huggett, M. (1993). The Risk-Free Rate in Heterogeneous-Agent Incomplete Insurance Economies, *Journal of Economic Dynamics and Control* 17, pp.953–969

Huggett, M. (1997). The one-sector growth model with idiosyncratic shocks: Steady states and dynamics, *Journal of Monetary Economics*, Elsevier, vol. 39(3), pages 385-403

Imrohoroglu, A. (1989). Cost of Business Cycles with Indivisibilities and Liquidity Constraints. *Journal of Political Economy*, 97(6), pp.1364–1383. <http://www.jstor.org/stable/1833243>

Judd, K. L. (1985). Short-Run Analysis of Fiscal Policy in a Simple Perfect Foresight Model. *Journal of Political Economy* 93, pp.298–319.

Judd, K.(1987).Welfare Cost of Factor Taxation in a Perfect Foresight Model. *Journal of Political Economy*, 95, pp.67-709

Kalecki, M.(2016). *Studies in the theory of business cycles: 1933-1939*. Routledge.

Kaplan, G., B. Moll, and G. L. Violante (2016).Monetary Policy According to HANK. Working Papers 1602, Council on Economic Policies.

Kaplan, G., B. Moll, G. L. Violante (2018). Monetary Policy According to HANK. *American Economic Review* 108, pp.697–743.

Kaplan, Greg, Violante,G.L. (2014).A Model of the Consumption Response to Fiscal Stimulus Payments. *Econometrica* 82 (4),pp.1199–1239.

Keynes, John M. (1936) *The General Theory of Employment, Interest and Money*. London:Macmillan.

Khan, A.,Thomas, J. K. (2008). Idiosyncratic Shocks and the Role of Nonconvexities in Plant and Aggregate Investment Dynamics. *Econometrica*, 76(2), pp.395–436. <http://www.jstor.org/stable/40056428>

Kiyotaki, N., & Moore, J. (1997). Credit Cycles. *Journal of Political Economy*, 105(2), pp.211–248. <https://doi.org/10.1086/262072>

Kolasa, M., Rubaszek, M., Skrzypczyński, P. (2012). Putting the New Keynesian DSGE Model to the Real-Time Forecasting Test. *Journal of Money, Credit and Banking*, 44(7), pp. 1301-1324.

Kopecky, K. A. and R. M. H. Suen (2010). Finite state Markov-chain approximations to highly persistent processes. *Review of Economic Dynamics* 13 (3), pp.701–714.

Krusell, P. and A. A. Smith (1997). Income and wealth heterogeneity, portfolio choice, and equilibrium asset returns. *Macroeconomic Dynamics*, 1 (2), pp.387–422.

Krusell, P. and A. A. Smith (1998). Income and wealth heterogeneity in the macroeconomy. *Journal of Political Economy*, 106 (5), pp. 867–896.

Lucas, RE. (1987). *Models of Business Cycles*. New York: Basil Blackwell.

Mankiw, N. Gregory. (2006) *Macroeconomics*, 6th ed. New York: Worth Publishers.

Ono, Y. (2011). The Keynesian Multiplier Effect Reconsidered. *Journal of Money, Credit and Banking*, 43(4), 787–794. doi:10.1111/j.1538-4616.2011.00397.x

Otonello, P., and T. Winberry (2017). Financial Heterogeneity and the Investment Channel of Monetary Policy. Working paper.

Patterson, C. (2021). The Matching Multiplier and the Amplification of Recessions, Mimeo University of Chicago.

Prescott, E. C., (2004). Why do Americans Work So Much More Than Europeans? *Quarterly Review*, Federal Reserve Bank of Minneapolis, July, 2-13.

Reiter, M. (2002). Recursive computation of heterogeneous agent models. Report, Universitat Pompeu Fabra.

Rouwenhorst, G. (1995). Asset pricing implications of equilibrium business cycle models. In T. F. Cooley (Ed.), *Frontiers of Business Cycle Research*, Chapter 10. Princeton University Press.

Sargent, T.J. (2023). *HAOK and HANK Models*, New York University

Slacalek, J., Tristani, O. and Violante, G.L. (2020). Household Balance Sheet Channels of Monetary Policy: A Back of the Envelope Calculation for the Euro Area, *Journal of Economic Dynamics and Control*, vol. 115, Article 103879.

Smets, F., Wouters, R. (2003). An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area, *Journal of the European Economic Association*, 1(5), pp.1123-1175.

Violante (2021). What have we learned from HANK models, thus far?. Panel on Monetary Policy, Employment and Inequality 2021 ECB Forum on Central Banking

Winberry, T. (2018). A method for solving and estimating heterogeneous agent macro models. *Quantitative Economics* 9 pp.1123–1151.

IMPACT OF VISUAL IDENTITY IN DIGITAL MARKETING FOR TOURISM BASED ON EXAMPLES FROM BULGARIA

Neviana Krasteva¹, Dessislava Alexova²

Abstract

The present study reveals the impact of the visual component in digital marketing in tourism and examines the relationship with the strategy for the overall unified branding and merchandising of the specific destination, using the example of Bulgaria. The fundamentals of digital marketing in tourism, its tools and how visual branding accents should be present in the main directions, based on specific examples.

Key words: digital marketing, tourist destination, visual identity, tourist brand

¹ Sofia University "St. Kliment Ohridski", neviaanak@feb.uni-sofia.bg

² International Business School, dalexova@ibsedu.bg

1. Introduction

Digital marketing in tourism is the actions taken in an online environment to attract visitors to a particular place. Hotels, cities, countries, attractions and other places related to entertainment and business travel implement basic online strategies or specific methods designed to increase the number of visitors. (Antevenio, 2019)

With such a large audience and huge potential profit, the tourism and travel sector is highly competitive. That's why businesses need to use innovative digital marketing strategies to stand out. Brexit, recession, oil prices, strikes, pandemic, military action. Travel companies, for all their charm, are often threatened by external factors completely beyond their control. Fortunately, they have digital marketing at their disposal, not only to protect their business, but also to turn risks into opportunities.

The aim of the present study is to reveal the impact of the visual component in digital marketing in tourism and to examine the relationship with the strategy for the overall unified branding and merchandising of the specific destination on the example of Bulgaria.

The basics of digital marketing in tourism, its tools and how visual branding accents should be present in the main directions will be examined.

2. Terms and means of digital marketing in tourism through visual identity

Until recently, we judged a city by its monuments and the hospitality of its people. Recently, we understand that as tourists we also value the experience of a city through its digital offerings. This is an invisible layer, but it ultimately provides three main benefits for visitors: saving time, discovering opportunities and saving money.

