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Leslie Bermont

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Leslie Bermont. Three essays on Development Economics : Food Security and Nutrition. Economics and Finance. Université Paris sciences et lettres, 2021. English. NNT : 2021UPSLD005 . tel-03545829

HAL Id: tel-03545829

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THÈSE DE DOCTORAT
DE L'UNIVERSITÉ PSL

Préparée à l'Université Paris-Dauphine

**Three essays on Development Economics:
Food Security and Nutrition**

Soutenu(e) par

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Le 5 Juillet 2021

Ecole doctorale n° ED 543

Ecole doctorale SDOSE

Spécialité

Sciences économiques

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A Marcos

“If your compassion does not include yourself, it is incomplete.”

Remerciements

Paris, 28 Avril 2021

Depuis presque cinq ans maintenant, je me suis lancée dans l'ardue (mais belle) aventure de la thèse. Par elle, simultanément à elle, et surtout grâce à l'amour qui m'entoure, ma vie est une chance et une merveille à chaque instant. Par les quelques lignes qui suivent j'aimerais humblement remercier les personnes qui ont rendu cette thèse possible et qui m'ont aidée à la vivre.

Je remercie de tout cœur ma directrice de thèse Emmanuelle Lavallée – pour m'avoir accompagnée et soutenue depuis le master, pour m'avoir encouragée à suivre et à peaufiner mes idées (même si elles ne semblaient pas être à la mode dans le monde de la recherche), pour m'avoir fait confiance et m'avoir aidée (peut-être même sans le savoir) à surmonter ma peur de l'imposture. Merci pour votre gentillesse, vos sourires et bien sûr vos nombreuses relectures et vos conseils précis et avisés. Merci de m'avoir montré que l'on pouvait être humaine, sensible, et chercheuse à la fois. Je suis convaincue que le monde académique nécessite plus de chercheurs qui vous ressemblent. Je franchis cette étape de la vie forte de toute l'expérience que j'ai acquis auprès de vous. Merci !

Aux membres de mon jury je souhaite leur exprimer toute ma gratitude. Merci d'avoir accepté de lire et commenter mon travail, merci de m'accorder une partie non négligeable de votre temps malgré toutes les difficultés actuelles. Je suis certaine que vos retours et points de vue sur ce travail contribueront à améliorer ma recherche – celle relayée par cette thèse mais également celle à laquelle je m'attèlerai peut-être dans le futur. J'adresse à Sylvie Démurger et Nicolas Sirven un remerciement particulier pour remplir le rôle de rapporteur ; j'ai conscience de la grande implication que cela leur demande. Merci à Paolo Veneri d'avoir la gentillesse de faire partie de mon jury, j'admire son travail au sein de l'OCDE et sais que son expérience m'aidera à affiner ma recherche ainsi que ma façon de travailler. Enfin, je souhaite porter un immense merci à Elodie Djemaï et Elise Huillery. Après avoir été membres de mon Comité de Suivi pendant quatre ans, elles sont aujourd'hui toutes deux membres de mon jury de thèse et j'en suis honorée. Merci pour votre bienveillance toujours, et pour vos précieux retours qui ont, chaque année, contribué à éclairer considérablement mes recherches.

Je n'aurais jamais pu évoluer dans un cadre de travail si paisible et fructueux sans la bienfaisance d'Hélène Lenoble, Baptiste Venet et Céline Lasnier qui m'ont permis de découvrir le métier d'enseignante dans les plus belles conditions qui soient (meilleur cours de macro !). C'est grâce à leur dévotion pour le bien-être de leurs chargés de TD que j'ai pu trouver petit à petit mon équilibre d'énergie entre enseignement et recherche. Avec le même esprit et la même pensée positive, je remercie Sandrine Dufour-Kippelen et Daniel Herrera qui m'ont si bien accueillie au sein de leur équipe et m'ont offert l'opportunité de me lancer dans une activité pour laquelle je n'aurais pourtant jamais pensé être à la hauteur – donner des cours de Stata, un régal. A leurs côtés, je remercie Marion Mercier, Florence Jusot et Marta Menendez pour leurs précieux retours sur mes papiers, ainsi que toutes les équipes du LEDa, de DIAL et l'Ecole Doctorale de Dauphine, et surtout Eve Caroli, pour m'avoir donné l'opportunité de m'inscrire en thèse même sans financement – cette décision à l'origine de ce merveilleux voyage de vie !

A tous les copains du doctorat, merci pour votre présence et votre bonne humeur tout au long de ces cinq années ! En commençant la thèse, je ne m'attendais pas à rencontrer de belles personnes comme vous ; et je m'attendais encore moins à faire l'expérience d'une telle entraide entre doctorants. Vous avez toujours été là pour démêler les petits soucis de raisonnement, pour résoudre les petits problèmes de code sous Stata, ou tout simplement pour écouter et partager un café (ou des gâteaux, souvent des gâteaux), discuter longuement et nous changer les idées ensemble. Doriane, mon acolyte sur tous les fronts (thèse, macro, Ecole Doctorale et j'en passe), merci d'avoir partagé avec moi tant de moments depuis le tout premier jour, merci pour ton soutien, pour ces innombrables allers-retours entre ton bureau et le mien, pour nos moments détente et pour ton optimisme qui m'a bien souvent réconfortée. Eugénie, merci d'avoir fait revivre la P157, dans tous les sens du terme ! Tu as été la meilleure voisine de bureau, merci pour ta joie de vivre, ton amour des plantes qui nous a permis d'enfin reverdir ce bureau (et d'encourager une vague verte à travers le LEDa) et pour ta confiance, ta sensibilité et ton amitié. Noémie, merci pour ta douceur, ton aide constante et ton immense gentillesse qui m'a toujours tant touchée, tu es une merveille de personne. Amis du bureau P157, Clara, Quentin, Amine et Paul B., j'ai adoré partager le bureau avec vous et travailler à vos côtés, vous avez apporté à ce petit espace une belle énergie motivante et beaucoup de rires, tout ce qu'il fallait pour se sentir bien, alors merci. Charlotte, merci pour tes conseils (dans tous les domaines), ta prévenance, ton sens du détail et tes délicates attentions (comme ces petits cadeaux déposés discrètement

sur mon bureau). Thomas, merci pour tes coups de pouce et ta tranquillité qui m'ont souvent bien rassurée, on en aura fait du chemin en tant que chercheurs depuis le master (reste toujours ce fameux papier conflits-sécurité alimentaire !). Aux copains de la première heure de thèse et autres co-équipiers de la harde, Sarah, Lexane, Morgan, Alexis, Maroua, Cristian, Emy, Sandra et Dio, merci de m'avoir transmis votre vitalité et de toujours m'avoir acceptée dans des discussions parfois bien animées. Paul C., Arnold, Yohan, Eléonore, Adèle, Cécile, Aimée, Julien, Michelle, merci pour votre noblesse de cœur et pour avoir clairement contribué à me faire me sentir bien au bureau et dans la thèse en général. Un petit clin d'œil spécial aux filles de la Team(s) Yoga du mardi soir qui m'ont aidée à canaliser un peu mieux toutes ces émotions intenses de la période thèse-premier confinement. Je souhaiterais aussi remercier Marine, Pierre, Marion et Yeganeh pour avoir partagé avec moi leurs conseils pour vivre la thèse un peu plus sereinement ; et Florence pour m'avoir accueillie dans ce bureau ensoleillé.

Simultanément à mes années de thèse, j'ai eu la chance de rencontrer de véritables amis. Tous comptent énormément pour moi et je leur suis tant reconnaissante d'avoir également appris à me connaître. Rojo te quiero agradecer por tu apoyo en la tesis desde el principio cuando tú y Marcos me ayudaron a revisar mi presentación de candidatura; y más allá de esto, agradecerte por tu amistad y tu corazón grande. Toño, gracias por aceptarme en el Château, este espacio intemporal que acepta el amor de todos. Tania, Diana, gracias por animarme y siempre cuidarme. Todos ustedes con Paula, José Luis, Jaime, Elodie, Homero, son una parte importante de mi vida. Los quiero mucho y sé que pronto festejemos y bailaremos de nuevo, en el jardín de Andrésy. Merci à tous mes amis, à Claire, Anne, Mathilde, Deborah, Djéné, Hélène, Lucie et Anna, pour leur soutien et leur amitié de toujours malgré mon emploi du temps débordé.

Ma vie est remplie d'êtres merveilleux, qui m'ont fait grandir avec tant d'amour dans le cœur. J'ai la chance immense d'être née dans ma famille ; vous m'avez toujours aimée, toujours valorisée, toujours encouragée si je doutais de moi, et rassurée quand j'avais peur ou que j'étais tourmentée. Maman, merci de toujours m'entourer de ta si douce tendresse, de veiller sur moi et de m'avoir inculqué ta force de vie, depuis toujours tu fais tout pour que je sois épanouie et heureuse et je le suis ; Papa, merci de m'avoir appris à voir et à penser avec mon cœur, merci d'être toujours auprès de moi, merci pour ton amour et pour me faire inscrire la vie dans l'Univers ; Lolo, merci d'être dans ma vie, merci de prendre soin de moi et de me chérir si

fortement depuis toujours. Chacun de vous m'a appris à sa manière à ouvrir mon esprit et mon cœur ; vous m'avez donné l'amour qui m'a aidée à tenir bon pendant toutes mes études et à construire sereinement ma vie. Papy, Mamie, Mamie Lou, Papy Georges, merci de m'avoir montré que l'on faisait toujours le bon choix et que tout était possible. Merci à Bruno, Jocelyne, Muriel et toute la famille pour veiller les uns sur les autres. A la hermosa familia que rencontré en Tijuana, Señora Patty, Señor Marcos, Patty, Eli, les quiero dar gracias por su energía y sus palabras de apoyo desde que nos conocimos, por aceptarme en su familia y por amarme. Depuis quelques mois un petit être au grand caractère fait partie de notre vie ; merci Rumba de m'avoir donné – à un moment de la thèse où j'en avais bien besoin – la force de me lever tôt et l'énergie pour mieux organiser mes journées, merci de te blottir tout contre moi lorsque je travaille ; et surtout, merci de nous apporter joie, rires et tendresse tout au long de la journée.

A Marcos A. Díaz Ramírez, le agradezco (¡tanto!) el trabajo, la dedicación y los esfuerzos incondicionales que dio – y dimos juntos – para que esta tesis exista. Marcos, depuis toujours tu me donnes la force d'agir pour ma vie. Après m'avoir donné le courage qu'il me fallait pour commencer la thèse, tu m'as offert la confiance de continuer à la façonner chaque jour et de réaliser tant de choses dans la vie. Tu me nourris tous les jours de toute la joie et l'amour qui me permettent aujourd'hui de porter ce travail jusqu'au bout. J'aime ma thèse parce que son histoire c'est aussi un peu la nôtre. Nos moments tous les deux, les chemins Dauphine-OCDE, le Yoga éternel avec Sandra, l'émotion de notre premier papier, Casablanca et l'effervescence de Marrakech, la summer school et la vivante Barcelone, le bonheur de m'asseoir à tes côtés pour l'écriture de ta thèse, toute cette année à la maison, les bouffées de joie de vivre à chaque instant. Le travail tous les jours, sa pesanteur parfois mais ton soutien toujours, ton dévouement pour m'aider à surmonter mes angoisses et me montrer qu'il n'y a jamais d'impasse, ta sagesse d'esprit pour me faire découvrir comment comprendre réellement ma recherche, ta confiance communicative, toutes ces heures passées à dénouer le labyrinthe de la thèse, à réfléchir, à créer. Et tout cela, toujours ensemble – mon équipier. Ma thèse, je te la dois et je me réjouis aujourd'hui de pouvoir inscrire dans l'univers que j'en suis fière. Parce que nous y avons mis notre bonté de cœur et notre sincérité. Marcos, tu es l'Ange grâce à qui je me sens libre et sereine d'être pleinement la personne que je suis. Amour, gracias por siempre transmitirme la luz de tu espíritu y de tu alma, y por compartir conmigo tu existencia.

Leslie

Notes to the reader

The three chapters of this thesis, while related through the topic of Food Security and Nutrition, are self-contained research papers that can be read separately. Their order of appearance in the manuscript mirrors their date of conception, linked to personal life events, over the past five years.

The topic of “Food Security and Nutrition” is often referred to using the singular form. All chapters use the pronoun “we” since they were created with my co-authors, whom I deeply acknowledge for working with me.

A general introduction and conclusion frame the document, while an extensive summary in French is available at the end of the manuscript.

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General Introduction of the Thesis

Food security and nutrition is a fundamental human right and an essential condition for sustainable development (United Nations, 1948 and 2015). This implies that every person in the world should be able to access the nutritious food needed for a healthy and blooming life. Indeed, food security and nutrition sets the core conditions for good health, personal growth and well-being throughout one's life, and thus for resilient, thriving, and peaceful societies (FAO, 2016). It helps children take full advantage of their education, adults to access better and fulfilling jobs, and everyone to enjoy more years of healthy life (FAO and WHO, 2018; GLOPAN, 2016; Paciorek et al., 2013).

Yet today, more than three billion adults and children around the world live in a situation of food insecurity or malnutrition (FAO et al., 2018; WHO, 2020a), while the ongoing COVID-19 pandemic has put the world at risk of a new global food emergency, thus making food security and nutrition a major challenge of our time. This thesis studies food security and nutrition to help inform decisions and design better policies against hunger and to demonstrate the crucial role of good nutrition as a source of health resilience.

Food security and nutrition

Food security and nutrition is ensured “*when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life*” (FAO et al., 2020).

In this sense, food insecurity and malnutrition is a complex issue that can take many forms. While undernourishment (causing underweight, stunting and wasting) results from not eating enough calories and nutrients (compared to one's needs), excessive food consumption and unbalanced diets can also lead to other forms of malnutrition such as overweight and obesity (WHO, 2020b). All these types of food insecurity and malnutrition are often interlinked and tend to co-exist within countries, places, households, and even individuals (over their lifetime). This thesis covers some of the multiple forms of food insecurity – notably

undernourishment and obesity – and focuses on specific indicators among the many possible ways to measure malnutrition.

Although the concept of food security and the global challenges associated to it are in constant evolution, the Food and Agriculture Organization (FAO) recognizes four key determinants to food security, namely food availability (i.e. food production and supply), food access (i.e. the economic and physical capacity to get food), food utilization (i.e. the consequences of the diet on the functioning of the body), and stability of the three former dimensions (FAO, 2008).

While sixty to seventy years ago the main challenge to ensuring food security was the limited global food supply, today the world produces enough food to feed every human living on the planet but wastes around one-third of the total food production (Dury et al., 2019; FAO, 2017). This implies that the main obstacle to food security nowadays is no longer an issue of food production but an issue of food distribution and accessibility (Battersby, 2011; Riley and Dodson, 2016).

Indeed, millions of people around the world face difficulties every day to access food that exists and is available but will end up lost or wasted. Either because they are too poor to pay for enough and nutritious food or because they cannot easily access markets, too many people in the world still face hunger and malnutrition that otherwise – with the right systems and policies in place – could have been prevented. When experienced at a larger scale, obstacles to access enough food can trigger food emergencies in entire countries and areas of the world. A generalized lack of access to nutritious food can also undermine public health and peace by reinforcing the emergence of diseases and wars.

Undernourishment and nutrients deficit

Undernourishment and deficiencies in nutrient intakes are two forms of malnutrition that mirror insufficient and poorly nutritive food consumption (i.e. small quantity and low-quality of food). Undernutrition is caused by a consumption of calories below the recommended levels according to the person's characteristics and needs. These needs are generally defined by sex, age, and lifestyle (e.g. type of job). When the intake of energy is not sufficient to sustain one's life in healthy conditions, the person is considered undernourished. There are three main

consequences of undernourishment: stunting, wasting, and underweight, which respectively refer to low height-for-age, low weight-for-height, and low weight-for-age. Each of these conditions seriously increases the probability of disease and early death, as well as the capacity of individuals to develop their full cognitive potential (WHO, 2020b). While undernourishment refers to small quantities of food consumed, it often comes along a deficit in vital micronutrients such as vitamins and minerals (e.g. iodine, vitamin A and iron) (WHO, 2020b).