It seems redundant to argue the importance of digital marketing in tourism, but here's an example - if you print 20,000 brochures selling your resort, that's only 20,000 people who will see your amazing vacation spot (and possibly a few friends or family members), but if you have a properly

optimized website, this number can reach millions. If the company has an active presence on social media, the number of people engaging with the brand increases even more. And there's still room for direct advertising with photo and video ads online and on mobile when a user opens a website or app.

Going back to printed brochures, what made them effective was the powerful combination of high-quality images and compelling textual content that made potential travelers pick up the phone and call a travel agent or stop by their office. But all this is static. Websites allow marketers to include both high-quality images - photos and videos - and compelling text, but they can also change them when the need arises. This gives dynamism and adaptability that are important.

Creating a unified and clear branding strategy requires establishing the main visual aspects of the brand - logo, font, primary colors, trademark, design, etc. Appropriate authentic merchandising to represent the destination. All this tailored for the digital environment.

Mobile friendly websites are a must. After 2020, having a mobile-friendly website is inevitable as 52.2% of all internet traffic comes from mobile devices. This means that if a business does not have a mobile-optimized website, it will lose more than half of its potential customers. It will also affect your search engine optimization result and Google Ads performance. A mobile-friendly website means that it must look and work perfectly on any mobile device, regardless of the display size and whether we are talking about a smartphone or a tablet.

The modern customer is always connected and eager to get the information they need, so a website tailored to their needs must be fast, secure, instantly accessible from mobile devices and full of useful content.

Using digital presentations with strong visual tools to present a multimedia view of the area, including a simulated walking tour, a virtual view of popular landmarks, and lists of fun things to do while guests are in town are just a few of these possibilities. This information will help potential

customers decide whether they want to visit a particular location. And if they do, they'll already be on the relevant site to book.

Storytelling is a fundamental aspect of marketing - any kind of marketing. Traditionally, this has usually been from a brand perspective and the focus has been on the hard sell. What digital marketing has done is allow content to become more inclusive and form different narratives. They outline a destination's selling points in a more nuanced way, extend the destination's identity to a more diverse audience, personalize the destination for individual viewers, and meet the demand for authentic local travel.

Websites have gone a step further by incorporating travelers into the story with user-generated content — including their photos and social media posts, etc. This is effective because people tend to trust other "non-experts" more than a perceived marketing machine.

Travelers regularly use review sites like TripAdvisor, Google and Yelp to guide their purchasing decisions. This is called "social proof". Businesses should be proactive in providing review sites with high-quality images and videos that showcase the brand and its products. This helps to direct the impression of the business to some extent.

Visual content is a big winner when using influencers as well. Instagram photos, vlogs and blog posts with lots of images help the audience visualize themselves in the destination. Plus, the aspirational element of an influencer-audience relationship can create an explosion of brand interest.

When we talk about the travel industry, the decision to book a trip is in most cases triggered by a visual element - which is why platforms like Facebook, Instagram and YouTube are best suited to promote the services of a travel agency.

3. Successful practices of building a visual identity of destinations in Bulgaria and recommendations for their digital transformation

The creation of a visual identity of a tourist destination necessitates a general concept of visual and communication impact in developing tourist destinations, by formulating clear and unambiguous goals and messages, targeting audiences and following a unified communication policy. A good example in this direction are the proposals for the visual identity of the municipalities of Radomir, Chiprovtsi, Gorna Malina and Kostinbrod developed as a result of in-depth research studies. The studies were carried out in the period 2021-2022 under contracts of the four municipalities with the company "Creativo.com" Ltd, under the leadership of Dr. Dessislava Alexova, and the logos and overall visual identity of each of the destinations were developed by Vihra Ognyanova, "Prim Design" Ltd., according to the tasks set by the author, based on the research studies done.

The key messages are associated with distinctive and recognizable symbols from the public and the local population, which were derived from surveys of the local population and potential visitors, as well as from focus group work. They are part of a unified communication policy that is aimed at the main target segments formulated during the study. The goal is for the displayed messages to show diversity, to connect travel with experience and discovery, to offer common tourism products, to support the development of local communities.

The messages and stories are aimed at provoking curiosity and adventure in tourists by stimulating interest in exploring a tourist destination.

The main messages that were formulated during the conducted focus groups and surveys in the four municipalities are: "Chiprovtsi - colors from Bulgaria", "Gorna Malina - in harmony with nature", "Radomir - the hidden treasures". They are reinforced by the corresponding sub-messages, derived according to the specifics of each of the destinations.

For the destination Radomir, the main symbols emerged: the horse, symbolizing strong will and nobility; the peony, the imperial flower, the

region's most emblematic plant; garlic, associated with traditional livelihoods, a symbol of health and strength, with Kuker traditions and mystical beliefs to ward off evil; the Radomir boza. As a result of the analysis, due to the relatively small recognition of the region, a clear font logo was chosen - the name Radomir with an additional graphic element implemented.

Concentrating the design in one symbol is also extremely useful from a marketing point of view, as it can be very easily communicated and enforced as a sign. Therefore, the most recognizable symbol was chosen - a peony with its characteristic shape, which replaces the letter "O" in the inscription, and other symbols typical of the region were developed as additional illustrations.

The color scheme is both elegant and spectacular - the specific pink-red of the peonies is combined with a warm gray-beige, which symbolizes the most popular local products - bosa and garlic, and soft green tones unite the whole composition, as a reference to the diversity of natural resources and the opportunities for diverse experiences. The message "Radomir - hidden treasures" fully reflects the variety of little-known cultural and natural features in the municipality, provokes curiosity, inquisitiveness and adventurous spirit in tourists, stimulating interest in exploring this developing tourist destination. (Aleksova and Ognyanova, 2022: p.17-19)

The main task in developing the visual identity of the municipality of Chiprovtsi is to create a common vision where the cultural-historical and natural heritage of the destination is the basis of the brand and the graphic symbols in the logo: the Chiprovtsi carpets - part of the world cultural heritage of UNESCO and the Balkans with the Three Hammers – the characteristic mountain landscape associated with the heroic history of the region.

The colors used are characteristic of the motifs of the Chipro carpets, as red also appears in the coat of arms of the municipality. The color scheme corresponds perfectly with the slogan "Colors from Bulgaria". The font is Pliska – classic, serif, reflecting patriarchal values and traditions, while also

being easy to read with a Bulgarian form of Cyrillic. (Aleksova, 2021: p. 340-341)

The graphic sign of the Gorna Malina destination brand corresponds to the slogan "In harmony with nature" and represents stylized leaves, an absolute symbol of nature and green. The continuous line made up of semicircles and angles carries the style of a modern drawing as well as elements of folk motifs, in tune with the proposals for eco and art experiences.

In addition to the green leaf, the graphic also features the silhouette of the majestic golden eagle, an iconic globally endangered species that inhabits the area. The final shape at the top visualizes the location of the destination between two mountains. The fonts used are from the Sofia Sans family, with a clean outline in sync with the logo, a Bulgarian form of Cyrillic and variations from Ultra light to Heavy for different applications.

The sun, as a symbol of light and resurrection, and the rooster, as an emblem of pride, bravery and honor were the main symbols that won the votes in the Kostinbrod municipality tourism logo survey. The color scheme is subservient to the same symbolism, the dominant sun yellow is accented with deep forest green and accented by the rooster's red crest. The non-standard font (Ouroboros), with its strongly illustrative characteristics, completes the composition.

The logotype and slogan of each destination are written in a characteristic way with variants in Bulgarian and English, since the main target audiences are Bulgarian and foreign tourists. With the relatively small popularity of the area as a tourist destination, the guiding idea in the design is that the logo is legible and absolutely clearly indicates the place. (Figure 1.)

Figure 1. Logos and typography of Radomir, Gorna Malina, Chiprovtsi and Kostinbrod municipalities



Source: author's development of Vihra Ognyanova, "PRIM DESIGN" OOD, 2023, developed on behalf of Dr. Dessislava Alexova

The visual identity of the destinations shapes the impression of the services and products offered, through the visible elements of the brand and is essentially its visual language. Images are an extremely powerful form of communication precisely because they communicate on a primal, emotional level and unify the different aspects of a brand through consistent visuals. The main focus is on the application of logos in the production of various electronic, multimedia and printed materials and souvenirs. (Figure 2.)

Figure 2. Application of the logos of Radomir, Gorna Malina, Chiprovtsi and Kostinbrod municipalities



Source: author's development of Vihra Ognyanova, "PRIM DESIGN" OOD 2023, developed on the assignment of Dr. Dessislava Alexova

The development and implementation of *voluntary quality certification* is a tool that is an integral part of the tourist brand of the destination. Its implementation is based on the need to create and impose a more effective marketing tool through which the products of the destination and the region are better recognizable and therefore more competitive in the market. The first regional quality brand of a tourist destination is implemented in the

municipality of Radomir and It is an integral part of the overall brand of the destination.

The standards for evaluation and certification with "Radomir Trademark" were developed by Dr. Desislava Aleksova on the model of the certification system of Pan Birds Foundation, that of the Regional Tourist Association "Stara Planina", Strandzha Nature Park and "Botevgrad Trademark". The main objective of the Standards is to support the imposition of a sustainable model of tourism and local economic development in the municipality of Radomir, as well as to choose a sign by which the tourist destination will be attractive enough and unique.

Voluntary quality certification includes three categories: **tourist sites**: accommodation places, catering and entertainment establishments, tourist attractions (equestrian centers, craft workshops, event-type attractions, etc.); cultural **institutes** – museums, galleries, community centers; local, **products** – farms, craft workshops, food and dishes, drinks, handicrafts, etc. (Figure 3) At the end of 2022, within the city holidays, the first 10 quality certificates were officially awarded – 3 for each category, as well as a special award to the mayor for the most active cultural figure in the municipality.

Figure 3. Certificates for quality "Regional Trade Mark Radomir"



Source: author's development of Vihra Ognyanova, "PRIM DESIGN" OOD 2023, developed on the assignment of Dr. Dessislava Alexova

The 7 main principles of responsible marketing on which the quality criteria of voluntary certification focus include: focus on the interrelationship of visitors with the natural environment and cultural heritage of the region; emphasis on good interpretation through better understanding, assessment and satisfaction with the contact with the culture and nature of the region and the relevant experience; efforts to prove existing practices of sustainability of tourism and minimal negative ecological impact; providing benefits to the local community; respect for the local culture by integrating it into the offered tourist products, services and goods; proven customer care through responsible attitude and meeting the expectations of the user; correctness and adequacy of the presented information, advertising and offering, forming realistic expectations of the guests.

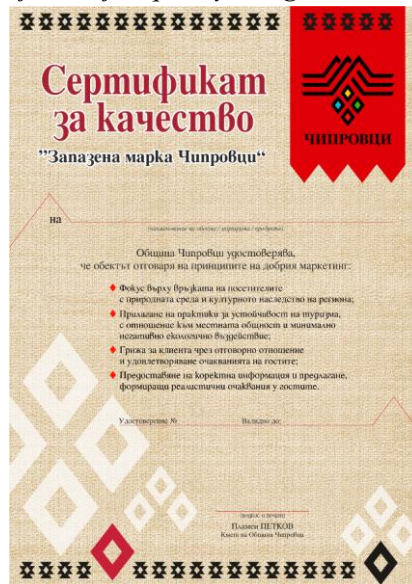
On the same principle, the author has developed concepts for voluntary quality certification of the municipalities of Gorna Malina (Figure 4) and Chiprovtsi (Figure 5). The regional trademark is included as a measure for the implementation of some of the priorities in the strategies for sustainable development of tourism in both municipalities but has not yet been implemented in practice.

Figure 4. Certificates for quality “Regional Trade Mark Gorna Malina”



Source: author's development of Mihail Tenev, 2021, developed on the assignment of Dr. Dessislava Alexova

Figure 5. Certificates for quality “Regional Trade Chiprovtsi”



Source: author's development of Vihra Ognyanova, "PRIM DESIGN" OOD 2021, developed on the assignment of Dr. Dessislava Alexova

An example of application can be given with the tourist portal of Botevgrad municipality, which was developed according to the author's concept of Dr. Desislava Aleksova and under her methodological guidance. The vision on which the web platform is developed is innovative, user-oriented and content moderator-friendly software.

Web design is characterized by originality and is in line with modern trends in the provision of information. It is characterized by intuitive navigation, product recognition, consideration of user habits, high level of digitization of tourist products and services. (Aleksova, 2018: p.64)

Built-in modern functionalities enable users and potential tourists looking for information to quickly and easily reach attractively presented electronic content, formed in logical structures - categories, subcategories, articles, tailored to user habits. (Figure 6.)