The stark imbalances in wealth and economic power between developing countries and more industrialized economies substantially contributed to the divergence in levels of undernourishment across the world. While today undernourishment has been (mostly) eradicated in high-income countries, it remains a significant challenge for the populations living in low and middle-income countries. In fact, undernourishment in the latter countries has been on the rise again since 2015 – mainly due to the persistence of poverty, the aggravation and emergence of more conflicts and wars, and the acceleration of natural disasters related to the climate crisis (United Nations, 2018a). As of today, around 820 million people in the world are undernourished, which represents almost 10% of the world’s population. While undernourishment can affect everyone, it is particularly dangerous for children as around half of deaths among children under five years old are related to undernutrition. Worldwide, 144 million children under the age of five are stunting and 47 million suffer from wasting (WHO, 2020).

Measuring undernourishment and undernutrition in all their complexity is key to track global progress towards food security goals and to better inform policies. Several indicators and methodologies exist to measure undernourishment. Calorie intakes compared to one’s energy needs is among the most relevant indicators. This indicator is widely used by governments and international organizations to set objectives and monitor progress towards food security (see the indicators proposed by the United Nations (UN) to measure Goal 2 on Zero Hunger in the UN Sustainable Development Goals (SDGs) framework (FAO et al., 2018; United Nations, 2018b)). Building such indicator requires reliable, precise and detailed survey data often based on questions regarding individuals’ food consumption by food item or type of product and frequency. Beyond food consumption measures, other indicators are useful to gauge undernourishment and its consequences, such as anthropometrics. By measuring height and

weight, anthropometric indicators can reflect stunting, wasting and underweight. While they are convenient to comprehend some of the health consequences of undernutrition, anthropometrics cannot be used to identify the source of undernourishment in terms of people's access to food. For this reason, and due to data availability, this thesis mainly relies on indicators of calorie intakes with respect to needs to assess undernourishment at the household level.

Overweight and obesity

With the intensification of globalization, urbanization and inequalities, and the new hegemony of the processed food industry, other forms of malnutrition such as overweight and obesity have become a new threat for the health of societies across the entire world, including for people living in developing countries.

The World Health Organization (WHO) defines overweight and obesity as an “abnormal or excessive fat accumulation that may impair health” (WHO, 2020a). The typical cause of overweight and obesity lies in an excessive and inadequate intake of food (often due to the consumption of energy-dense foods that are highly concentrated in fat, sugar, and salt) compared to the energy requirements associated to the person's physical activity.

Together with the rise of the processed food and beverage industry, the acceleration of globalization, urbanization, and technological progress across the world have reinforced sedentary and unhealthy lifestyles, such as the dependency on motorized modes of transport (which reduces physical activity). Unhealthy food consumption has also increased due to a colossal supply of processed (and ultra-processed) food products – which are poorly nutritive (e.g. lacking micronutrients such as vitamins and minerals) – more accessible to everyone, as they are cheap and easy to prepare or even ready to consume (WHO, 2020a; Dury et al, 2019; OECD, 2019a; Monteiro et al., 2013; Pi-Sunyer, 2002).

With more than two billion adults being overweight or obese worldwide, this new malnutrition epidemic has rapidly spread across both developed and developing countries (Dury et al., 2019; FAO and WHO, 2018). Today, 40% of the global adult population is overweight and 13% is obese. Similarly to undernourishment, the epidemic of overweight and obesity hit harder the youth population, particularly in developing countries. In the world, more than

38 million children under the age of five and 340 million of adolescents are currently overweight or obese (WHO, 2020a; FAO and WHO, 2018).

Although the epidemic of obesity and its related diseases have spread at an impressive pace across the planet during the past thirty years, populations living in the Americas – and more particularly in the United States and in Mexico – have been the most affected. In the Americas region, 62% and 26% of the population were respectively overweight and obese in 2015, these rates are significantly larger than in other regions of the world, such as Asia, where obesity rates average 5% (OPS-WHO, 2015; OECD, 2019a; Ramachandran et al., 2012). Beyond country averages, the damages of obesity also spread unequally within-countries, as it disproportionately affects vulnerable groups such as low-income individuals and women – mirroring pre-existing social and educational inequalities (OECD, 2017).

Measuring obesity and overweight has been less subject to discussion than measuring undernourishment. The standard measure to identify overweight and obesity at the individual level is the Body Mass Index (BMI) (i.e. the ratio of the weight in kilograms over the square of the height in meters). For adult populations, the usual classification of BMI indicates overweight when the ratio is above 25 kg/m², and obesity when it exceeds 30 kg/m² (WHO, 2020a), while underweight appears in cases where the BMI is below 18.5 kg/m². A more nuanced categorization of BMI can also be adopted to differentiate moderate obesity (BMI between 30 and 35 kg/m²) from severe obesity (BMI above 35 kg/m²). Complementary indicators can be used to identify the origins of obesity, such as calorie intakes with respect to one's needs and the diversity of the diet (to account for diet quality). With respect to overweight and obesity, this thesis builds mainly on measures of excessive calorie consumption with respect to needs and on BMI data.

Why should we study food security and nutrition?

Each form of food insecurity and malnutrition comes with devastating immediate and long-lasting consequences on people's health and well-being. Governments, international organizations and the civil society have aspired to eradicate food insecurity formally since the

middle of the 20th century, but the issue persists and is even expanding, in old and new forms, due to the emergence of recent global crises, including the COVID-19 pandemic.

Research on food security and nutrition is key to help improve the lives of billions of persons around the globe. Indeed, to better inform decisions and design effective public policies, it is essential to understand the evolving causes of malnutrition and its repercussions on societies and public health. What is more, documenting trends on food security and nutrition may help create synergies with other global development goals, including actions to protect the planet.

The devastating health and socio-economic consequences of food insecurity

Undernourishment and obesity cause devastating short- and long-term consequences on health, well-being and personal development. Food insecurity intensifies individuals' vulnerability to diseases – including to the COVID-19 – and the risk of premature death, while it also jeopardizes individuals' socio-economic conditions and quality of life.

Undernutrition and nutrients deficiencies are particularly harmful when experienced during childhood or even *in utero* (Neelsen and Stratmann, 2011). In developing and middle-income countries, undernutrition (acute or not) is responsible for 45% of all children deaths under the age of 5 (WHO, 2020b). When experienced at the foetal stage, or early in life, undernourishment and malnutrition can generate what is known as “metabolic imprinting”, which states that early life food security conditions predetermine the risk of diseases during the adult life (FAO et al., 2018). This period of life (and up until 2 years old) is determinant for future personal development as it is when the most important growth of the body and the brain takes place (Dewey and Begum, 2011).

When lacking certain micronutrients (i.e. vitamins and minerals), the organism downscapes the production of chemical elements such as hormones and enzymes that are key to a sound development of the body and the brain. This is one of the reasons why malnutrition substantially alters individuals' physical and cognitive development, affects children's capacity to learn and study, and diminish their ability to work when they enter adulthood. Previous research shows that when undernourished in utero or early in life, people tend to attain lower education levels, earn lower incomes and have lower quality jobs (McGovern et al., 2017,

Dewey and Begum, 2011; Prendergast and Humphrey, 2014; Maccini and Yang, 2009; Jürges, 2013). Similarly, stunting and wasting can generate long-lasting effects in life. More precisely, they severely impair individuals' cognitive development, locomotor capacities and memory, thus affecting present and future socio-economic and well-being outcomes.

On the other side of the food insecurity spectrum, obesity also comes with numerous and long-lasting adverse consequences. First, it increases the vulnerability of individuals to suffer from other diseases. The risk to be affected by a non-communicable disease (NCD) (e.g. diabetes, cardiovascular disorders, hypertension) increases with BMI. In fact, obesity is the primary factor for the development of NCDs, which have now become the first cause of death around the world as they account for 71% of all adult deaths (WHO, 2020c; FAO and WHO, 2018; GLOPAN, 2016). Besides increasing the risk of NCDs, obesity also affects the immune systems and the capacity of the body to overcome infections and viruses. In particular, obesity significantly reduces lung capacity and represents a major vulnerability in the face of respiratory diseases. While it has been shown that obesity increases the health impact of other epidemics such as H1N1 (van Kerkhove et al., 2011), new research – including this thesis – demonstrates the considerable role that obesity plays in aggravating COVID-19 severity and mortality (see for instance Sattar et al., 2020; Simonnet et al., 2020).

In addition to severe physical and mental health consequences, obesity is also a factor for social and economic inequalities and exclusion. Overweight and obesity come along with significant discrimination on the labor market. In general, obesity is associated with lower wages, lower probability of employment, long-term unemployment, and fewer chances to occupy a managerial position (Böckerman et al., 2018; Finkelstein et al., 2005; Lindeboom et al., 2010; Norton and Han, 2008). When experienced during childhood, obesity typically affects the formation of human capital because of several social and inclusion factors, which directly jeopardize the capabilities of individuals to integrate the labor market later in life, and thus their lifelong income and well-being (OECD, 2019a).

The world is not on track to achieve better food security and nutrition for all by 2030

Ensuring food security and nutrition for all has been at the forefront of global development agendas for decades, with a strong focus given to the fight against hunger in less

developed countries and regions. The objective of achieving food security worldwide first appeared at the World Food Conference in 1974, with the declaration that “*within a decade, no child [should] go to bed hungry, that no family [should] fear for its next day’s bread, and that no human being’s future and capacities [should] be stunted by malnutrition [...]*” (United Nations, 1975). More than forty years later, tackling food insecurity and malnutrition remains one of the most important challenges of our time as highlighted by the United Nation’s (UN) Sustainable Development Goals (SDGs) – in which UN member countries committed to “*end hunger, achieve food security and improved nutrition [...]*” by 2030 (United Nations, 2015).

Despite outstanding global and local efforts, some of them worthy of the Nobel Peace Prize such as the World Food Program (The Nobel Prize, 2020), current data and projections suggest that the world is not on track to achieve food security and nutrition for all by 2030 (FAO et al., 2020). While global trends in undernourishment had started to decrease in the late twentieth century, food insecurity has been on the rise again since 2015. The UN indicates that between 2014 and 2018, the number of food insecure people in the world increased by more than 23%, meaning that today almost 3 billion people are either undernourished, malnourished, overweight or obese.

Only nine years are left for the world to meet the global goal (SDG 2) of ensuring better food security and nutrition for all before 2030. Overall, targets to reduce hunger and malnutrition are still far from being achieved – for instance, the UN member countries committed to reduce the number of stunted children to 82 million and the proportion of wasting to 3% by 2030. Yet in 2019, 144 million children under the age of five were still stunted and 47 million were suffering from wasting (representing 7% of all children) while an additional 38 million were affected by overweight or obesity. Globally, almost 30% of the whole world’s population is suffering from at least one form of food insecurity (United Nations, 2020a).

National and local governments, together with international organizations, the private sector and the civil society, should more than ever increase their efforts to reverse the rising trends in undernourishment and obesity, also considering that the current COVID-19 pandemic is an additional threat to people’s food security and nutrition, health and lives. In particular, COVID-19 recovery plans, which will utilize trillions of dollars in public resources, should integrate food security and nutrition as a key element for a long-term and resilient recovery.

The COVID-19 pandemic puts the world at risk of a new global food crisis

The COVID-19 pandemic hit the world during a time that was already very uncertain regarding the future of food security globally. Undernourishment and obesity were both on the rise due to new conflicts and climate change-related disasters, as well as the expansion of the processed food industry through global markets. Adding to these pressing issues, the COVID-19 pandemic is now worsening hunger and malnutrition in most countries, putting the world at risk of a new global food emergency (United Nations, 2020b). The World Food Program estimates that between April 2020 and April 2021 (i.e. the first year since the COVID-19 was declared a pandemic), 110 million more people fell into undernourishment due to the COVID-19 crisis (World Bank, 2021).

The current pandemic is also exacerbating existing food insecurity issues across and within countries, regions and cities, mainly by disrupting global and local food supply chains, by making more people fall into poverty, and by reducing physical mobility and accessibility. Containment measures such as lockdowns, shops and restaurants closings, as well as borders controls, put on hold the global economy and international trade. By contributing to decelerate food production globally, these policy measures taken at the dawn of 2020 directly affected farmers' lives and incomes, while also constrained availability and access to fresh food products in many places, notably in cities of developing countries (United Nations, 2020b).

Since the beginning of 2020, 50 million people have fallen into poverty due to the consequences of the COVID-19 crisis, and new projections suggest that this number could soon increase dramatically ranging between 150 million and 580 million (Pereira and Oliveira, 2020; Sumner et al., 2020; United Nations, 2020b; Laborde et al., 2021). During the pandemic, millions of people around the globe have reduced their food consumption because of new financial constraints. Lower incomes and soaring unemployment, coupled with food supply chains disruption and currency depreciation (mainly in Latin America and Africa), are all contributing to the relative increase of food prices that is forcing many households to reduce both the quantity and the quality of their diet (United Nations, 2020c).

Beyond the direct impact of the COVID-19 pandemic on food consumption and nutrition at the individual level, the sanitary crisis is also likely to affect food security through indirect channels. For example, by depleting a large part of the governments' budgets and resources that

otherwise would have been dedicated to social policy. If governments do not integrate the costs of malnutrition on short- and long-term health, including in the face of COVID-19 and the risk of future pandemics and disasters, they might stop funding current programs and policy interventions that are key to tackle undernourishment and obesity. For instance, within a year after the beginning of the pandemic, 370 million children that were benefitting from school free meals programs were put at risk of malnutrition due to school closings, without any solutions of replacement for the food aid they were receiving (United Nations, 2020b).

While on the one hand, the COVID-19 crisis severely endangers food security on a global scale; on the other hand, malnutrition – particularly in the form of obesity – enhances the negative health impact and death toll due the COVID-19 pandemic. In this context, assessing the effectiveness of existing food security programs and understanding the role of good nutrition for health resilience and for a long-term recovery is crucial to inform decisions and to design better policies.

Main topics addressed in the thesis

In a context of growing malnutrition and the emergence of new threats to people's food security, it is essential to enrich the knowledge about the drivers and advantages of ensuring food security and nutrition for all. This thesis studies food security and nutrition in the specific contexts of Peru and Mexico. While the cases about Peru (Chapters 1 and 2) provide evidence on the effectiveness of specific types of policies (food programs), governance (decentralization) and mobility (private transport modes) to improve food security outcomes, the case of Mexico (Chapter 3) demonstrates the role of good nutrition as a source of health resilience during the COVID-19 pandemic.

What works to improve food security and nutrition?

The first two chapters of this thesis contribute to understand how specific policies and public interventions might work best to improve people's food security and nutrition. While the first chapter focuses on the impact of decentralizing food aid programs, the second chapter explores the role of urban mobility, through vehicle ownership, as an enabler of food access.

Decentralization and effectiveness of public food programs

In the first chapter, this thesis addresses the topic of the effectiveness of public food programs when managed by local authorities rather than by national governments. More specifically, Chapter 1 estimates the impact of decentralizing the Peruvian Complementary Food Program on its capacity to raise calorie consumption at the household level. Besides documenting the evolution of calorie intakes in Peru before and after decentralization, the chapter also explores the channels through which the shift in the governance of the program (from the national government to the subnational authorities) improved food security across the country.

The analysis suggests that depending on specific characteristics of local authorities, decentralization processes can have either positive or negative impacts on well-being outcomes. In the case of Peru, the study reveals that due to opposing “proximity” and “capacity” effects, the decentralization policy generated heterogeneous outcomes across the territory that, overall, led to a positive regional convergence in calorie consumption. While calorie consumption increased in most of the provinces due to the better understanding of local communities by subnational governments (positive “proximity” effect), it decreased in Lima due to the lower capacity of local authorities compared to the central government (negative “capacity” effect).

This chapter corroborates the main findings of the literature regarding the impact of decentralization processes on economic and social outcomes. Some research advocates for decentralization since, under certain conditions, it can improve democracy, foster economic growth, and reduce territorial inequality thanks to higher efficiency in the public sector that ensures a better quality in the delivery of public services. One of the main advantages of decentralization is that it enables a bottom-up approach in policymaking and gives more incentives to subnational governments to respect their political engagements. By being more aware of local challenges, subnational governments have a greater faculty to design and implement policies tailored to local populations’ needs, and in a more efficient way (OECD, 2019b; Wallis and Oates, 1988; Bardhan, 2002; Leer, 2016). Despite these beneficial mechanisms, the literature also identifies several potential detrimental effects of decentralization. The main sources of inefficiency from decentralizing relate to the lack of financial resources and the typically low administrative, political, and technical capacity of

subnational authorities. Beyond financial constraints, local authorities may lack the appropriate skills and competences to deliver on their devolved responsibilities (OECD, 2019b; Willis et al., 1999; Falletti, 2005).

The findings of this chapter support that governments should promote a more localized approach to food security and nutrition, while simultaneously ensuring (including by providing adequate capacity building and resources if needed) that subnational entities have sufficient financial and technical means to manage efficiently the designated programs.

Urban mobility and increased food access

The second chapter of this thesis focuses on the issue of food access – one of the fundamental dimensions of food security according to the FAO – and considers urban mobility through vehicle ownership as one of its potential determinants. More precisely, the analysis investigates whether households who enjoy higher degrees of mobility within the urban space have access to more food of greater diversity, and discusses how Peruvian authorities could promote urban mobility – and in particular by considering different types of vehicles – as a lever to improve food security and nutrition.

Low economic and physical access to food are the most important obstacles to food security and nutrition in cities. Research on food access suggests that in addition to low incomes and poverty, the lack of individual mobility – and particularly the absence of reliable transport – can also threaten food security and nutrition (Coveney and O’Dwyer, 2009). By reducing time and efforts to reach local markets, private vehicles contribute to lower the costs of accessing food and constitute a substantial channel to achieve more diverse and nutritive diets.

The analysis conducted in Chapter 2 reveals a significant positive association between mobility and food security outcomes. In addition, the analysis supports that clean and affordable modes of transport such as bicycles are a better option to enhance food security and nutrition compared to cars, which are both more expensive and highly pollutant. Through this finding, the chapter relates to core topics of global agendas such as sustainable urbanization, as vehicles and urban mobility are acutely interlinked with issues of climate change, environmental health risks, inequalities, and numerous objectives to improve people’s lives and well-being. While the literature shows that having a reliable mode of transport is key to ensure a continuous, sufficient, and diverse access to food (Coveney and O’Dwyer, 2009), not all types of vehicles

should be promoted as a way to enhance food security. Today, most cities around the world rely on the use of cars, which results in severe social and environmental issues including air pollution and greenhouse gas emissions that threaten people's lives today and for future generations (Giles-Corti et al., 2016).

Urban mobility and accessibility are highly unequal across population groups and across space. In particular, lower-income households tend to lack effective mobility and accessibility options. While cars are an expensive mean for mobility, bikes (that are usually more affordable) are not easily usable for food shopping across the whole urban space and their benefits are often reserved to the share of the population at the top of the income distribution, that live closer to the urban centers, where most investments in urban design and urban planning are made. The chapter touches upon this topic and finds that only the higher-income households are able to take advantage of clean and cheap modes of transportation to enhance their food security and nutrition.

Good nutrition is a source of health resilience

While the first two chapters of the thesis concentrate on identifying how specific policies and systems can improve food security, the third and final chapter explores some of the consequences and risks associated with malnutrition, and more particularly with obesity.

At the individual level, obese people are more likely to develop more comorbidities and diseases that increase the risk of death. Beyond the health dimension, obese people are also more likely to be discriminated in the labour market, which reduces their opportunities for higher living standards and quality of life. At a larger scale, societies with high prevalence of obesity, such as Mexico, are generally more unequal and register lower life expectancy. On the contrary, societies where nutrition is better benefit from a lower burden of diseases, which makes them more resilient in the face of shocks, including pandemics such as the COVID-19.

While on the one hand, the COVID-19 crisis severely endangers food security; on the other hand, malnutrition substantially increases the negative health impact of the COVID-19 pandemic. The third chapter of the thesis sheds light on the essential role of good nutrition as a source of health resilience, particularly in the context of the COVID-19 pandemic in Mexico. The findings of this study coincide with recent research – mostly from the medical field – in

demonstrating that obesity has been a significant and direct driver of COVID-19 severity and mortality. Beyond the fact that obesity increases the risk of other comorbidities that relate to COVID-19 complications, obesity *per se* is a factor for severe COVID-19 cases since obesity jeopardizes individuals' immune response and tends to reduce lung capacity (WHO, 2020c; Sattar et al., 2020).

The chapter also shows that at the country level, obesity substantially worsened the impact of the pandemic in terms of human losses and healthcare expenditure. Societies with high obesity rates tend to register higher number of severe COVID-19 cases, and thus face larger economic and health consequences of the pandemic. More broadly, the chapter highlights the urgent need for more effective policies to tackle obesity and improve nutrition, as this would reduce the burden of diseases, increase healthy life expectancy, and significantly ameliorate people's lives and well-being.

*Summary of the Chapters**Chapter 1: Can Decentralization enhance Policy effectiveness? Evidence from the Peruvian Complementary Food Program*

This chapter assesses the impact of decentralizing the Peruvian Complementary Food Program (PCA) on its efficacy and explores the channels through which this shift in governance improved food security across Peruvian regions.

Since the 1980s, many countries around the globe have initiated decentralization processes that reshaped the way they address most social, development, and economic issues. Many authors have studied the impact of decentralization on a wide range of topics such as institutions, economic growth, poverty, and education (e.g. Basurto et al., 2018; Leer, 2016; Galasso and Ravallion, 2005); however, little research has been done on the impact of decentralization on food security. This chapter contributes to filling this gap in the literature by providing evidence about the different consequences of decentralization on food security.

Ensuring food security and good nutrition across the world remains today a major and evolving issue. Worldwide, more than 800 million people are suffering from hunger and contrary to the common belief, food insecurity has been on the rise again for the past years due to new conflicts, drought and disasters associated to climate change, mostly in Africa and South America – from 2014 to 2017 the number of undernourished people increased by 37 million (FAO et al., 2018).

In Peru, despite remarkable progress in the last years, food security and nutrition is still an important topic. In 2000, around one-fifth of the Peruvian population was undernourished, leading the government to the creation of social programs such as the Complementary Food Program (PCA). The PCA is one of the oldest and most important social programs dedicated to food aid in Peru. The main objective of the PCA is to increase food consumption among the poorest and most vulnerable populations, by providing them with additional food intakes distributed in social centers that are operated by volunteers from local communities. Since its creation in 1992, the central government fully managed the PCA. However, with the objective

to enhance its effectiveness and to tackle regional inequalities in food security, the government decided to decentralize the PCA. Between 2003 and 2014, the management of the program was progressively transferred to the subnational authorities of the country.

To assess the causal impact of the PCA's decentralization on households' food security, we implement an adapted difference-in-differences model that relies on the gradual implementation of decentralization across subnational governments. We combine rich data on households' food consumption (items and quantities) with official tables of calorie requirements by gender-age groups to construct an indicator of food security, also referred to as "gap in calories", which measures the difference between household calorie consumption and household calorie needs. The variable of gap in calories can either take negative values (the household suffers from a food deficit and is at risk of undernourishment) or positive values (the household consumes the minimum caloric requirements or more).

Our results indicate a negative overall impact of decentralization on the surplus of households' calorie intakes with respect to their minimum calorie requirements. However, the impact of the policy is not homogeneous across territories; our estimates show that the consumption of calories decreased in Lima while it increased in the rest of the provinces of the country, leading to a regional convergence in food security in Peru. Our results show that decentralizing the PCA generated a decrease of 219 kcal per day in Lima with respect to the required minimum levels in an average household; while it increased the calorie intake for households living in the rest of the provinces (excluding Lima) by 318 kcal per day with respect to their minimum needs.

We explain these findings by the existence of two opposite effects of decentralization – a positive "proximity effect" and a negative "capacity effect". These effects originate respectively from the fact that on the one hand subnational governments have a better understanding of local communities and regional specificities, relative to the central government; while on the other hand, they tend to suffer from lower financial, technical, and human resources.

In the provinces outside Lima, decentralizing the PCA is beneficial to the population's food security because the positive "proximity effect" overweighs the negative "capacity effect". The advantages associated to the transfer of the program to the provincial authorities – that are

by essence closer to local populations than the national government – are greater than potential drawbacks stemming from their lower institutional and financial capacity. On the other hand, decentralization has a negative effect on calorie consumption in Lima because the negative “capacity effect” surpasses the positive “proximity effect”. The province of Lima concentrates on its territory both the central administration and the local district authorities. Being based in the same place, local government employees benefit from the same knowledge of the situation in Lima than the central government officials, which generates a close to zero gain in the “proximity effect” after decentralization. Yet, compared to the central government, local district authorities have less technical and financial capacity, which results in a negative “capacity effect” after decentralization.

Finally, using complementary measures of food security, we show that regional convergence in calorie intakes in Peru is welfare improving. While decentralizing the PCA boosted the consumption of calories in provinces with initial high levels of undernourishment, the fall in calorie intake in the districts of Lima is mainly driven by a share of the population shifting from very high levels of calorie consumption (“over-nourished”) to more standard ones.

Chapter 2: How does Mobility improve Food Security and Diet Diversity? The role of vehicle ownership in Peruvian cities

This chapter explores the linkages between mobility, food security and diet diversity in Peruvian cities. It assesses the respective roles of motorized and non-motorized vehicles in shaping food consumption patterns at the household level. The analysis focuses on urban areas across Peru, which are increasingly facing urban mobility and malnutrition issues.

Over the last two decades, Peru has successfully lowered undernourishment rates. Despite this notable progress in the fight against hunger, today more than two million Peruvians still do not have access to sufficient food and suffer from insufficient daily calorie intakes (World Bank, 2018). Simultaneously, the urban population is increasingly more exposed to unhealthy food products – often processed, high in fat and sugar – that contribute to a higher risk of overweight and obesity (Pia Chaparro and Estrada, 2012; McCloskey et al., 2017; Smith Torres-Roman et al., 2018). While poverty and inequality are known to be core factors of food

insecurity, the lack of physical access to nutritious food (through mobility options) might also be among the main causes of new forms of food insecurity in Peruvian cities.

In urban Peru, mobility still has important limitations. Public transport is usually deficient, overcrowded and follows inadequate routes (OECD, 2016). However, since a large share of urban households cannot afford a car, they need to rely on public transport or look for other mobility options (including scooters or bicycles). Access to basic amenities, including food shops and markets, may thus be difficult and erratic. What is more, ageing of public transport vehicles and increasing vehicle ownership (among higher- and middle-income households) are putting cities under major congestion and environmental pressures, notably Lima. Urban households in Peru are being threatened by high levels of pollution, with exposure to fine particulate matter PM_{2.5} that averages 37 $\mu\text{g}/\text{m}^3$, a threshold largely above the WHO's guideline of 10 $\mu\text{g}/\text{m}^3$ (OECD-European Commission, 2020; WHO, 2016). In such pressing context, this chapter provides insights on mobility policies that could contribute to both higher access to food in cities and lower emissions and air pollution.

While the literature comprehends numerous studies on the economic and social barriers to food access (e.g. Sen, 1981), little is known about the role of physical access to food, particularly through transport mobility. The independent role of increased mobility (by owning a vehicle) on food security and nutrition has been little explored in the literature. In some cases, the effect of mobility on people's capacity to access food has been confounded with income and wealth effects associated to vehicle ownership. This chapter contributes to filling this gap in the literature by disentangling the mobility effect associated to vehicle ownership from the income and wealth effects.

The chapter makes use of the rich households survey ENAHO to construct indicators of food security and diet diversity. It then explores the linkages of food security and diet diversity with vehicle ownership at the household level (i.e. if the household has a car, a bike or a scooter). We start by verifying these associations through simple linear regressions and Tobit models, while controlling for income and wealth variables. However, our preferred specification consists in exploiting the panel dimension of our database by including household fixed-effects, which take into account time-invariant household unobserved characteristics.

The results reveal a significant positive association between mobility on food security outcomes. When breaking down vehicle ownership by type, the analysis supports that cleaner and more affordable modes of transport are a better option to enhance food security and nutrition. Indeed, our findings reveal that having a car is not essential per se to enhance household access to food in urban Peru, whereas bicycles and scooters are two modes of transport that help families reaching more and better-balanced food baskets, although to a moderate extent (which suggests that mobility is a relevant but secondary driver of food security). The effects of bikes and scooters, although significant, are moderate in magnitude and mainly driven by middle- to high income families who tend to live closer to the city center compared to lower income households, and thus benefit from urban spaces better adapted to the use of non-motorized and small vehicles. We verify that using a bike improves food access only when the distance of households to the city center is relatively short (within 30 km). This finding is coherent with the literature showing that non-motorized modes of transport tend to be less effective for people in the lower part of the income distribution, because of income concentration across the urban space (Ortegon-Sanchez and Oviedo Hernandez, 2016).

Policies aiming at improving food security and nutrition through mobility should prioritize and incentivize the use of clean modes of transport such as bicycles over private cars. In addition, while Peruvian authorities could improve mobility by investing in the public transport system, redesigning the periphery of cities is also key to increase the availability of amenities such as quality food shops. This could enhance the practicability of cycling across space and extend the use of bikes among more groups of the population for better access to food, including for the poorest households in the outskirts of cities.

Chapter 3: How heavy was the cost of Obesity during the pandemic? Obesity and COVID-19 severity in Mexico

The objective of this chapter is twofold, first it sheds light on the role of obesity in aggravating the COVID-19 disease at the individual level; second, it quantifies the additional deaths and healthcare expenditure that obesity, combined with the COVID-19, generated during the first wave of the pandemic in Mexico.

With more than 13% of all adults being obese across the world (WHO, 2020), the epidemic of obesity has become one of the main food security and nutrition challenges of our times. The rise of the processed food and beverage industry together with increasing trends in globalization, urbanization and inequalities have considerably changed the way in which people live, work, and consume. In particular, these global trends have reinforced sedentary and unhealthy lifestyles that lead to higher risks of obesity. While obesity is a global issue, some places are being more impacted than others are. Mexico, with more than 36% of its adult population being obese, is one of the most affected countries in the world by obesity (the second most obese after the United States) (INEGI, 2018; OECD, 2019a).

Obesity comes with numerous negative consequences that seriously jeopardize people's health, socioeconomic development, and overall well-being. In the context of the current COVID-19 pandemic, this has become even more evident. Recent medical literature – through experiments characterized by relatively low sample sizes – is showing that obese patients are more likely to develop severe forms of COVID-19 if infected with SARS-CoV-2 (see for example Cai et al., 2020; Sattar et al., 2020; Simonnet et al., 2020). Nevertheless, little research has been conducted on larger populations and with a broader public health perspective. This chapter aims at filling this gap in the literature by providing evidence on the role of obesity in COVID-19 severity and by estimating the additional healthcare expenditure associated to obesity during the first wave of the pandemic in Mexico (here defined as from 1st January 2020 to 9th August 2020).

The chapter makes use of the rich administrative register of COVID-19 cases and deaths published daily by the Secretary of Health of Mexico, which contain detailed individual data on COVID-19 test results and other medical information – including comorbidities such as obesity, diabetes, and hypertension. We implement a series of logistic regressions that control for relevant individual and local characteristics, including the local health system capacity. Through these estimations and additional robustness checks mitigating some endogeneity concerns, we demonstrate that obesity is a significant driver of COVID-19 severity at the individual level, even when controlling for all relevant comorbidities. Obese patients are 50% more likely to develop a severe form of COVID-19 compared to non-obese patients, on average.

We also show that the cost of obesity on the COVID-19 death toll in Mexico has been very high. Our model predicts that between 4 200 to 5 900 COVID-19 deaths could have been avoided between January and August 2020 if there were no obesity at all in Mexico. This means that obesity is responsible from 8% to 12% of all COVID-19 deaths in the observed period. The high prevalence of obesity contributes to make SARS-CoV-2 more deadly in Mexico than in other places of the world, partially explaining the relatively high COVID-19 death toll observed in the country.

Results also suggest that obesity and its implications on COVID-19 severity stepped up healthcare expenditure by USD 220 to USD 240 million, making many families face catastrophic health expenditure and generating pressure on public health budgets since the additional costs represent around 2% of the annual budget dedicated to universal healthcare in Mexico (Gobierno de México, 2020).

This paper demonstrates that people with obesity belong to the most vulnerable populations in the face of COVID-19. Authorities in charge of the COVID-19 response should consider obese people among the primary targets during the vaccination campaign. Overall, our findings provide insights on the urgent need for more effective policy and action to tackle obesity in Mexico. By shedding light on the costs of obesity for the Mexican population, we hope this work can contribute to support the implementation of policies needed to enhance better nutrition in Mexico.