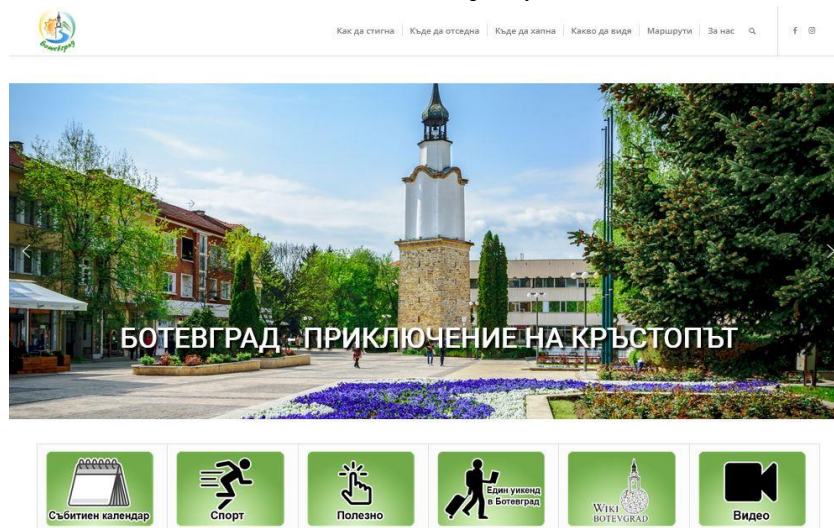
The web portal is developed graphically, taking into account modern trends: clean web design, recognizable colors characteristic of the destination, fast

loading content and "responsive" design - recognizes the type of mobile device used by the user and rearranges electronic content in the most convenient way for him a way.

The basis for development is a content management system (CMS) with a database (DB), which allows rapid further development as needed: addition or exclusion of existing functionalities, archiving of information, subscription system for automated sending of information to users, after publication of new information and depending on the sections of content to which the respective user has subscribed.

The electronic profiles have their own software solution ("custom software development"), which enables the various categories and subcategories to be individualized according to the need to add or reduce functionalities (tabs, buttons, Google maps, internal and external hyperlinks and etc.).

Figure 6. Home page of the tourist portal of Botevgrad municipality



Source: <http://www.visitbotevgrad.com/>

The website features integration for quick connection with social networks and a purpose-built YouTube channel where event videos are posted to attract visitors and tourists. (Aleksova, 2018: p.65)

There is convenience in creating, publishing and managing electronic content with easy tools to edit text, post photo, add hyperlinks, add video, create

site/landmark map, etc. The software solution enables the management of various roles in publishing and content management.

4. Conclusion

In summary, the digital transformation of the tourism business requires: a clear branding strategy; mobile-optimized e-commerce website and store; online marketing strategy before, during and after the trip; a marketing team that monitors trends in tourism markets; share (at least 20%) of the tourism company's marketing budget allocated to new digital media (webfx, Digital marketing for tourism).

Creating a visual identity of a tourist destination is an essential element of digital marketing, as the goal is to achieve emotional impact and brand attachment among consumers. The formulation of preferences for it is based on a recognizable image, a good reputation, awareness of its main competitive advantages. Managing these components helps the destination stand out in the minds and hearts of consumers.

The developed visual identity of the municipalities of Radomir, Chiprovtsi, Gorna Malina and Kostinbrod contributes to building their image and is an integral part of an overall concept for their unique positioning as emerging tourist destinations. This is done by formulating key messages that are linked to distinctive and recognizable symbols by the public and the local population, choosing an appropriate color scheme and typography.

Thus, through visualization, the tourism brand of each of the four destinations aims to be recognized, accepted and promoted by the local community and the general public. The example with the visualization and functionalities of the Botevgrad municipality web portal shows how the advantages of digital marketing are applied in practice in a user-friendly way.

The visual identity, tailored to the particularities of the destination, helps to focus on the product with high development potential and to stimulate the drive to improve the tourist offer and strengthen the brand. A necessary condition is the active use of the brand, its enrichment over time with new elements in sync with the developed visual identity, while at the same time steadfastly following the goals defined in the strategic documents.

For this purpose, it is mandatory to have a clear marketing plan aimed at the identified audiences, to apply the practically defined marketing and communication guidelines and to develop different types of advertising, according to the goals and guidelines of the plan.

The methodology used (Aleksova, 2020), the research and community approach to work is based on surveys and work with local people and external audiences, to whom the digital marketing will be directed and thus contributes to the perception of the visual identity of the destination.

References

Aleksova, D., V. Ognyanova. (2022). Building a visual identity as part of the tourist brand of the destination following the example of Radomir. In: Collection of reports from the V scientific conference with international participation "Geography, regional development and tourism - modern dimensions", Univ. ed. "Bishop Konstantin Preslavski", Shumen, pp. 13-21

Aleksova, D. (2021). Sustainable development of Chiprovtsi municipality as a tourist destination. Creating a tourist brand and strategic planning, Academic publishing house: About letters - About letters, Sofia, 418 p.

Aleksova, D. (2018). Innovative initiatives contributing to the transformation of Botevgrad municipality into an attractive tourist destination. In: Proceedings of the XIV International Scientific Conference Tourism - Research, Development and Training. Sofia, MVBU, pp. 63-80.

Aleksova, D. (2020). Methodology for sustainable development of a tourist destination, In: collection of reports from the International Student-Doctoral Conference "Sustainable Tourism - Perspectives and Challenges", ed. "Avangard Prima", Sofia, pp. 263-277

Antevenio, Examples of tourism digital marketing, <https://www.antevenio.com/usa/examples-of-tourism-digital-marketing/>

Digital Marketing for Tourism: 4 Undeniable Advantages, <https://www.webfx.com/industries/tourism-hospitality/tourism/>

DOI: 10.20544/SERBE.08.02.23.P04

STRATEGIES FOR RISK MITIGATION IN THE SUPPLY CHAIN SYSTEM

David Saltamarski¹

Abstract

Supply chains are a critical aspect of how the economy works, but they are not often highly visible. The paper aims to emphasize the potential risks that may arise in the process of global supply chains. Namely, in the past, various crises appeared quickly and threw new risks into the supply chain. In this paper, attempts have been made through desktop research of relevant publications and analysis of some practices to identify various risks caused by COVID-19 and to propose strategies for dealing with them. Several scientific research methods were used during the work of the paper: analysis and synthesis, the method of induction and deduction, and descriptive analysis. The main challenges were uncertainty in demand, logistical disruptions, and dependence on China as a supply chain partner. Regarding the solutions, every challenge needs a different approach, and the solution can vary in the industry and the region. The main proposed solutions were focused on the improvement of operational flexibility, digital and advanced technologies, localized supply sources, and resilient sourcing strategy.

Keywords: Supply Chain Risk, Supply Chain Management, Strategy, Supply Chain Challenges, COVID-19

¹ Faculty of Economics - Prilep, PhD candidate, davidsaltamarski@yahoo.com

1. Introduction

In the era where disruption is the new normal, supply chain resilience has become a critical requirement for businesses rather than an optional strategy. The supply chain and its management are the hidden engines that drive the economy. Global events, ranging from trade wars to pandemics to military conflicts, have highlighted the fragility of our interconnected global supply chains. Ensuring their reliability and robustness in uncertain times is a challenge that businesses must confront. Lockdowns, including closing businesses and remote working, in countries around the world, have hindered the flow of raw materials, people, and finished products in the supply chain.