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Chapter 1. Can Decentralization enhance Policy effectiveness? Evidence from the Peruvian Complementary Food Program

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Abstract¹: This paper estimates the impact of decentralizing the Peruvian Complementary Food Program (PCA) on its efficacy and explores the channels through which this governance shift improved food security across Peruvian regions. We exploit differences in the timing of decentralization between local authorities to implement a difference-in-differences approach. Our results indicate a negative overall impact of decentralization on the surplus of households' calorie intakes with respect to their minimum calorie requirements. However, the impact of the policy is not homogeneous across territories; our estimates show that the consumption of calories decreased in Lima while it increased in the rest of the provinces of the country, leading to a regional convergence in food security in Peru. We explain these findings by the existence of two opposite effects of decentralization – a positive “proximity effect” and a negative “capacity effect”, originating respectively from the fact that on the one hand subnational governments have a better understanding of local communities and regional specificities; while on the other hand, they tend to suffer from lower financial, technical and human resources. Finally, using complementary measures of food security, we show that regional convergence in calorie intakes in Peru is welfare improving. While decentralizing the PCA boosted the consumption of calories in provinces with initial high levels of undernourishment, the fall in calorie intake in the districts of Lima is mainly driven by a share of the population shifting from very high levels of calorie consumption (“over-nourished”) to ones that are more standard.

¹ Authors are grateful to Javier Herrera, Research Director at IRD, who provided substantial data from ENAHO and valuable advice.

1.1. Introduction

The 2030 Agenda for the Sustainable Development Goals (SDG) adopted in September 2015 by the member Countries of the United Nations defines the “fight against hunger” as the Second Global Goal, with the aim to “ensure access to safe, nutritious and sufficient food for all [and to] eliminate all forms of malnutrition”. Despite remarkable progress by some countries, there were still 821 million undernourished people worldwide in 2017 (FAO et al., 2018), meaning that one person out of ten is suffering from hunger. Contrary to the common belief, food insecurity has been on the rise for the past years due to new conflicts, droughts and disasters associated to climate change (UN, 2018b), mostly in Africa and South America.

As highlighted by the UN and the OECD who advocate for the “localization” of the Sustainable Development Goals, the active participation of all levels of governments as well as private organizations and citizens is key to achieve a durable reduction in hunger at a larger scale (UN, 2016). “Localizing” implies understanding subnational realities and their impact in people’s lives to generate adequate and more effective solutions for sustainable development. It also promotes a bottom-up approach that requires local governments to fully engage and participate in the process. To unleash their capacity to design and implement policies that are better adapted to the local context, subnational governments need to have, among other things, enough political power for decision-making. In this perspective, processes of decentralization that promote cooperation and support among all levels of government are a positive step towards better policies for development.

It has been shown that, under certain conditions, decentralization can contribute to reduce territorial inequalities, foster economic growth and improve democracy – through the higher efficiency in the delivery of public services (Wallis and Oates, 1988; Bardhan, 2002; Leer, 2016). However, some risks are also associated to decentralization. For example, local authorities may lack the adequate financial, administrative and institutional capacities to sustain the provision of public services and social programs (OECD, 2019).

This paper explores whether in a context of large inequalities in access to food, decentralization can lead to an increase in the efficacy of public policies that fight undernourishment, and if so, under which conditions.

In the last two decades, Peru has experienced one of the greatest economic and social progress compared to its Latin American neighbors; yet the levels of poverty and food insecurity in the country remain high. In 2011, two thirds of the Peruvian population were facing food insecurity problems (FAO, 2013); and in 2016, 7.5% of the population were undernourished and living below the minimum level of dietary energy requirements (WHO, 2018a). Territorial inequalities in nutrition and access to food, often masked by country-averages, are persistent in Peru. The prevalence of undernourishment is more severe in the rural Andean and Amazonian areas than in the urban zones of the coast (World Food Program, 2018).

With the objective to halt the growing disparities in regional development and food security outcomes, the Peruvian central government launched in 2003 a process of decentralization of an important food aid program – the Complementary Food Program (Programa de Complementación Alimentaria – PCA). At the same period, the prevalence of undernourishment started to decrease sharply, passing from 22.6% in 2003 to 7.9% in 2015, which draws the attention on the role that the decentralization of the program played in the reduction of food insecurity in Peru. To the best of our knowledge, there is no research on the links between decentralization and food security in Peru and very few studies test the channels through which decentralization affects social outcomes in general (Leer, 2016). This paper contributes to the literature on decentralization by proposing an interpretation of the mechanisms – a positive “proximity effect” and a negative “capacity effect” – that explain the heterogeneous effects of a decentralization policy in Peru.

In this paper, we empirically study the causal effect of decentralizing the Peruvian Complementary Food Program and test whether it helped improve food security within the country. We exploit differences in the timing of decentralization between local authorities to estimate the causal impact of the policy; more precisely, we run a difference-in-differences model using multiple treatment groups. We exploit data from the National Households Survey about Living Conditions and Poverty (ENAHO), a rich database from the Peruvian National Institute of Statistics (INEI) covering the whole country, that enables us to analyze a large array of households’ characteristics and food consumption habits over the period 2001-2016. This survey is representative at the national level as well as for various subnational divisions –

departmental, urban and rural. Thanks to the richness of the database, we are able to construct our own indicator of food security, which is the adequacy of households' calorie intakes with respect to their minimum calorie requirements.

The results indicate a non-homogeneous impact of decentralization across the country. While the consumption of calories was reduced in Lima due to decentralization, it was improved in the other provinces of the country. We explain these results by the existence of two opposite effects of decentralization – a positive “proximity effect” and a negative “capacity effect”, originating respectively from the fact that subnational authorities have a better understanding of local communities and their specific issues compared to the national government, but are restrained by lower financial and technical resources. An exploration of complementary food security indicators reveals that national inequalities in terms of calorie consumption are lessened after decentralization. While we find that decentralizing the PCA enables a greater consumption of calories in provinces that are on average undernourished, we show that the fall in calorie intakes in the Province of Lima is partly due to a lower risk of being “over-nourished”, i.e. of consuming calories in excess.

The following section sets the scene by explaining the context of food security in Peru. It then presents the findings of the literature on decentralization and summarizes the characteristics of the PCA and its process of decentralization. While section 3.3 presents the data and explains the construction of our variables, section 3.4 defines the empirical strategy. Finally, section 3.5 discusses the results and section 3.6 concludes.

1.2. Food Security, Decentralization and the Peruvian Complementary Food Program

Ensuring Food Security and good nutrition across the world is still a major and evolving issue. Food security and the fight against hunger have been at the forefront of the global political agenda for many years with a distinctive and increasing engagement of national and subnational governments, as well as international and civil organizations around the world. The World Food Conference of 1974 is one of the first examples of this global effort, followed by the Millennium Development Goals (MDG). Today, the 2030 Agenda for the Sustainable Development Goals (SDG) – adopted in September 25, 2015 by 193 member countries of the United Nations –

defines the “fight against hunger” as the second Global Goal, with the aim to “ensure access to safe, nutritious and sufficient food for all [and to] eliminate all forms of malnutrition”.

More efforts and new strategies are needed to tackle food insecurity across the globe, especially as the shapes and consequences of this issue have been evolving and becoming more complex – nowadays, not only people suffer from undernourishment and undernutrition; but also from obesity and overweight issues due to the low quality of food that is available and affordable to them. Undernutrition and obesity are phenomena that coexist within countries (FAO et al., 2018), regions, and even families, making the fight against food insecurity even more challenging in terms of public policies. While 151 million children under the age of five are still stunting and 50 million suffer from wasting, one adult over eight is obese (FAO et al., 2018).

The short- and long-term consequences of food insecurity are immense, as suffering from malnutrition intensifies individual vulnerability to other diseases – including the current global pandemic – and increases the risk of mortality. Beyond health issues, malnutrition (either undernourishment or obesity) negatively affects the capacity of individuals to acquire education and work, and thus to generate income, since it deteriorates physical and cognitive abilities (Paciorek et al., 2013). When experienced at the fetal stage, or early in life, malnutrition enters the mechanism called “metabolic imprinting”, which states that early life food security conditions predetermine the risk of diseases during the adult life (FAO et al., 2018). Being malnourished early in life, even during a short period, can thus hinder long-term individuals’ cognitive and physical development, and have strong repercussions during the whole life cycle. Eliminating malnutrition is thus critical to improve people’s health and well-being, and to ensure sustainable development around the world.

1.2.1. Food Security and Nutrition in Peru

Undernourishment in Peru

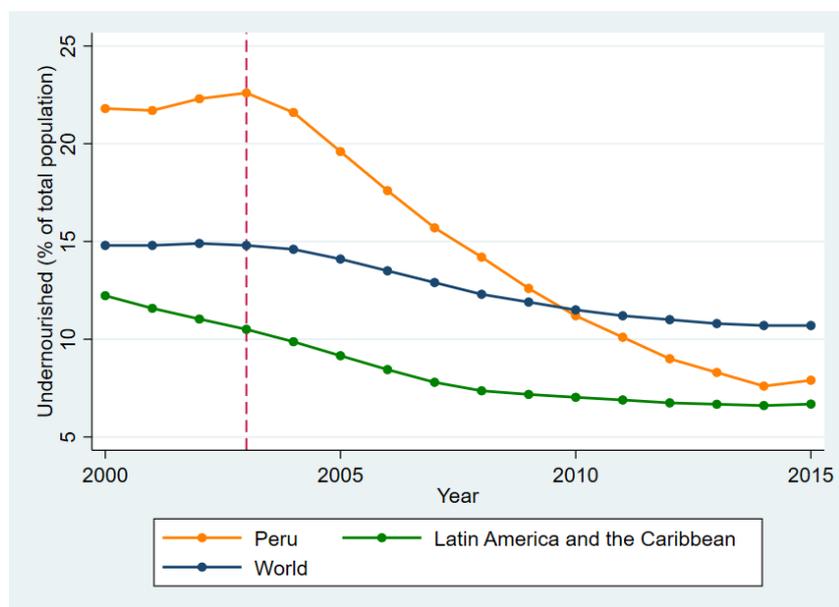
Food insecurity and malnutrition in Peru remain at high levels. In the last two decades, Peru has experienced one of the greatest economic and social progress compared to its Latin American neighbors. The country has taken advantage of its rapid economic growth to favor development in many areas. However, levels of poverty and food insecurity remain high; for example, around one third of the population was food insecure in 2011 (FAO, 2013). The

country is lagging behind with respect to its Latin American peers and is ranked at the 53rd position in terms of food security (out of 113 countries internationally) by the Economist's Global Food Security Index (FAO, 2018b). Over the period 2014-2016, 7.5% of the total Peruvian population was undernourished and living below the minimum level of dietary energy requirements defined jointly by the Food and Agricultural Organization (FAO), the World Health Organization (WHO) and the United Nations (UN) (WHO, 2018a).

Besides, such figures hide latent and persistent territorial inequalities in nutrition and access to food. In general, the prevalence of undernourishment is more severe in the rural Andean and Amazonian areas than in the urban zones of the coast. For example, while the country average suggests that only 13.1% of children under the age of five suffer from chronic malnutrition (i.e. either wasting, stunting or underweight), more granular estimates reveal that in rural areas the share of children suffering from chronic malnutrition goes up to 33.4% (World Food Program, 2018).

To halt the exacerbation of such sharp regional disparities and to ensure food security everywhere in the country, the government has adopted a multi-stakeholder approach that promotes the engagement of all levels of government and members of society in the fight against hunger. The first step was the launch of the decentralization process in the early 2000s. In 2003, in an attempt to stimulate adaptability and efficiency in public policies (Willis et al., 1999), the central government started to officially transfer the responsibilities of several public programs to local authorities. The Complementary Food Program (Programa de Complementación Alimentaria – PCA), the policy of interest of this paper, was part of the first wave of decentralization.

From 2000 to 2015, the prevalence of undernourishment in Peru decreased by close to 14 percentage points – from around 22% in 2000 to 8% in 2015. According to Figure 1.1, the sharp decrease in undernourishment began in 2003, the same year that the PCA's decentralization process started. This paper aims at quantifying the impact of decentralizing the PCA in shaping food security outcomes in Peru.

Figure 1.1. Prevalence of undernourishment in Peru, 2000-2015

Source: Authors' elaboration based on FAO's data, Health Nutrition and Population Statistics.

Over-nourishment in Peru

Being “food secured” implies having access to enough and nutritious food. Malnutrition can lead to overweight and obesity, which are other forms of food insecurity. This type of food insecurity has now become a global issue that affects developed and developing countries (Amugsi, 2018). Around the world, obesity has tripled since 1975 and it now coexists with undernourishment and hunger within the same countries, cities or even households (WHO, 2018b).

Medical research has highlighted that the roots of obesity are complex but mainly rely on lifestyles changes associated to urbanization and globalization (WHO, 2018; Kim et al., 2017). Life in cities de-incentivizes physical activity (Day et al., 2013) and makes it easier (e.g. large presence of supermarkets that sell processed food) and sometimes inevitable to consume energy-dense products (Kirby, 2013). Fast food can indeed appear as the only affordable diet for the poorest populations, providing them with low-quality food, rich in calories but poor in nutrients and in fibers (Rosenheck, 2008; French et al., 2000). An increased consumption of calories coupled with a decrease in physical activity can result in more unbalanced diets and potentially lead to overweight, obesity or other chronic diseases (Kim et al, 2017).

Peru is no exception to the worldwide growing obesity issue. The prevalence of overweight and obesity in the Peruvian population has been increasing at a rapid pace, leading to an average obesity rate of 18.3% and an overweight prevalence rate of 54% in 2016 (Ministerio de Salud, 2017). Nevertheless, large territorial disparities prevail in the country as overweight and obesity mainly concern coastal and urban regions and, above all, Lima (Ministerio de Salud, 2017; Preston E.C. et al., 2015; Wisniewski, 2017; Pajuelo-Ramírez, 2017; Villena Chávez 2017; Hernández-Vásquez, 2014; Diez-Canseco, 2017).

1.2.2. Decentralization

Since the 1980s, many countries around the globe have initiated decentralization processes that reshaped the way they address most social, development and economic issues (Bardhan, 2002; Dethier, 2000). Decentralization happened for diverse reasons across countries and took different forms. Decentralizing means transferring part of the responsibilities and decision-making power from central governments to subnational authorities (OECD, 2019; von Braun and Grote, 2003; Leer, 2016). However, fiscal, political and policymaking competences are not necessarily all devolved at the same time.

We can distinguish several types of decentralization (OECD, 2019; von Braun and Grote, 2003; Schneider, 2003): 1) *political* decentralizations, which consist of the creation of new lower administrative units and the organization of local elections; 2) *fiscal* decentralizations, which refer to the new fiscal power and authority of subnational governments to raise taxes and receive financial support from national governments; and 3) *administrative* decentralizations, that represent the devolution of policymaking and implementation responsibilities in the area of public policies (von Braun and Grote, 2003; Litvack and Seddon, 1999). In practice, these three elements are often interlinked; however, in this paper we only refer to the “administrative decentralization” component and consider that “decentralizing” means that the central government transfers the management of public policies and social programs to subnational authorities, along with the budget allocated to them.

Although the specific motivations for undertaking a decentralization process are very different across countries according to their own history and economic situation, we can identify common goals, such as the willingness to improve democracy in highly concentrated economies, or to raise efficiency in the delivery of public services (OECD, 2019). Therefore,

decentralization has been largely promoted by international organizations and was often a condition for international development aid (Jütting et al., 2004; White, 2011). Yet, it has been argued that decentralization is not a flawless answer to foster development and, under certain conditions, could be detrimental to economic growth and people's well-being (OECD, 2019; Leer, 2016).

Decentralization, a complex process with conflicting effects

While many authors have studied the impact of decentralization on a wide range of topics, such as institutions (Carlitz, 2017; Azfar et al., 1999; Joanis, 2014; Bardhan and Mookherjee, 2005), economic growth and reforms (Aizenman and Isard, 1993), poverty and inequalities (Bardhan, 2002; Galasso and Ravallion, 2005; von Braun and Grote, 2003; Alderman, 2002; Basurto et al., 2018; Jütting et al., 2004), public services and education (Joanis, 2014; Leer, 2016; Martinez-Vazquez et al., 2017; Galiani et al., 2002), and health outcomes (Hutchinson and LaFond, 2004; Boyer et al., 2010); little research has been undertaken about the impact of decentralization on food security. This paper aims at filling this gap in the literature by providing evidence about the effects of decentralization on food security in Peru.

Some research advocates for decentralization since, under certain conditions, it can improve democracy, foster economic growth and reduce territorial inequality thanks to higher efficiency in the public sector that ensures a better quality in the delivery of public services. The literature highlights a number of mechanisms explaining the positive outcomes of decentralization.

One of the main advantages of decentralization is that it enables a bottom-up approach in policymaking. Since local authorities are in direct contact with local populations, they are able to obtain relevant information about citizens' needs and preferences at a lower cost compared to the central government. By being more aware of local challenges, subnational governments have a greater faculty to design and implement policies tailored to local populations' needs, and in a more efficient way (OECD, 2019; Wallis and Oates, 1988; Bardhan, 2002; Leer, 2016). Since local authorities are more relevant to identify specific causes of poverty and inequality, they are also more able to combat them (von Braun and Grote, 2003). Obtaining local information is too costly for central governments, which often incentivize them to apply uniform – and potentially less effective – policies across the country (OECD, 2019).

Decentralization is also expected to give more incentives to subnational governments to respect their political engagement. As local authorities are closer to the citizens (who have the power to reelect them or not), they have more incentives than the national government to deliver public services with high quality and at a lower cost. Competition with neighboring localities intensifies this phenomenon as each local authority seeks to attract workers and foster economic activity in their jurisdiction to ensure their reelection (Hatfield, 2015; OECD, 2019; von Braun and Grote, 2003; Leer, 2016). It follows that if subnational governments are more accountable, citizens will have more incentives to participate in the civil life of their community (e.g. by volunteering in social programs).

Despite these beneficial mechanisms, the literature also identifies several detrimental effects of decentralization. The main sources of inefficiency from decentralizing relate to the lack of financial resources and the typically low administrative, political and technical capacity of subnational authorities. For this reason, decentralization should always be implemented in a context of strong subnational capacity and adequate resources or, alternatively, be accompanied by a process of capacity building and investment plans for the local authorities (Willis et al., 1999; Falleti, 2005).

Local authorities are often in need of the adequate resources to implement effectively the new policies they are in charge of (OECD, 2019). In practice, under-funded mandates are common as subnational governments may not have the capacity to raise their own taxes – or may not be allowed to do so (e.g. due to legal constraints). To improve the efficacy of decentralization while preserving local governments' autonomy, a right balance must be found between their own sources of revenue and the financial support coming from the national government.

Beyond financial constraints, local authorities may lack the appropriate skills and competences to assume their new responsibilities. In 2015, 65% of subnational governments within OECD countries declared lacking the capacities for their strategic planning activities (OECD, 2019). Lower managerial capacities may come from a lack of expertise in policymaking, fewer human resources with a lower education profile than the employees working in national institutions, and weaker institutional and legal frameworks (Leer, 2016). Finally, the literature on decentralization also highlights the risk of a capture of power by local

elites (Devas and Delay, 2006; OECD, 2019), which would endanger the efficiency of public policies implemented by local authorities and deteriorate the participation of the citizens (von Braun and Grote, 2003).

We classify the positive and negative effects of decentralization into two main channels: a negative “capacity effect” and a positive “proximity effect”. Since these two effects are opposite, the overall impact of decentralization in a given territory will depend on the respective intensity of each effect. While the “proximity effect” should always be positive, the “capacity effect” can be either negative, null or positive. Nevertheless, in the particular case of Peru (as in most developing countries), evidence suggests that the capacity of subnational authorities is lower than that of the central government, and thus the “capacity effect” should be negative.

A negative “capacity effect” refers to the fact that subnational authorities tend to face higher financial and managerial constraints than the national government. They may be less able to allocate sufficient budget to the programs they are in charge of, as their capacity to raise taxes is weaker, and may also face managerial difficulties as their employees’ professional training and education tend to be lower on average compared to national institutions. On the contrary, the “proximity effect” is positive as it refers to the fact that subnational governments tend to have a better knowledge of local contexts and challenges. They may also be more able to generate trust and confidence from the population as they are in more direct and transparent contact with the citizens (e.g. a mayor has more opportunities to discuss local problems with the population than a minister does). This can trigger positive spillovers since more trust should increase the willingness of the population to participate in the implementation of the programs.

The weaknesses of decentralization in Peru

Some studies have highlighted disappointing results of decentralization in Peru. The World Bank (2010) performed a very rich analysis of the country’s decentralization process and showed that the quality of public services has not been improved afterwards. However, this research underlines that when subnational authorities are capable of generating more revenues by themselves, social programs deliver better results. This fact goes in line with the argument that weaker local capacities can jeopardize policy effectiveness.

In Peru, the transfer of social programs to local authorities in 2003 was undertaken at a premature stage of the country’s political development. It was only in 2002 that the

Constitutional Reform (27680) established the creation of the current regional and local authorities. After the fall of the dictatorial and highly centralized Fujimori's regime (1990-2000), both authorities and citizens pushed for a more decentralized organization of the country, which led to initiate the decentralization process right after the 2001 elections. This process lacked from a common vision and strategy between the different levels of government (including the newly created local authorities), in particular regarding the modalities of decentralization of the social programs.

1.2.3. The Peruvian Complementary Food Program (PCA)

The Peruvian Complementary Food Program (PCA) is one of the oldest and most important social programs dedicated to food aid that have been implemented in Peru with a national coverage over the past decades.² Even though the coverage of the PCA varies widely across districts and provinces, the program reaches up to 35% of the population in certain areas³ and all households living in poverty are eligible beneficiaries of the program. The PCA is the first food aid program to have been decentralized in Peru, and its decentralization process offers interesting modalities that enable us to build a solid identification strategy.

In 1992, the Ministry of Women and Social Development merged several food programs into a unique national program, under the name of PRONAA (Programa Nacional de Asistencia Alimentaria), with the general aim of reducing undernourishment across the country. This program then became the PCA and started to be decentralized in 2003, leading the decentralization wave that was going to spread over the country in the 2000s.

² Among other influential food aid programs are the program "Vaso de Leche" that provides dairy products only, primarily to children and to pregnant or breastfeeding mothers; as well as the program "Qali Warma" that provides food complement to pupils directly at schools. While the former was created in 1985, the latter dates back only to 2012. (FAO, ALADI and CEPAL, 2019; Ministerio de Desarrollo e Inclusión Social).

³ In the province of Ayabaca, the population benefiting from the PCA represents 35% of the total provinces' population. Authors' calculations based on INEI's population data and Ayabaca municipality's data (<http://www.muniayabaca.gob.pe/pagina.php?post=644>).

The main objective of the PCA is to increase food consumption of the poorest and most vulnerable populations⁴, by providing them with additional food intakes distributed in social centers that are operated by volunteers from local communities.

Although distribution centers are more likely to be located in rural and in poor urban areas, the program is nationwide and available in all provinces and districts. Although all food baskets delivered to the beneficiaries should cover around 30% of their daily energy needs, their content varies widely across territories as it depends on: 1) local populations' consuming habits, 2) local populations' needs regarding their environment and type of daily activities (e.g. rural workers have in general higher energy needs due to higher physical activity), 3) local availability of food, and 4) local authorities' budget for the program. The reference food basket for a household of one person is composed of 150g of cereals, 50g of vegetables, 20g of fish or meat and 10g of fat (MIDIS, 2013).

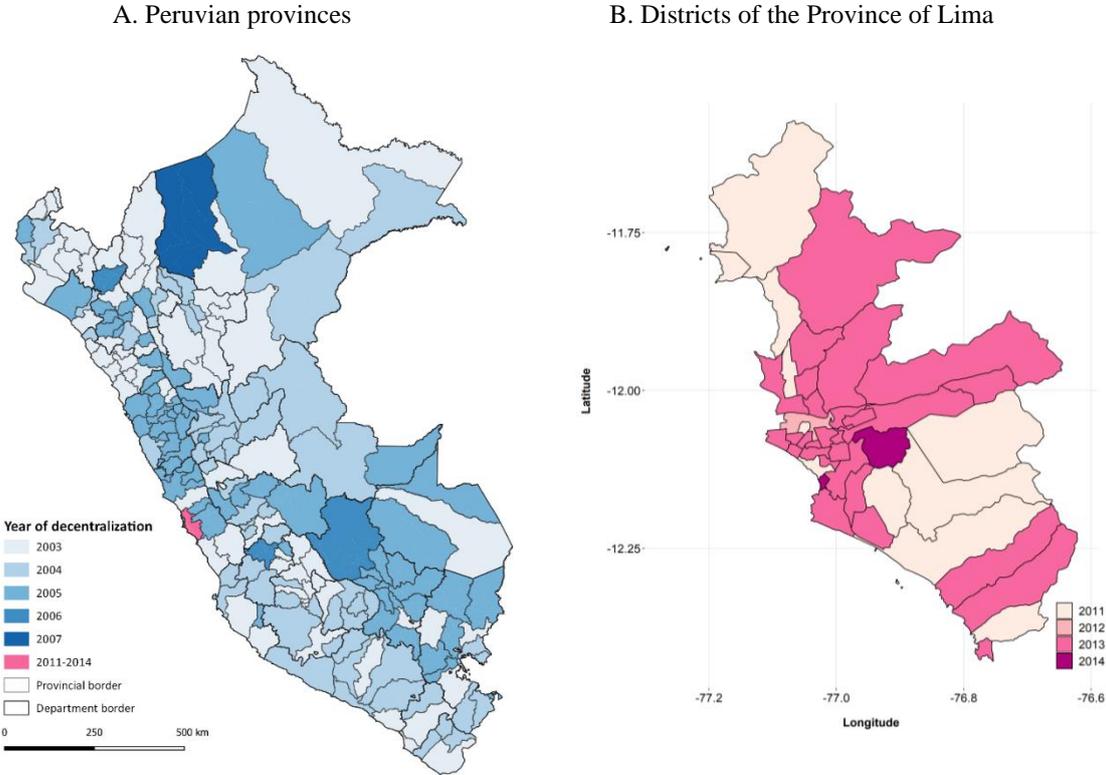
The PCA's decentralization process

Since its creation in 1992, the PCA had been fully managed by the national government; then, between 2003 and 2007, the program was progressively transferred to the provincial authorities across the country, except for the Province of Lima. In Lima, the PCA was directly and gradually handed to the 43 district authorities composing the province between 2011 and 2014⁵. Since the Province of Lima presents structural differences – being the urban, political and economic center of Peru – the national government considered that delegating the program to a lower level of government was possible and more adequate. As coordinating with district authorities was a more complex process, it was decided to start the decentralization process for Lima in a second phase (Ministerio de Justicia, 2006; CND, 2006b). Figure 1.2 shows the heterogeneous timing of decentralization across the territory.

⁴ Primary targets are poor and extremely poor households, children and adults with mental and physical disabilities, victims of domestic or political violence, as well as volunteer workers and individuals suffering from tuberculosis and their families.

⁵ Peru is organized through three main administrative levels, namely departments (25), provinces (196) and districts (1 976) (INEI, 2018).

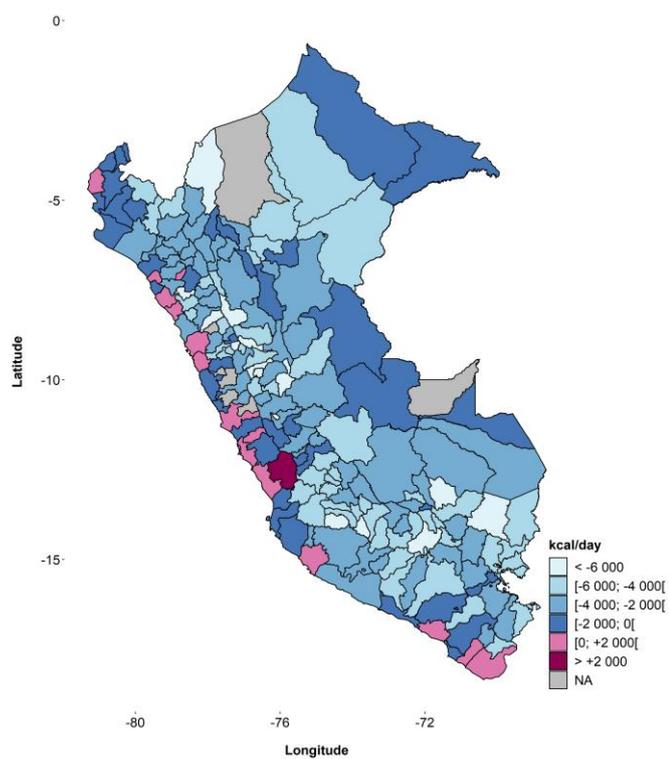
Figure 1.2. Roll-out dates of decentralization across the Peruvian territory



Source: Authors' elaboration based on the Peruvian Official Journal and GADM's data.

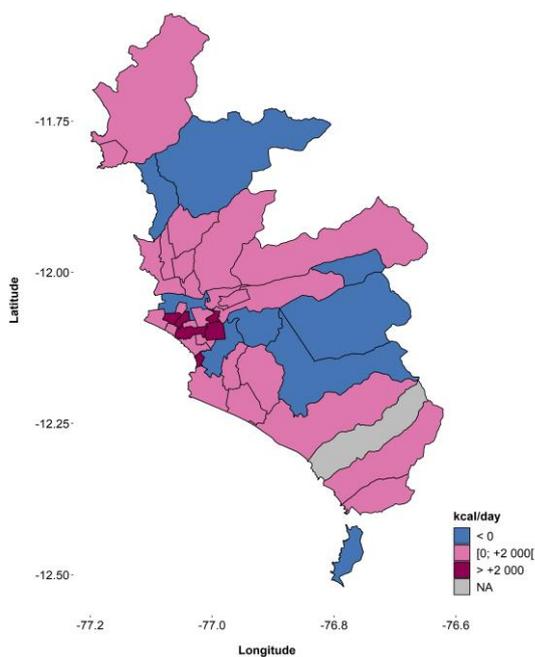
One of the main objectives of decentralizing the PCA was to reduce the large territorial inequalities in food security in Peru. Figure 1.3 reveals important disparities in provinces' average food deficits in 2002, a year before the launch of the decentralization policy. While all provinces of the Andean and Amazonian regions suffer on average from a food deficit (i.e. the population consumes less calories than they need), some provinces of the coastal area are not considered at risk of undernutrition (the pink provinces on Figure 1.3). Such averages also hide large inequalities within provinces – Figure 1.4 depicts the average adequacy of calorie intakes relative to the needs for Lima districts, and reveals that residing in a large urban area does not guarantee protection against undernutrition.

Figure 1.3. Average gap in calories by province, 2002



Source: Authors' elaboration based on INEI's data.

Figure 1.4. Average gap in calories by district in the Province of Lima, 2002



Source: Authors' elaboration based on INEI's data.

By decentralizing the management of the PCA to subnational authorities, the effectiveness of the program was expected to increase as local governments should more easily: 1) reach all the potential beneficiaries of the program to leave no one behind while avoiding free riding behaviors; 2) design an adequate food basket to better fit local needs and to increase the program cost-efficiency by reducing food wastes and food shortages; and 3) incentivize citizens in participating in the distribution of the food baskets, so as to foster the efficacy and scope of the program in the long-run.

With the decentralization of the program, the provincial and district authorities are responsible for the design, implementation and management of the PCA. The national government, through the Ministry of Development and Social Inclusion (MIDIS), still has a pivotal role to play as it transfers funds to support the subnational governments in the implementation of the program. The central government should also provide technical assistance and capacity building along the process, particularly for the monitoring of the program. Both parties are tied by a bilateral contract (named “Convenio de Gestión”) signed after the subnational governments are validated and authorized by the National Council of Decentralization (CND – Consejo Nacional de Descentralización) to receive the transfer of responsibilities.

1.3. Data

1.3.1. Main sources of data

Food insecurity is a multidimensional concept that can take various forms, from undernutrition (i.e. insufficient calories and nutrients consumption) to excessive food intakes or unbalanced diets. It relates to both the quantity and the quality of the food consumed and, in this sense, can be measured in a variety of ways. Since the main goal of the PCA is to increase calorie intake in Peru, our analysis focuses on measures of calorie consumption. Our main indicator of food security is the gap in calorie intake at the household level, measured as the difference between the calories consumed and the calories needed by the household. This indicator, as well as other necessary controls and information for our empirical strategy, were collected or constructed using the following databases:

- The *National Households Survey about Living Conditions and Poverty*⁶ (ENAHO) from the Peruvian Institute of Statistics (INEI) (2001-2016);
- The *Peruvian Tables of Food Composition*⁷ (2009) prepared by the National Center for Food and Nutrition (CENAN);
- The *Energy Requirements of the Peruvian Population*⁸ (2012) constructed by the CENAN;
- The *National Record of Municipalities*⁹ (RENAMU) from the INEI (2004 and 2009); and
- Supreme Decrees and Ministerial Resolutions from the Peruvian Official Journal *El Peruano*¹⁰.