Institute of Shipping Economics (ISL) measured the container throughput index, which is used to measure the volume of goods moving through shipping ports each day, fell from 113.3 in January 2020 to 107.7 in September 2020 down to 9,5%. According to the estimation of the United Nations (UN), global demand and disruption through global supply chains decreased by around 15% in 2020, due to the pandemic.

When it comes to risk in the literature, there are many types and concepts of risks. Businesses face various challenges such as pandemics, military crises, and energy problems. Each of these situations presents unique obstacles, and businesses must adapt to the changing landscape to survive and thrive. To identify certain applied strategies for solving risks in the supply chain were analyzed seven papers dealing with topics related to supply chain and the challenges of COVID-19.

2. Literature review

Since the first outbreak of the COVID-19 pandemic, more than 220 countries and territories have seen more than 1 infection so far. By early December 2023, there are more than 774 million confirmed cases of COVID-19, persistently and more than 7 million deaths in the World Health Organization. (<https://data.who.int/dashboards/covid19/cases?n=c>)

Many studies indicate that the crisis with the Covid 19 pandemic has caused serious economic disruptions and seriously damaged supply chains (Mooshavi 2022). Major companies operating in the world market have experienced a severe contraction in operations, and production flows have been affected (Ivanov 2022). All parts of the supply chain experienced serious challenges, discontinuity and inefficiencies along the supply chain and major delays in distribution. The shock that was a product of the pandemic that resulted in the disruption of travel and the slowdown of trade caused the stock markets to fall. Due to trade relations between the US and China, many companies have reconfigured their supply chains, diversifying their choice of suppliers to achieve greater flexibility (Lorenzo 2023). According to Paul, (2022) uncertainty of demand and serious logistical disruptions were among the top challenges in the crises. Only a few industries (accounting for 11%) reported having a positive impact during the pandemic. These companies are predominantly in the life sciences sector and the positive impact can largely be attributed to the core products they produce.

3. Research Methodology

The purpose of this research is to analyze, write a literature review, and discuss the proposed solutions to the matter. Furthermore, for this paper relevant literature has been selected. To investigate supply chain challenges, a two-step procedure was followed. In the first step, relevant articles were identified via the Research Gate database search engine, using the keywords- (“COVID-19”) and (SUPPLY CHAIN CHALLENGES/ BARRIERS)”. The Research Gate results initially suggested a lot of articles. There are a lot of studies specifically discussing the challenges to the supply chains during the COVID-19 pandemic. We focused on articles where specific challenges were researched and proper solutions were given. Several scientific research methods were used during the work of the paper: analysis and synthesis, the method of induction and deduction, and descriptive analysis. When presenting the material, the methods of theoretical and empirical analysis were used through desktop research.

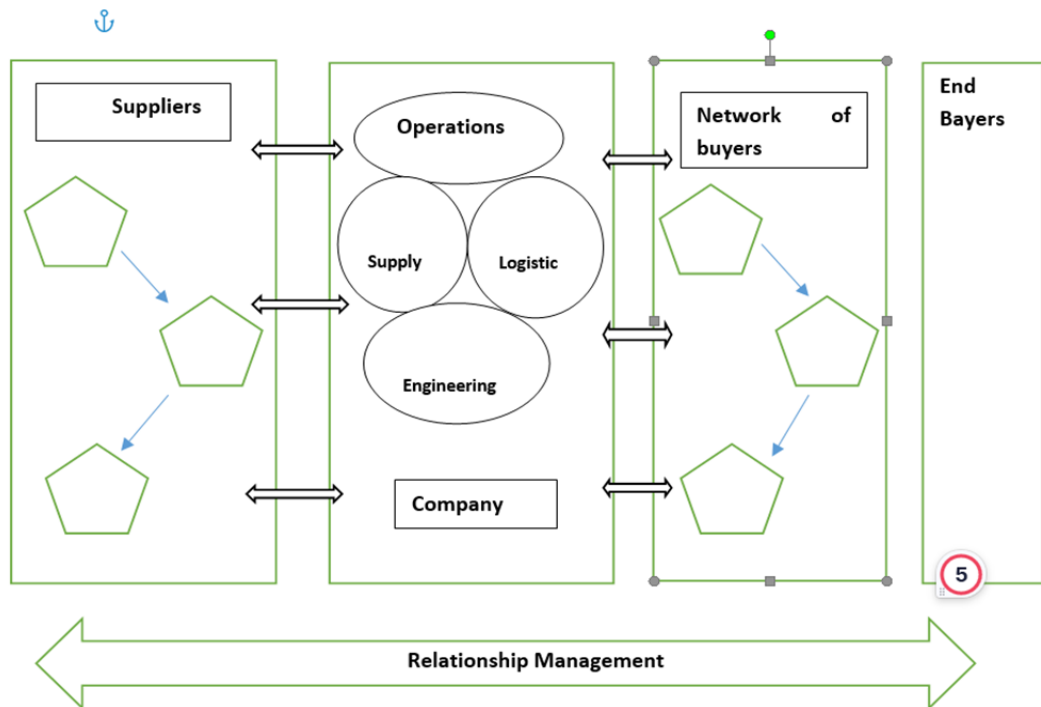
4. Supply Chain management characteristics

With the increase in work processes and the need to overcome human and organizational barriers, there is a great expansion and diversification of the market. Towards the end of the 20th century, the economic trends were marked by the massive globalization of goods and information services, as well as the intensive development of processes. Competition has reached large proportions, while consumers have become even more demanding and with greater demands. The previous work of the business entities increased and burdened the distribution channels in those circumstances. Supply chains represent complex and dynamic systems in which the flows of production, services, information, capital, and knowledge are intertwined. Intensification of globalization processes of the markets, companies increasingly realize the necessary development of efficient supply chains and logistics networks around the world. Supply chains can help the management of globally oriented companies to identify better suppliers, increase productivity in supply, reduce total operating costs, and improve competitive position in given markets. (Regojic, 2014)

The term supply chain management (SCM) was first used by consultants in the early 1980s, and since then has become a widely used term. (Oliver, Webber, 1982).

However, there is no unified definition of what exactly the supply chain means, so different authors give different definitions on this topic. The author Christopher (2011) defines the supply chain as the relationship between dependent and independent organizations that work together to implement, control, and upgrade the material and information flow from the supplier to the buyer. Supply Chains (SC – Supply Chain) are complex and dynamic systems with intertwined flows of products, services, information, money, and knowledge.

Figure 1. The flow of production, services, information, money, and knowledge



Source: Regodic, 2014 (p.10)

With the intensification process of market globalization, companies increasingly understand the necessity of developing effective supply chains and logistics networks around the world. Supply chain studies can help the management of a globally oriented company to identify superior suppliers, increase productivity in supply, to reduce the total cost of doing business, and improve competitive position in target markets. To understand how a company can improve its supply chain and above all its efficiency and speed, we must consider and understand the driving elements in the supply chain, namely: facilities, inventory, transportation, information, sources, and prices. According to Chopa and Meindel (2013), these driving elements can determine the performance of supply chains in terms of their efficiency and speed.

5. Risk in the Supply chain

When it comes to risk in the literature, there are many types and concepts of risks. Businesses face various challenges amid pandemics, military crises, and energy problems. Each of these situations presents unique obstacles, and businesses must adapt to the changing landscape to survive and thrive. Singh, Jain, and Mishra (2009) defined risk as "a process in which decisions are made to accept a known or estimated risk and/or implement actions to reduce the consequences or probability of occurrence".

The dynamism of business processes and the market in today's globalized economy is characterized by a great deal of turbulence and uncertainty. Market turbulence refers to periods when the financial markets are experiencing rapid and violent price movements (Hull, 1996). According to the World Bank "Market turbulences during the COVID-19 pandemic were characterized by heightened volatility, liquidity concerns, and rapid shifts in investor sentiment, reflecting the uncertainties surrounding the economic impact of the virus."

Market "turbulences" have increased especially in recent years, and the Covid pandemic has had a large and significant effect on such processes. Demand in almost every industry sector is more sensitive than in the past. At the same time, the vulnerability of supply chains and their disruption or disruption has increased. It is not only the effect of external events such as natural disasters, strikes, or terrorist attacks but also the impact of changes in the business strategy of companies (Christopher, 2011).

Many companies have experienced changes in their supply chains and as part of changes in business models. According to Christopher (2011), research done in North America suggested that when companies experienced significant changes there were problems in the chains. Of course, if this problem becomes public, the fall of the companies' shares is inevitable. The research indicated that companies that faced such problems saw their operating income drop by 107%. There was also a 114% decrease in the

return on sales, while the return on assets decreased by 93% (Christopher, 2011).

There are two types of risks that the supply chain can face, and they can be of an internal and external nature. External risks can occur as a cause of an epidemic such as COVID-19, war, or terrorist attack or as a cause of a government decision or state legislation. On the other hand, internal risks come as a reason for the management and structure of the chain. According to Christopher, (2018), we can consider that there are five generic sources of risks in the supply chain, and they are: (Christopher, 2018)

- Supply risk - Supply chain risk refers to any potential disruption that can negatively impact the supply chain. (Sheffi and Rice, 2005).

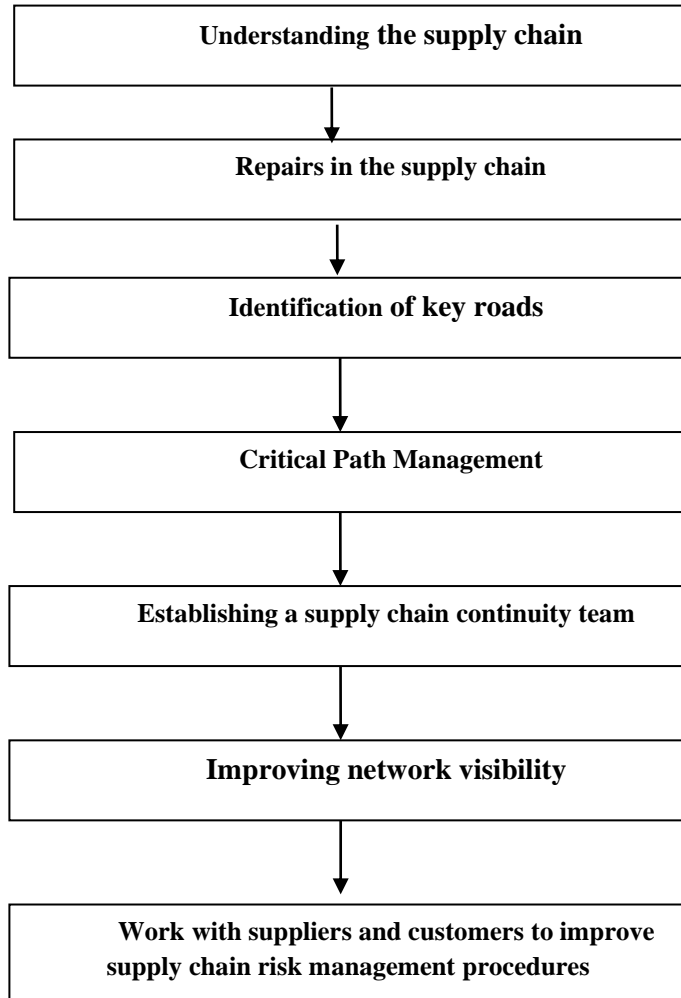
- Risks in the process - In "Managing Risk to Avoid Supply-Chain Breakdown" (2014), Chopra and Sodhi emphasize the risk of disruptions in the supply chain processes. This includes the potential for disruptions in transportation, production, or sourcing that can impact the flow of goods

- Controlled risk- In their paper "Developing market specific supply chain strategies" (2002), Christopher and Towill discuss the concept of agile and responsive supply chains as a means of controlling risks. Such supply chains are designed to adapt quickly to changes and disruptions.

- Environmental risks - In their paper "From a Literature Review to a Conceptual Framework for Sustainable Supply Chain Management" (2008), Seuring and Müller discuss the challenges of integrating environmental concerns into supply chain management. They highlight the need for a conceptual framework that includes environmental risks and sustainability practices.

Considering the risks, there are seven stages of risk management in the supply chain, and those stages are shown in Figure 2:

Figure 2: Stages of risk management



Source: Christopher, 2018

Every company is exposed to supply chain vulnerabilities, and this is characteristic of all business environments. That is why company decision-makers and managers need to assess the vulnerability of the supply chain that their company could experience. Sheffi and Rice, (2005), argue that vulnerability assessment primarily involves asking and answering three key

questions. The first one is what can go wrong. The second one is about the probability of this happening, and the third one is about the consequences if that happens.