The ENAHO is a very rich database representative at the national and departmental levels. From this survey, it is possible to obtain precise data on households' food consumption (items and quantities) and location (GPS coordinates) by year, for each of the 16 years spanning the period 2001-2016, as well as other household and individual characteristics that we include as control variables, such as income, age, sex and education of household's head, among others. Our baseline sample¹¹ is composed of more than 300 000 households for which we are able to analyze their consumption patterns based on 482 food items overall.

While the Peruvian Tables of Food Composition provide the content in calories of each of the aforementioned 482 food items, the Energy Requirements of the Peruvian Population estimate individuals' needs in calories, according to their age, sex and place of residence. By

⁶ “Encuesta Nacional de Hogares sobre Condiciones de Vida y Pobreza” (INEI), available at: <http://iinei.inei.gob.pe/microdatos/>.

⁷ “Tablas Peruanas de Composición de Alimentos” (CENAN), available at: <http://www.ins.gob.pe/insvirtual/images/otrpubs/pdf/Tabla%20de%20Alimentos.pdf>.

⁸ “Requerimientos de Energía para la Población Peruana” (CENAN), available at: <https://fr.scribd.com/document/140295535/Requerimiento-de-energia-para-la-poblacion-peruana-pdf>.

⁹ “Registro Nacional de Municipalidades” (INEI), available at: <http://iinei.inei.gob.pe/microdatos>.

¹⁰ Accessible at: <https://busquedas.elperuano.pe/>.

¹¹ After cleaning the database and excluding anomalies and outliers, such as households at both ends of the distribution of the calorie consumption (bottom and top 1%).

combining these elements together, it is possible to construct the variable “gap in calories” of each household.

1.3.2. Measuring Food Security

While the first part of the analysis focuses on the impact that the PCA’s decentralization had on caloric intake – measured as households’ gap in calories; subsequent sections of this chapter explore and discuss complementary food security measures, such as over-consumption of calories.

The main dependent variable: household’s gap in calories

The gap in calories is calculated as the difference between calorie intakes and calorie needs ($gap = calorie\ intakes - calorie\ needs$). As we measure it at the household level, it represents the distance of each household from meeting the aggregated daily energy requirements of its members. A negative household calorie gap reflects a food deficit, meaning that on average the household’s members are not eating enough food to reach the minimum calories they should consume each day, putting them at risk of undernutrition. On the contrary, a positive household gap in calories highlights either an adequate intake of calories (since eating more than the minimum requirements is good until a certain point) or an excessive intake of calories (if it exceeds a certain threshold, this possibility is discussed later in this chapter).

We use the following steps to construct the gap variable:

1. We determine the quantity in kilograms (q_{iht}) of each food item i purchased by household h over year t (using the ENAHO database, INEI);
2. Following the methodology of Babatunde and Qaim (2010) and Hoddinott (1999), we assign a coefficient ($coef_i$) to each food item i to convert its consumption in kilograms into kilocalories (the content in kilocalories of one gram of each food product is given by the *Peruvian Tables of Food Composition*, CENAN);
3. We sum the consumption of kilocalories over all products consumed by household h in year t , and divide by the number of days in year t to obtain an approximation of the household’s daily calorie intakes in that year (c_{ht}), expressed as:

$$c_{ht} = \frac{\sum_{i=1}^k q_{iht} \times coef_i}{365 \text{ (or } 366)}$$

-
4. We determine the total calorie needs of each household (r_{ht}), by aggregating the individual needs of each member m in household h and year t ($r_{ht} = \sum_{m=1}^n r_{mht}$). Individual calorie needs are based on age, gender and place of residence. While the ENAHO allows identifying the age, gender and place of residence of each household member, the tables of *Energy Requirements of the Peruvian Population* (from CENAN) provide the calorie needs by socio-demographic groups.

Thanks to this database conceived specifically for the Peruvian population, we are able to assign specific minimum calorie requirements for each individual, adapted to its age, sex and place of residence. This is an improvement compared to previous literature, as authors are often limited to the use of the generic WHO's worldwide average minimum energy requirements, regardless of the country or the population they are focusing on (Babatunde and Qaim, 2010). On the other hand, it is worth noting that the personal minimum energy requirements for the Peruvian population have been calculated only once with data of 2012. Due to this data limitation, we assume that energy requirements by age, gender and place of residence in Peru have not dramatically changed in the period of study.

5. We calculate the household gap in calories as the difference between the calories consumed and the calories needed, for each household:

$$gap_{ht} = c_{ht} - r_{ht}$$

While negative values represent a deficit in calories (i.e. the household is undernourished as a whole), positive values stand for an adequate or, in some cases, for an excessive consumption of calories on average for the household.

It is worth noting that due to the scope of ENAHO, our measure of gap in calories does not take into account the calories from food prepared and consumed outside the house (e.g. restaurants and street food).

Discussion on the main food security variable: the household's gap in calories

Household vs. Per capita gap in calories

Since individual food consumption is not provided by our main data source, we are only able to obtain a measure of the gap in calories at the household level. Although some of the

papers of the literature prefer to use a measure of calories at the individual level (Smith et al., 2016), we focus on the household variable and choose not to divide it by an adult equivalent scale that would give us an approximate measure of consumption per capita. The main reason for this is to avoid imposing either high or low intra-households inequalities in calorie consumption. For example, a measure of kilocalories per capita would generate inefficient allocations of calories as working adults require more kilocalories than children do. On the other hand, assuming that everyone consumes a proportion according to its needs would minimize potential intra-household inequalities in food security (see Lise and Seitz, 2011). Yet, evidence suggests that in Peru, large intra-household inequalities in the repartition of food exist. For example, some households can present excessive calories consumption due to obese parents, while children are undernourished.

Although the variable gap in calories at the household level does not allow us to measure intra-household inequalities in calorie consumption, it does not force us to make any assumption about it. The risk associated with a gap variable at the household level is that we could miss out some level effects in our regression analysis. To address this, we always include a control for the size of the household in each of our regressions.

Gap in calories vs. Nutrition variables

There is no consensus in the literature about the best indicators to measure food security. The most suitable indicator depends on the topic, the context, available data and the objectives of the research. In this chapter, we chose to focus on a measure of the “quantity” of food and energy transferred to the body through diet choices, based on the number of calories consumed. This indicator does not allow us to scale the quality of the diet. High levels of calorie consumption do not guarantee a balanced healthy diet and can even be detrimental if excessive (e.g. fast foods) (Headey and Ecker, 2013).

Nevertheless, we prefer this indicator over nutrition variables (e.g. nutrient content or diversity of the diet) for the following reasons: 1) the main objective of the PCA is to increase calorie consumption and our goal is to gauge the efficacy of the program to reach its objectives after its decentralization; 2) the Peruvian national government considers the evolution of calorie intakes as a key indicator in its “National Strategy of Food and Nutrition Security” (Comisión Multisectorial de Seguridad Alimentaria y Nutricional, 2013); 3) since calories are still widely

used in the literature about undernutrition to measure the sufficiency of the diet (Iram and Butt, 2004; Tschirley and Weber, 1994), our measure of the gap in calories could increase the comparability of our results with other studies and official reports; and 4) international organizations utilize the consumption of calories to calculate the prevalence of undernourishment, a key indicator in the UN SDGs framework to measure SDG 2 on Food Security (FAO et al., 2018; UN, 2018a).

Complementary measures of food security: undernourishment and over-nourishment

The primary objective of this chapter is to evaluate the impact of decentralization on the PCA's efficacy to increase calories consumption. However, we also use complementary food security measures to explore the effects of the policy on other types of food insecurity in Peru. More precisely, we are also interested in verifying if the policy helped families to exit the undernutrition status, as well as the effect on over-nourished households. Using the variable gap in calories, we construct the following three binary variables that categorize households according to their consumption of calories relative to their needs:

Undernourishment. We construct a dummy variable taking value 1 if the households' calorie consumption is strictly below their recommended needs (i.e. if the gap in calories is negative), and 0 otherwise (i.e. if the households eat the right number of calories, or more).

Over-nourishment. Excessive calorie intakes can put individuals at risk of overweight, obesity and other related health issues. We consider that households are over-nourished when their consumption of calories represents at least 150% of their actual energy requirements (also referred to as the "150-threshold") – i.e. their consumption is 50% or more above their actual needs.

It is worth noting that there is no literature linking which calorie consumption threshold is most adequate to determine a risk of overweight. This comes from the fact that overweight is a complex issue that also depends on other factors, such as the intakes of nutrients and the intensity of the physical activity. As an example, Bonnet et al. (2014) consider that eating 20% more fats than required significantly increases the probability of being obese. As our own threshold is to a certain extent arbitrary, we do not pretend to define a generic level over which calorie intakes would always be excessive and dangerous for health. However, this threshold

helps us to approximate excessive consumption of calories. To verify our results, we perform robustness checks using different thresholds to define an excessive calorie consumption.

Good track. This variable is equal to 1 if households are neither undernourished nor over-nourished, i.e. if their intakes of calories are superior to their minimum energy needs but below the 150-threshold (or other tested thresholds).

1.3.3. Explanatory variables

To evaluate the impact of decentralizing the PCA, it is necessary to control for several characteristics at the household and provincial or district level that could also account for the gap in calories.

From the ENAHO database, it is possible to make use of the data related to the households' overall economic and well-being situation. The regressions always include household gross equivalized income and its square, as well as characteristics of the household's head such as its educational attainment, its gender and if its sector of activity is agriculture. Households in the agriculture sector could require more energy on average to sustain their daily physical workload, while they could also benefit from their own food production. In this perspective, we also include a variable for self-consumed food (i.e. food produced by the households for their own consumption). This variable also allows controlling, to a certain extent, for the households' degree of exposure to international food prices – the less food-sufficient households are the most vulnerable to volatility in prices of imported food. Finally, we consider the size of the household (i.e. the number of members) to account for the level effects generated by the aggregated needs of calories measured at the household level.

The roll-out dates of the decentralization of the PCA in each of the 195 provinces of the country and the 43 districts of Lima were collected from official decrees published in the Peruvian Official Journal. Complementary data on provinces and districts characteristics were obtained from the National Record of Municipalities (RENAMU).

From the RENAMU database, we extract information on each local authority (provinces and Lima districts) that helps us controlling for the local context before decentralization. The regressions include the controls of population size by locality, the number of government employees in local administrations per 1 000 inhabitants, the administrative status of each local authority (e.g. if the province is the capital of a department), and a measure of local government

capacity to spend the budget, namely the budget utilized by the local authority at the end of the budgeting period as a percentage of the budget planned at the beginning of the year. To account for the quality of governance, we use perception-based measures of corruption from the ENAHO. We look at the perception in the evolution of corruption (the percentage of people that believe corruption has risen over the last year). When exploring the capacity effect of decentralization, we focus on the share of people that believe corruption is among the three main problems in the country.

Finally, to explore the role of proximity in the gains associated to decentralization of the PCA, we use one variable of physical and cultural distance. For physical distance, we simply calculate the geographical distance of each province or district to Lima capital – where the national government is based. The largest the distance to Lima, the stronger the “proximity effect” should be – as the local government should have more knowledge of the local communities, relative than the central government¹². On the other hand, our variable of cultural distance relates to language. This variable measures the difference in the proportion of the population speaking Spanish in the provinces and districts compared to Lima capital. Spanish is one of the three official languages of Peru¹³, and has been dominantly spoken in Lima over the years. Yet, Peru is one of the most culturally diverse countries in South America, with 47 other languages being spoken across its territory (Ministerio de Educación, 2017) by around 55 native indigenous peoples. The purpose of this variable is to measure the cultural proximity of local authorities to their population, as opposed to the central government. We calculate the proportion of native Spanish speakers in each province and district using data from the ENAHO (individuals were asked which language they have been speaking since childhood).

¹² We compute the distance of each province’s and district’s centroid to the center of the capital city Lima using the `gCentroid` function in R. Distances to Lima are constant over the studied period.

¹³ Quechua and Aymara are the two other official languages. In Lima, 89% of the population speaks Spanish as their main language, while in the rest of the provinces this is the case for 73% of the population. However, large discrepancies in the proportion of Spanish speakers remain across provinces (based on INEI’s data).

1.4. Empirical strategy

To assess the causal impact of the PCA's decentralization on households' gap in calories, we implement an adapted difference-in-differences model that relies on the gradual implementation of the policy (decentralization) across subnational governments.

The transfer of the program (PCA) from the central government to the local authorities (provinces and districts) was made progressively across the national territory between 2003 and 2014. In the first year (2003), 67 provinces received the responsibility to manage the PCA; in the following year (2004), the program was transferred to another 58 provinces (Decreto Supremo n°088-2003-PCM, 2003; MIMDES, 2005). This gradual execution of decentralization took place almost annually until 2014, when the last two remaining districts (in the Province of Lima) inherited the administration of the program. Provinces and districts were thus treated at different dates. We exploit this geographic discontinuity in the timing of the PCA's decentralization to estimate its impact, with a difference-in-differences methodology that builds on multiple years of treatment and evolving control groups.

Based on the year of treatment (decentralization), the model identifies a total of nine treatment groups, named T_g (dummy variables), denoting the local governments that received the transfer of the PCA in year g . For instance, T_{2003} gathers the 67 provinces for which the program was decentralized in 2003 ($T_{2003} = 1$); while, for the same year, all the other provinces and districts of Peru are considered as part of the control group ($T_{2003} = 0$). In 2004, 58 new provinces become responsible for the administration of the PCA – and thus are classified as the treatment group T_{2004} . The same logic is applied until year 2014, where the last two districts that received the program are denoted as $T_{2014} = 1$.

1.4.1. Construction of the decentralization variable

The Decentralization Policy variable $D_{g,t}$, which is our explanatory variable of interest, is a binary variable representing the interaction between the treatment group dummy T_g and its corresponding post-treatment time dummy. In other words, the policy variable is equal to 1 only when a household from a locality that adopted the program in year g is observed from year g onwards (i.e. when the actual year t is equal or higher than the year of entry into the program, $D_{g,t} = 1$ if $t \geq g$). For instance, for households living in a province that was decentralized in

2004 (i.e. belonging to treatment group T_{2004}), the policy variable equals 0 when we observe these households in years 2001, 2002 and 2003, but it equals 1 when the households are observed in 2004 and all the following years (our period of observation ranges from 2001 to 2016). The policy variable ($D_{g,t}$) captures the overall effect of decentralization from the moment it was first rolled-out in each province and district, until the last year available of observation.

1.4.2. Potential endogeneity issues

To ensure that our estimates capture the causal effect of decentralization, we need to verify that the identification strategy is not biased by an endogenous selection of the provinces and districts into the roll-out process of decentralization. Two potential sources of endogeneity in the date of decentralization exist: 1) simultaneity bias and 2) omitted variable bias.

First, a simultaneity bias may appear if pre-treatment food security outcomes played a role in the timing of decentralization. For example, if the national government considered the least food secure provinces and districts as priority areas, it might have granted them an access to the management of the program earlier. Alternatively, if the government assumes that the least food secure areas are less capable of managing the program, decentralization could have started later in these regions (i.e. asymmetric decentralization due to capacity of local authorities).

Secondly, omitted variable bias might affect our estimates if there are some characteristics of the provinces and districts that explain both food security outcomes and the date of entry into the program. Although each subnational government had to validate the same prerequisites to prove their preparedness to receive the transfer of the PCA, the completion of these criteria could have been highly dependent on their initial economic and demographic endowments, such as population size, poverty rates and degree of rurality, among others.

More precisely, the requirements for decentralization related mostly to the local governments' institutional and managerial capacity (e.g. having a Local Development Plan, constituting specific committees for the fiscal management of the program, etc.) and to the strength of their human resources (e.g. sufficient number of government employees) (CND, 2006a; MIMDES, 2011b). Thus, depending on their initial endowments before 2003 – the

starting date of the PCA's decentralization policy – some subnational governments might have been able to fulfil the requirements more easily than others, which could explain different dates of entry into the program and different outcomes in food security.

Political outcomes might be another potential source of bias. For example, provinces and districts with more political influence (e.g. better connections with the incumbent government) might have been favored by the central government and authorized to roll-out the decentralization of the PCA earlier than others – even without fulfilling the prerequisites. We address this point by controlling for perceived evolving corruption in the timing of the decentralization process. If corruption in Peru was predominantly low, the political connections of provinces and districts with the central government should not determine the date for decentralization. On the contrary, high levels of corruption could have accelerated unevenly the process of decentralization across the national territory.