As I mentioned earlier, risks and interruptions can be caused by external and internal factors and the probability assessment methods for each class differ. Natural disasters such as earthquakes, hurricanes, floods as well as other external hazards can be estimated based on historical data for the given region or object of interest. The likelihood of accidents can also be estimated from industry data, previous events, and the company's safety program. (Bird F, Bird Jr, 2003). On the other hand, according to Sheffi and James, (2005), deliberate interruptions known as adaptive, i.e. adaptive threats designed by the perpetrators themselves to cause maximum damage, can also occur and are very difficult to assess because there is no historical data for them. (Sheffi and James, 2005). Authors Sheffi and James, (2005), in their research review of the supply chain in resilient enterprises present an enterprise vulnerability map. Nowadays, especially with the rise of AI, software tools are playing a crucial role in this sector. In "Supply Chain Risk Management: A New Methodology for a Systematic Literature Review" (2019) from Trkman, P., & McCormack, K, the authors discuss the potential of blockchain technology to enhance transparency and reduce risks in the supply chain. Blockchain can be utilized to create a secure and transparent record of transactions across the supply chain. Supplier Relationship Management (SRM) software tools can help companies assess and manage the performance and risks associated with their suppliers (Monczka et.al 2015).

6. Strategy for Mitigating Supply Chain Risks

To identify certain applied strategies for solving risks in the supply chain were analyzed seven papers dealing with topics related to supply chain and the challenges of COVID-19.

As for this section, various research papers are analyzed throughout desktop research, and they are shown in the table below. To investigate supply chain

challenges, a two-step procedure was followed. In the first step, relevant articles were identified via the Research Gate database search engine, using the keywords- (“COVID-19”) and (SUPPLY CHAIN CHALLENGES/ BARRIERS)”. The Research Gate results initially suggested a lot of articles. There are a lot of studies specifically discussing the challenges to the supply chains during the COVID-19 pandemic. We focused on articles where specific challenges were research topics and proper solutions were given. The main challenges that were found were uncertainty in demand, logistical disruptions, and dependence on China as a supply chain partner. Regarding the solutions, every challenge needs a different approach, and the solution can vary on the industry and the region. The main proposed solutions were focused on the improvement of operational flexibility, digital and advanced technologies, localized supply sources, and resilient sourcing strategy. (Raj et.al 2022)

Table 1: Supply chain Challenges and Barriers

<i>Paper</i>	<i>Challenges</i>	<i>SUPPLY CHAIN CHALLENGES/ BARRIERS</i>
A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19 (Paul and Chowdhury 2021)	Uncertainty of Demand	Significant improvements in the total profit if manufacturers can implement both recovery strategies simultaneously
Strengthening supply chain resilience during COVID-19: A case study of JD.com (Sun and Shen 2021)	severe logistical disruptions	Suggests firms pay attention to operational flexibility and collaboration

		beyond supply chains to deal with a large-scale supply chain disruption, such as the COVID-19 outbreak
Manufacturing in the Time of COVID-19: An Assessment of Barriers and Enablers (Okorie O at al ., 2020)	Endogenous disruption of manufacturing processes and systems as well as extreme shifts in demand and supply caused by exogenous supply chain disruption.	The rejigging of Manufacturing Toolboxes; Building Organizational Flexibility; Digital Technologies; Rapid Decision-Making; Identifying and Dedicating Resources for Repurposing; Benchmarking
Manufacturing and service supply chain resilience to the COVID-19 outbreak: Lessons learned from the automobile and airline industries (Belhadi et al., 2021)	Dependence on China as a global supply chain partner over the past two decades.	The automobile industry perceived that the best strategies to mitigate risks related to COVID-19 were to develop localized supply sources and use advanced industry 4.0 (I4.0) technologies.; The airline industry on the other hand, perceived that the

		<p>immediate need was to get ready for business continuity challenges posed by COVID-19, by defining their operations both at the airports and within the flights; Importantly, both the sectors perceived Big Data Analytics (BDA) to play a significant role by providing real-time information on various supply chain activities to overcome the challenges posed by COVID-19; Cooperation among supply chain stakeholders is perceived, as needed to overcome the challenges of the pandemic, and to accelerate the use of digital technologies.</p>
<p>Supply chain management challenges of the food industry during the outbreak</p>	<p>Significant weaknesses of the transport</p>	<p>Identify trusted suppliers capable of availing needed</p>

<p>of covid-19 pandemic (Albufalah and Tariq 2020)</p>	<p>sector</p>	<p>products during this period of the pandemic. The management should consider developing a lasting relationship with these suppliers. These firms must find ways of storing food products that are not perishable. The government should consider empowering local farmers to reduce the level of reliance on imports.</p>
<p>Covid-19 and the South African pharmaceutical supply chain: drivers, strategies, and recommendations (Takawira and Pooe 2023)</p>	<p>Price hikes, supply shortages, and logistical complications</p>	<p>Implementing dynamic pricing mechanisms, developing resilient sourcing strategies, using ICT effectively, improving inventory management, and enhancing logistics management are recommended for robust supply chain</p>

<p>Impacts of COVID-19 on the Food Supply Chain for Arable Crops in Latvia (Upite, et al., 2022)</p>	<p>Unprecedented stress to food supply chains, pointing to weaknesses in the labor, processing, transport, and logistics spheres, as well as significant changes in demand</p>	<p>operations</p> <p>1) Prioritizing food production and processing, through ensuring the flow of food and raw materials between countries, stimulating domestic consumption and introducing measures to increase exports; improving access to loans during the crisis; improving the availability of services provided by national institutions under the conditions of remote work;</p> <p>2) effectiveness and availability of financial support measures already in place need to be improved, yet it is required to cut red tape and increase the flexibility of conditions for receiving government support</p>
--	--	---

	<p>during the crisis;</p> <p>3) more stable public policies for business development, access to loans and the willingness of banks to lend to businesses both during and after the crisis, increased protection of domestic goods, support for export-orientated businesses and reduced VAT rates on food products are needed.</p>
--	--

Source: Author Analysis

Supply Chain Management (SCM) is the management of a network of interconnected businesses involved in the ultimate provision of product and service packages required by end customers (Harland, 1996). For the supply chain drivers to work together, with the goal of integrated and effective supply chain management, the sharing of information among supply chain networks is crucially important. Information also improves performance and mitigates the risk in the supply chain because it provides processes executed transactions and creates opportunities for decision-makers when they need it and in the format, they need it. (Varma, Khan, 2014) In essence, that is the IT role and it consists of hardware and software applications. To satisfy the quality of the product, Information technology plays a significant role in integrating the suppliers, distributors, and manufacturers as well. Enabling a

single point of contact for data, providing information availability and visibility, allowing decisions based on total supply chain information, and enabling collaboration with partners are the objectives of IT in SCM. (Simchi et al ., 2003)

In addition, IT has the role of linking the point of production seamlessly with the point of delivery or purchase. It is of crucial importance to have an information trail that follows the product's physical trail. These essentials allow for planning, tracking, and estimating lead time based on real data (Simchi et al ., 2003).

The application of diverse technologies such as sensors, artificial intelligence, cloud computing, digital twins, and predictive analysis is rapidly changing the way companies design, manufacture, distribute, and service products. It is also changing how they perceive and manage supply chain risk. The primary driver behind a digitalized supply chain is to create a responsive, agile, and transparent supply chain network that can adapt quickly to unknown variables (Trent, 2021).

In the recent wake of COVID-19, disruptive digital technologies have emerged as a key tool to manage supply chain risk (Yang 2020).

7. Conclusion

In the contemporary landscape, characterized by persistent disruptions, the imperative for supply chain resilience has transcended the realm of optional strategy to become a critical necessity for businesses. Global events such as pandemics, trade wars, and military conflicts have underscored the vulnerability inherent in our interconnected global supply chains. Navigating the uncertainties of these complex challenges has become an intrinsic part of business operations.

The research undertaken in this paper sought to emphasize the potential risks embedded in the processes of global supply chains, with a focus on COVID-19 crises. Through a comprehensive desktop analysis of relevant publications and an examination of practical approaches, the study identified

and delineated various risks, especially those emerging during crises. The main challenges that were found were uncertainty in demand, logistical disruptions, and dependence on China as a supply chain partner. Regarding the solutions, every challenge needs a different approach, and the solution can vary in the industry and the region. The synthesis of findings revealed that businesses must adopt a multifaceted and agile approach to risk management, tailoring their strategies to the unique demands of each challenge.

References

Albufalah and Tariq (2020). Supply chain management challenges of food industry during the outbreak of covid-19 pandemic

Belhadi Amine Belhadi, Sachin Kamble, Charbel Jose Chiappetta Jabbour, Angappa Gunasekaran, Nelson Oly Ndubisi, Mani Venkatesh (2021). Manufacturing and service supply chain resilience to the COVID-19 outbreak: Lessons learned from the automobile and airline industries DOI: 10.1016/j.techfore.2020.120447

Chorpa S and Sodhi M (2004). Managing Risk to Avoid Supply - Chain Breakdown MIT Sloan Management Review

Christopher and Towill (2002). Developing market specific supply chain strategies, DOI: 10.1108/09574090210806324

Christopher, M. (2011). Logistics and Supply Chain Management. 4th Edition, Prentice Hall, London.

Chopra, S., & Meindl, P. (2013). Supply Chain Management: Strategy, Planning, and Operation (5th ed.). Prentice Hall.

Harland S, (1996). Supply Chain Management: Relationships, Chains and Networks, *British Journal of Management*

<https://www.worldbank.org/en/what-we-do> (accessed 03.12.2023)

Ilze Upite, Dina Bite, Irina Pilvere Aleksejs Nipers (2022). Impacts of COVID-19 on the Food Supply Chain for Arable Crops in Latvia

Jiayan Yang, Vikas Kumar, Vikas KumarBanu, Yetkin Ekren, Banu Yetkin Ekren, Evgeny Kuzmin, Evgeny Kuzmin, (2020). Understanding the role of digital technologies in supply chain risks DOI: 10.1007/978-3-030-73261-5_13

John C. Hull (1996). Financial Market Volatility: Measurement, Causes, and Consequences

Kim, K.; Kim, S.; Park, C.-Y. (2020). Food Security in Asia and the Pacific amid the COVID-19 Pandemic. ADB Briefs

Lin, B.-X.; Zhang, Y.Y. (2020). Impact of the COVID-19 pandemic on agricultural exports. J. Integr. Agric

Monczka, R. M., Handfield, R. B., Giunipero, L. C., & Patterson, J. L. (2015). Purchasing and Supply Chain Management

Okorie Okorie, Ramesh Subramoniam, Ramesh Subramoniam, Fiona Charnley Fiona, Charnley Show, Konstantinos Salonitis, Fiona Charnley

John Patsavellas (2020). Manufacturing in the Time of COVID-19: An Assessment of Barriers and Enablers, DOI: 10.1109/EMR.2020.3012112

Oliver, R. K and Webber, M. D. (1982). Supply chain management: logistics catches up with strategy

Paul and Chowdhury (2021). A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19, DOI: 10.1108/IJPDLM-04-2020-0127

Raj A, Mukherjee A, Jabbour A, Srivastavac S, (2022). Supply chain management during and post-COVID-19 pandemic: Mitigation strategies and practical lessons learned, DOI: 10.1016/j.jbusres.2022.01.037

Regojic D, (2014). Logistika , Univerzitet Singidunom

Seuring and Müller (2008). From a Literature Review to a Conceptual Framework for Sustainable Supply Chain Management, DOI: 10.1016/j.jclepro.2008.04.020

Shefi and Rice (2005). A Supply Chain View of the Resilient Enterprise. MIT Sloan Management Review 47

Simchi L., (2003). Designing and managing the supply chain. Concepts, strategies, and case studies (2nd ed). Boston

Singh A.R, Rajeev Jain, Mishra P.K, (2009). Risk in Supply Chain Management. DOI: 10.13140/2.1.4093.7923

Sun and Shen (2021). Strengthening supply chain resilience during COVID-19: A case study of JD.com DOI: org/10.1002/joom.1161

Takawira and Pooe (2023). Covid-19 and the South African pharmaceutical supply chain: drivers, strategies, and recommendations DOI: 10.20525/ijrbs.v12i8.2973

Trent R. (2021). Managing risk better, faster, and smarter with digitized supply chains

Trkman, P., & McCormack, K, (2019). Supply Chain Risk Management: A New Methodology for a Systematic Literature Review

Varma and Khan, (2015). Information technology and e-risk of supply chain management, DOI: 10.5897/AJBM2013.7308

About the publisher

The Faculty of Economics - Prilep is a member of the University “St. Kliment Ohridski” – Bitola. The Faculty of Economics – Prilep is divided in Departments embracing a range of related disciplines that enables successful implementation of the teaching and applicative activities, as well as the scientific research. The departments mainly cover issues regarding development of the study programmes, teaching and research work and other administrative activities. The Faculty of Economics - Prilep comprises the following five departments: Management, Marketing and Business; Economics and development; Accounting, finance and audit; International economics and Business informatics. The research activities in the Faculty of Economics - Prilep are organised by the Research Centre as a separate organisational unit. The Centre has played a key role in the preparation and realisation of several international conferences on various subjects. In addition, the members of the Centre have participated in a number of international projects, the main goal of which is implementing reforms in the higher education. The Faculty of Economics - Prilep was a coordinator in some of these projects, whereas in others it was a partner together with other institutions from South-Eastern Europe and the European Union. Therefore, the Faculty of Economics - Prilep has developed itself into a modern higher education institution which represents an example of successful promoter of knowledge in the region of South-Eastern Europe