Testing for endogeneity in the year of treatment

To test if the date of decentralization is endogenous to our variables of interest, we explore whether certain characteristics of the provinces and districts before the first year of decentralization influenced the year in which they received the transfer of the PCA. More specifically, we examine if ex-ante average levels of food security, poverty, population size, rurality, corruption and other institutional and managerial capacities are associated to the actual year of decentralization of provinces and districts. To do so, we apply the simple linear regression model described by Equation 1.1, where $group_m$ stands for the date of decentralization of the province or district m .

$$group_m = FS_{m,y_0}A + TC_{m,y_0}B + prerequisites_{m,y_0}C + rcorruption_{m,y_0}D + \gamma_d + \varepsilon_m \quad 1.1$$

FS_{m,y_0} is either the average amount of calories consumed or average gap in calories (calories consumed minus calories required) observed in the province or district m in year y_0 , where y_0 stands for the year just before the start of the decentralization process (i.e. 2002 for the provinces and 2009 for the districts of Lima). TC_{m,y_0} is a set of indicators encompassing territorial characteristics of the province or district m before the start of the decentralization policy, namely poverty rate, population size, percentage of the population that is rural, and a dummy that equals 1 if the province is the capital of its department. Similarly,

$prerequisites_{m,y_0}$ is a set of variables that capture the prerequisites of the “verification mechanism” for decentralization. More precisely, it accounts for the administrative capacity of the local authority m before the treatment and includes: 1) the number of local government employees per 1 000 inhabitants¹⁴, 2) public expenditure as a percentage of total budget, and 3) a dummy variable that equals 1 if the local authority has a formal Local Development Plan to guide its development policy.

Finally, corruption is also taken into account. The variable $rcorruption_{m,y_0}$ is defined as the share of the population in the province or district m that perceived more corruption in year y_0 than during the year before. As other contextual (time-invariant) characteristics of each department may influence the preparedness of provinces to receive the qualification for the transfer of the program, department fixed effects (γ_d) are also included (except for the regressions that consider only the districts of Lima since they all belong to the same department). Finally, ε_m stands for the error term. Standard errors are corrected for heteroskedasticity.

Is the date of decentralization endogenous?

Table 1.1 shows which regional characteristics observed before the start of the policy predict date of entry into the decentralization process. While columns 1 and 3 explore entry into the program using the variable of average consumption of calories, columns 2 and 4 use our measure of gap in calories (our preferred measure of food security as it takes into account the actual caloric needs of the household). The indicator of average consumption of calories is included since it is more likely that policy makers would have looked at this variable to prioritize decentralization rather than to a more detailed measure such as gap in calories. Regardless of the measure of caloric intake, Table 1.1 shows no significant correlation between pre-program food security levels and the year of the decentralization, which excludes one of the main concerns about potential endogeneity in the model.

¹⁴ As the provinces outside Lima are concerned, we could not measure human resources endowments and the other administrative variables before 2003 due to a lack of data in the RENAMU database. Instead, we use data from 2004 and assume that the changes were marginal between 2002 and 2004.

In all specifications showed in Table 1.1, it is possible to observe that decentralization began later in the most populated provinces and districts – a result potentially driven by the year of entry of the districts of Lima (since all of them decentralized after 2010). On the other hand, the PCA's transfer began earlier in provinces that are capital of their department. There is evidence that capital-regions tend to be more economically developed than their peer regions (OECD, 2019), which might also relate to having greater technical capacities, resources (budget) and political connections with the central government.

Table 1.1. Testing for endogeneity in the date of decentralization

	All provinces and Lima districts			
	(1)	(2)	(3)	(4)
	Date of decentralization	Date of decentralization	Date of decentralization	Date of decentralization
Average calories	-0.0000959 (0.000121)		-0.0000968 (0.000122)	
Average gap in calories		-0.000141 (0.000122)		-0.000146 (0.000124)
Poverty rate	-0.0185 (0.0102)	-0.0195* (0.00966)	-0.0192 (0.0103)	-0.0204* (0.00982)
Population size (thousands)	0.00282* (0.00121)	0.00268* (0.00120)	0.00276* (0.00123)	0.00261* (0.00122)
Rurality rate	-1.280 (0.763)	-1.534 (0.851)	-1.371 (0.797)	-1.652 (0.896)
The municipality is a capital of department	-1.26 1** (0.435)	-1.253** (0.427)	-1.253** (0.439)	-1.243** (0.430)
Government employees per 1 000 inhabitants	0.306* (0.135)	0.319* (0.136)	0.297* (0.136)	0.309* (0.137)
Budget capacity	0.00994 (0.00803)	0.0102 (0.00803)	0.0105 (0.00805)	0.0109 (0.00806)
Local Development Plan	-0.258 (0.298)	-0.269 (0.300)	-0.243 (0.298)	-0.252 (0.299)
Evolving corruption in the last year			-0.786 (0.952)	-0.885 (0.955)
<i>N</i>	196	196	196	196
<i>R</i> ²	0.822	0.824	0.823	0.825
adj. <i>R</i> ²	0.787	0.789	0.787	0.789
Department FE	Yes	Yes	Yes	Yes

Note: Due to data availability, this table only includes 159 provinces (out of 196) and 37 districts of Lima (out of 43). *p* < 0.05, ** *p* < 0.01, *** *p* < 0.001.

Subnational governments with a higher number of government employees per capita decentralized the PCA in later years, and there is no significant role of either local public expenditure or the fact of having a local development plan. Thus, provinces and districts that seemingly fulfilled the pre-requisites for decentralization in 2002 do not seem to have received the management of the PCA before others. Overall, we do not find a significant contribution of

corruption in the timing of decentralization (columns 3 and 4). Finally, poverty rates in 2002 seem to be associated to early entry into the program.

Since the pre-policy characteristics of population size, being a capital-region, government employees per capita and poverty rates are significantly associated to the date of decentralization, we include them as control variables in all the specifications that aim at measuring the impact of decentralization on food security outcomes.

1.4.3. Validity of the common trend assumption

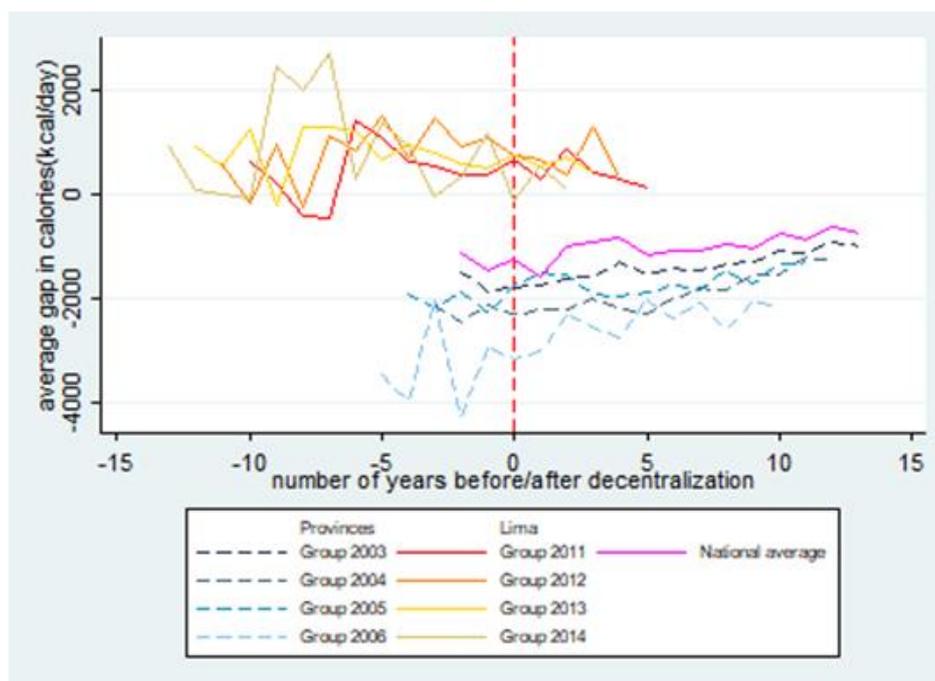
Figure 1.5 plots the evolution of the average gap in calories by treatment group and enables us to verify the common trend assumption – necessary to validate our adapted difference-in-differences approach – for two different groups of local authorities, the provinces and the districts of Lima.

Two opposite patterns of calorie consumption appear across Peru's local authorities. The provinces that were decentralized between 2003 and 2007 (i.e. all the provinces except Lima) present on average a food deficit before being decentralized. Over the years after decentralization, and despite some fluctuations, these provinces follow a similar upper trend in their average consumption of calories and are getting progressively closer to a zero gap in calories. Overall, their situation seemed to have improved at an akin pace after decentralization.

Contrary to the provinces, the districts of Lima do not suffer from initial levels of calorie deprivation, on average. What is more, they display positive gaps in calories before decentralization, meaning that overall Limeans were consuming substantially more calories than their minimum requirements. However, Figure 1.5 shows that after decentralization all the districts of Lima experienced a similar decrease over time in their average consumption of calories, relative to their needs.

Thus, the overall trends in calorie intakes with regards to energy needs seem to follow common patterns before decentralization. What is more, levels are very similar within two main groups of local authorities – the districts of Lima on one side and the rest of provinces on the other side – suggesting a regional convergence in food security over the period after decentralization.

Figure 1.5. Trends in the average gap in calories by group of decentralization



Notes: The horizontal axis displays the number of years before and after decentralization for each treatment group (e.g. for the 2006 treatment group, the value 0 represents 2006 and the value 10 stands for 2016, ten years after they rolled-out the policy). For presentation purposes, the graph excludes the 2007 treatment group.

Source: Authors' calculations based on INEI's data.

1.4.4. Main specification

To capture the overall effect of the decentralization of the PCA on households' food security (gap in calories variable), and based on the identification strategy previously described, we define our baseline model as in Equation 1.2, where gap_{hgt} is our preferred food security variable and stands for the gap in calories for household h who belongs to the treatment group g ¹⁵ and is observed in year t .

$$gap_{hgt} = D_{gt}\beta + Z_{my0}A + X_{hgt}B + F_m + post2002_t + \varepsilon_{hgt} \quad 1.2$$

D_{gt} is the decentralization variable for a household belonging to the treatment group g in year t . The yielding coefficient β can be interpreted as the intention-to-treat effect of the policy. Z_{my0} is the set of pre-decentralization characteristics that are correlated to the date of entry in

¹⁵ Belonging to the treatment group g means that the household resides in a province or district that received the transfer of the program in year g .

the decentralization process for the province or district m . Besides, X_{hgt} is a group of time-variant controls at the household level and F_m are province and district fixed effects that account for time-invariant territorial characteristics. Finally, $post2002_t$ is a time fixed effect that enables us to distinguish the periods before and after the start of the general decentralization process (i.e. after 2002). ε_{hgt} is the error term; standard errors are corrected for heteroskedasticity and clustered at the province and district level. All regressions are weighted (based on the weights provided in the survey).

Due to data limitations, we cannot control for the effect of other food aid programs; however, considering the magnitude of the PCA across the whole country, it is very unlikely that other small or medium size food aid programs would significantly affect our estimates. What is more, we argue that our results are not driven by the decentralization of the other social programs because they were all decentralized in a second step, after the PCA was completely transferred to all local authorities (Contraloría General de la República, 2014).

1.5. Results

This section shows whether the decentralization of the PCA was successful in improving the consumption of calories in Peru, it analyzes the mechanisms at play and explores other food security outcomes, such as over-consumption of calories (which can also lead to malnutrition), to better understand the effect of the policy across the country. As a reminder, the variable gap in calories is measured as the difference between household calorie consumption and household calorie needs. The variable of gap in calories can either take negative values (the household suffers from a food deficit and is at risk of undernourishment) or positive values (the household consumes the minimum calorie requirements or more).

1.5.1. *The heterogeneous impact of the PCA's decentralization across the territory*

We present the results of our main specification (Equation 1.2) in Table 1.2. The first column of this table gathers the overall results for Peru – pooling all provinces and Lima districts together – and enables us to verify some associations between the dependent and the control variables. For example, households with higher incomes tend to consume more calories, although this relationship is not linear and consumption of calories finds its maximum at a certain level of income. Table 1.2 also suggests that when the head of the household is a woman,

the availability of calories in the household is higher. This result echoes with other works showing that women are more likely to spend the family's revenues in health and education (EBRD and World Bank, 2013; UN Women). We also observe that households relying on self-consumption and working in agriculture are more likely to consume fewer calories with respect to their needs, whereas the consumption of calories increases with the educational attainment of the household's head.

Table 1.2. The impact of decentralizing the PCA on households' gap in calories (main specification)

	All provinces and Lima districts (1)	Provinces (excluding Lima) (2)	All districts of the Province of Lima (3)
	Gap in calories	Gap in calories	Gap in calories
Decentralization policy	-274.5*** (62.86)	318.3* (133.4)	-219.5*** (60.21)
<i>Local authority characteristics before decentralization</i>			
The local authority is a capital	-560.1*** (20.15)	168.5*** (14.13)	-162.7*** (40.34)
Government employees (per 1,000 inhabitants), circa 2002	-26.74*** (3.853)	286.2*** (2.157)	-80.09*** (5.938)
Population (in thousands), circa 2002	0.906*** (0.0491)	2.786*** (0.0507)	0.114*** (0.0242)
Poverty rate, circa 2002	-49.96*** (0.770)	-18.01*** (0.618)	-30.05*** (0.482)
<i>Household characteristics</i>			
Gross equivalized income	23.32*** (3.526)	44.78*** (5.183)	-0.217 (1.856)
Gross equivalized income ²	-0.0746*** (0.0154)	-0.169*** (0.0339)	0.00648 (0.00666)
Self-consumed food	-0.612*** (0.0191)	-0.596*** (0.0213)	-0.645*** (0.0465)
Household's size	-580.9*** (31.07)	-673.6*** (39.94)	-288.4*** (26.57)
Main activity: agriculture	-1149.9*** (74.22)	-1059.5*** (69.16)	153.5 (235.8)
Household head is a woman	149.8*** (29.84)	211.8*** (30.10)	-83.09 (56.90)
Primary education (head)	-30.27 (34.81)	25.16 (32.97)	-339.7*** (79.93)
Secondary education (head)	77.72 (49.78)	150.9** (51.42)	-329.6*** (72.57)
Tertiary education (head)	200.5*** (52.62)	301.6*** (59.88)	-255.4** (87.26)
<i>N</i>	260454	238011	22443
<i>R</i> ²	0.343	0.365	0.105
adj. <i>R</i> ²	0.342	0.364	0.103
Province / Lima district FE	Yes	Yes	Yes
Post 2002 FE	Yes	Yes	Yes

Note: The category of reference for the educational attainment is "No education". Robust standard errors in parentheses;
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Overall, the decentralization of the PCA had a negative impact on calorie consumption, with respect to calorie needs (Table 1.2, column 1). However, the effects are very heterogeneous across regions (columns 2 and 3). In particular, the generalized negative effect of the policy is mainly driven by the districts of the province of Lima, which are relatively more populated than the rest of the provinces.

When analyzing the differentiated effect of the policy across groups of regions, our results reveal a negative effect of the policy in the districts of Lima (Table 1.2, column 3), but a positive one in the rest of the provinces (Table 1.2, column 2). More precisely, decentralizing the PCA decreased calorie consumption (relative to calorie needs) in the households of Lima by 219 kcal per day on average. On the other hand, the policy increased calorie consumption (relative to calorie needs) by around 318 kcal per day for households living in the rest of the provinces. This amount of energy for the provinces represents around 4% of the average requirements for a Peruvian household¹⁶.

Channels of impact of the decentralization policy

To explain the heterogeneous regional effects of the policy, and based on the literature of decentralization, we identify two major mechanisms behind the process of decentralization – a positive “proximity effect” and a negative “capacity effect” that tend to vie with each other.

Our interpretation is that in the provinces (excluding Lima), decentralizing the PCA was beneficial to the population’s calorie consumption (relative to their needs) because the “proximity effect” overweighed the “capacity effect”. The advantages associated to the transfer of the program to the provincial authorities – who are by essence closer to local populations than is the national government – are greater than the potential drawbacks stemming from their lower institutional and financial capacity. It is easier and less costly for subnational governments to communicate with local populations and obtain information about their needs or preferences. For instance, provincial authorities may be better able to target the population in need of food support and may choose a more suitable composition of the food basket regarding local populations’ typical daily activities or culture. Central governments, on the

¹⁶ These calculations are based on the average energy requirement of the average Peruvian household (1900 kcal/day), based on INEI’s and CENAN’s data.

other hand, tend to face more difficulties to access such information, as they are generally located somewhere else (e.g. capital cities – here Lima) and operate through larger institutions that are less accessible to the citizens. Thus, even if provincial governments in Peru face tighter capacity constraints compared to the national government, the gains they obtain by tailoring the program to the local needs seem to dominate.

Conversely, we project that decentralization had a negative effect on calorie consumption (relative to their needs) in Lima because the “capacity effect” surpassed the “proximity effect”. The Province of Lima concentrates on its territory both the central administration and the local district authorities. Being based in the same place, it is very likely that government employees working in either one or the other of these administrations benefit from the same knowledge and awareness of the situation in Lima. Yet, they differ in their financial and management capacities. Literature has shown that financial resources and managerial skills of local authorities are likely to be weaker than those of central governments (OECD, 2019). Consequently, transferring the program from the Ministry of Woman and Social Development to the district authorities in Lima should be mainly associated with a decrease in management and budget capacities, without any or a very marginal gain in the knowledge of the local context.

Testing the “proximity” and “capacity” effects

To estimate the “proximity” and “capacity” effects of decentralization separately, we use Equation 1.3; which is a modified version of Equation 1.2 that includes the “proximity” variables of distance and language, or the “capacity” variables of budget utilization and perceived corruption, as well as their interaction with the decentralization policy variable.

1.3	
1.3.a	$gap_{hgt} = D_{gt}\beta_1 + distance_m\beta_2 + (D_{gt} * distance_m)\beta_3 + Z_{mgb}A + X_{hgt}B + F_m + post2002_t + \varepsilon_{hgt}$
1.3.b	$gap_{hgt} = D_{gt}\gamma_1 + language_{mt}\gamma_2 + (D_{gt} * language_{mt})\gamma_3 + Z_{mgb}A + X_{hgt}B + F_m + post2002_t + \varepsilon_{hgt}$
1.3.c	$gap_{hgt} = D_{gt}\alpha_1 + budget_m\alpha_2 + (D_{gt} * budget_m)\alpha_3 + Z_{mgb}A + X_{hgt}B + F_m + post2002_t + \varepsilon_{hgt}$
1.3.d	$gap_{hgt} = D_{gt}\theta_1 + corruption_m\theta_2 + (D_{gt} * corruption_m)\theta_3 + Z_{mgb}A + X_{hgt}B + F_m + post2002_t + \varepsilon_{hgt}$

The variable $distance_m$ stands for the geographical distance to Lima city from the province or district m (3.3.a). As a proxy of cultural distance we use the variable $language_{mt}$,

which is the difference in the proportion of native Spanish speakers between Lima district and the province or district m in year t (3.3.b). For the equations testing the capacity variables, $budget_m$ (3.3.c) denotes the capacity of the local government to utilize its budget (percentage of total budget spent at the end of the budget period), while $corruption_m$ indicates the level of perceived corruption in government by the local population. The food security variable gap_{ngt} and the rest of the controls are the same as in Equation 1.2. The coefficients of interest for proximity are β_3 and γ_3 that respectively measure how the effect of decentralizing the PCA varies with physical or cultural distance to the central government. On the other hand, α_3 and θ_3 capture the interaction effect of decentralization with either budget utilization or corruption, respectively.

We find that decentralization is more beneficial in regions farther away from the central government, both in terms of physical and cultural distance. While larger physical distance to the central government is negatively associated with food security outcomes, the interaction decentralization and physical distance is positively associated to adequate calorie consumption. The latter result also holds for the interaction of decentralization and cultural distance (Table 1.3, columns 1 and 2). Although the overall effect of the policy is negative when pooling together all the provinces (including Lima), the provinces farther away from Lima have positive gains from the proximity effect of decentralization. More precisely, and everything else being equal, the gain of decentralization for a province which is at 390 km from Lima capital district (the average distance in the sample) is of around 483 kcal per day by household.

Ideally, capacity should be measured through the level of skills or performance of the managing authorities before and after decentralization. This would imply measuring the capacity of the central government to manage the PCA before decentralization (for each province and district), and then the capacity of the new (local) managing authorities after decentralization (by province and district). Due to data availability constraints, we can only provide rough estimates of the role of capacity of local authorities at the time of decentralization (one point in time) in shaping the effectiveness of the policy.

According to Table 1.3 (columns 3 and 4), the provinces or districts with more capacity to spend their budget and with lower levels of perceived corruption tend to benefit more from decentralization. However, this positive association is not very robust – only statistically

significant at the 90% level. Overall, the most robust channel seems to be the proximity effect through physical distance, which is statistically significant at the 99%.

Table 1.3. The “proximity” and “capacity” effects

	All provinces and Lima districts			
	(1)	(2)	(3)	(4)
	Gap in calories	Gap in calories	Gap in calories	Gap in calories
Decentralization policy	-464.9*** (63.49)	-407.2*** (68.34)	-908.9** (282.60)	213.8 (191.10)
<i>Proximity effect</i>				
Decentralization*Distance to Lima	1.241*** (0.19)			
Decentralization*Difference in the main language spoken		11.20* (4.57)		
Distance to Lima	-4.922*** (0.19)			
Difference in the main language spoken		-3.099 (4.87)		
<i>Capacity effect</i>				
Decentralization*Budget capacity			6.798* (2.98)	
Decentralization*Perceived corruption				-15.19* (5.97)
Budget capacity			137.8*** (2.69)	
Perceived corruption				284.1*** (5.69)
Benchmark model's controls	Yes	Yes	Yes	Yes
N	260454	246682	258971	260454
R ²	0.343	0.342	0.341	0.343
Adjusted R ²	0.343	0.341	0.341	0.342
Post 2002 FE	Yes	Yes	Yes	Yes
Province/District FE	Yes	Yes	Yes	Yes

Notes: Robust standard errors in parentheses. * p < 0.05, ** p < 0.01, *** p < 0.001.

To verify which effect dominates, we include both proximity and capacity variables simultaneously in the horseshoe regressions of Table 1.4. Columns 1 and 2 show that the coefficient of the interaction of decentralization with physical distance is very stable even when including alternative variables of capacity, such as budget utilization and perceived corruption. What is more, the interaction effect of distance remains statistically significant at the 99%, while the interaction effects of capacity lose their statistical significance.

On the other hand, while the interaction effect of cultural distance remains similar in magnitude when including capacity variables, its statistical significance is low. When controlling for any interaction of decentralization with physical or cultural distance, budget capacity after decentralization loses its statistical significance even at the 90% (columns 1 and

3). These results support our interpretation that the proximity effect is the main channel through which decentralization improved the effectiveness of the program in the provinces. Lima districts are too close from the capital to significantly benefit from proximity effects.

Table 1.4. Horserace between the “Proximity” and “Capacity” effects

	All provinces and Lima districts			
	(1)	(2)	(3)	(4)
	Gap in calories	Gap in calories	Gap in calories	Gap in calories
Decentralization policy	-709.2* (273.14)	-291.0 (199.04)	-885.9* (367.87)	94.75 (252.83)
<i>Proximity effect</i>				
Decentralization*Distance to Lima	1.192*** (0.21)	1.163*** (0.21)		
Decentralization*Difference in the main language spoken			9.986* (4.96)	10.40* (4.73)
Distance to Lima	-1.931*** (0.21)	-6.901*** (0.20)		
Difference in the main language spoken			-2.191 (5.05)	-2.989 (4.96)
<i>Capacity effect</i>				
Decentralization*Budget capacity	2.726 (2.92)		5.249 (3.98)	
Decentralization*Perceived corruption		-5.030 (6.00)		-15.11* (7.56)
Budget capacity	111.1*** (3.11)		169.3*** (5.51)	
Perceived corruption		-144.4*** (5.91)		342.7*** (8.61)
Benchmark model’s controls	Yes	Yes	Yes	Yes
N	258971	260454	245257	246682
R ²	0.342	0.344	0.340	0.342
Adjusted R ²	0.341	0.343	0.339	0.341
Post 2002 FE	Yes	Yes	Yes	Yes
Province/District FE	Yes	Yes	Yes	Yes

Note: Robust standard errors in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001.

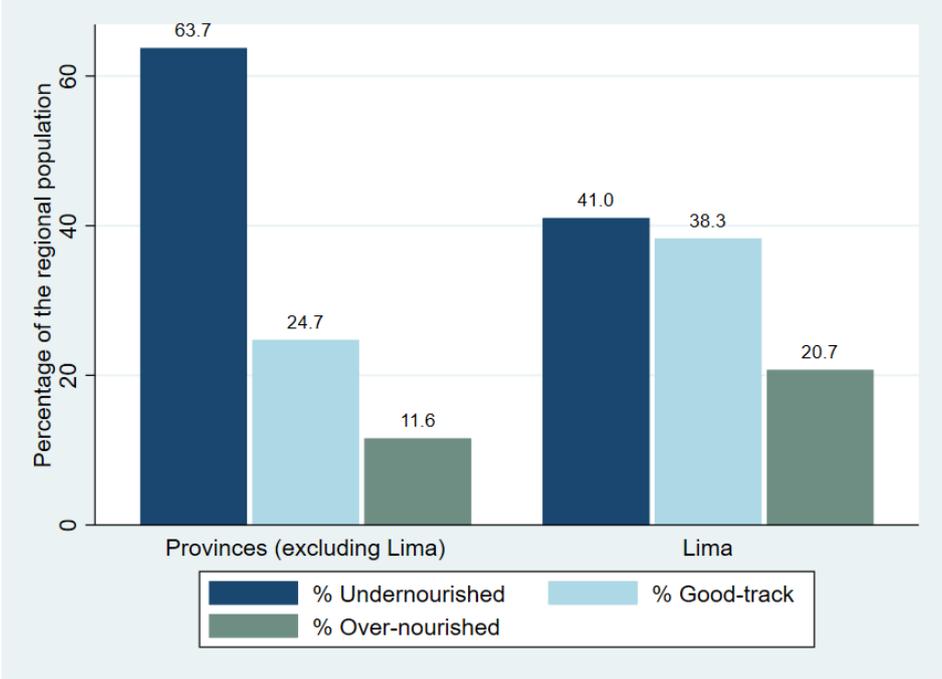
1.5.2. Regional convergence in food security

Our results suggest that decentralizing the PCA has a detrimental impact on households’ calorie consumption in Lima but a positive one in the rest of the provinces. Yet, food security is a multidimensional and complex issue that not only relates to undernourishment, but also to excessive food consumption issues (hereafter “over-nourishment”). Being “food secured” not only implies having access to adequate quantities of food, but also requires that the food is nutritious enough. Malnutrition – e.g. through over-consumption of calories, among other factors – can lead to overweight and obesity, which are other forms of food insecurity.

Since the main objective of the PCA is to provide food for the undernourished, our main dependent variable throughout this study has been calorie consumption relative to calorie needs. Nevertheless, this variable does not allow accounting for levels of over-consumption, which can also lead to other types of food insecurity. In what follows, we explore complementary measures of food security that capture the impact of decentralization in the prevalence of “undernourishment” (consumption below calorie needs), “good-track” and “over-nourishment” (consumption 50% or more above the calorie needs).

While undernourishment is the most important food security issue in the provinces (compared to Lima), over-consumption of calories is a major issue in the Province of Lima (relative to the other provinces). For instance, on average in the period 2001-2016, the prevalence of over-consumption in the Province of Lima was of 20.7%, around 9 percentage points above the levels in the rest of the country (Figure 1.6).

Figure 1.6. Prevalence of undernourishment and over-nourishment in the Provinces and in the districts of Lima, average 2001-2016

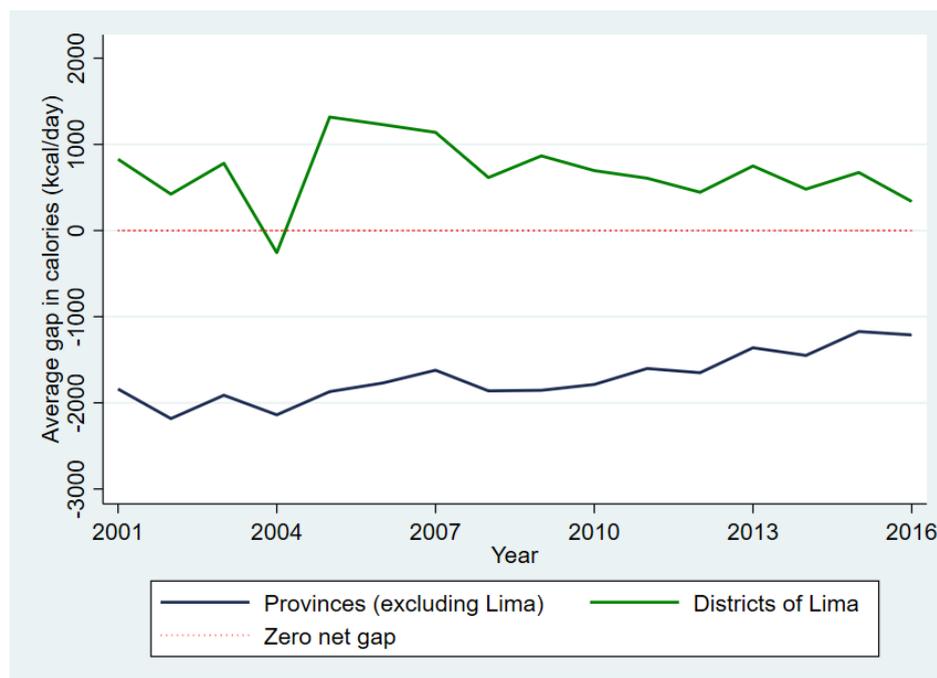


Source: Authors' calculations based on INEI's data.

If decentralization has led to more calorie consumption in the initially undernourished provinces (all provinces excluding Lima) and to a lower consumption in the over-nourished (i.e. Province of Lima), this would result in a regional convergence in calorie consumption and

lower risks of food insecurity across the country. Figure 1.7 suggests that regional convergence in food security is taking place in Peru. From 2001 to 2016, the provinces (excluding Lima) have reduced their deficit in calorie consumption by half, while in Lima the surplus in calorie consumption is decreasing.

Figure 1.7. Average gap in calories by group of local authorities, 2001-2016



Source: Authors' elaboration based on INEI's ENAHO data.

The impact of decentralization on other food security outcomes

To explore further the negative effects of decentralization within the Province of Lima, this section extends the analysis to complementary food security outcomes. Through linear probability regressions, we estimate the effect of decentralizing the program on different binary outcomes determined by the total household calorie consumption: 1) the probability of being undernourished, 2) the probability of being in good-track, and 3) the probability of being over-nourished.

To assess whether decentralization increases the chances for households to exit undernutrition or over-nutrition (to be in good-track), we estimate Equation 1.4, where $FS\ dummies_{hgt}$ are either $undernutrition_{hgt}$, $goodtrack_{hgt}$ or $overnutrition_{hgt}$. All the

other variables in the specification are identical to the ones described in the previous sections. Standard errors are robust and clustered at the province and district level.

$$FS\ dummies_{hgt} = D_{gt}\beta + Z_{mgb}A + X_{hgt}B + F_m + post2002_t + \varepsilon_{hgt} \quad 1.4$$

Our results suggest that in the provinces (excluding Lima), the decentralization of the PCA did not significantly decrease the probability of being undernourished (Table 1.5, columns 1 to 3); although it decreased the average deficit of calorie consumption (based in our previous results, see Table 1.2, column 2). In other words, decentralization improved households' calorie consumption in the provinces (excluding Lima), but not enough for them to exit undernourishment.

On the other hand, when looking at the impact of the policy in Lima, our results indicate that decentralizing the PCA significantly reduced the probability of being over-nourished (Table 1.5, column 6) without significantly raising the risks of falling into undernutrition (Table 1.5, column 4). It is worth noting that this improvement in food security in Lima might be unintentional, as the main objective of the PCA is to increase calorie intakes. The drop in capacity (after decentralization) to manage the PCA in Lima decreased local calorie intakes (see Table 1.2, column 3). The fall in average calorie consumption combined with Lima's initial levels of over-consumption, translated into lower risk of over-nourishment in Lima. We perform robustness checks using different thresholds to define an excessive calorie consumption; our findings remain stable when considering both a 120- and 200-threshold for over-nourishment (see Annex Table 1.1-Annex Table 1.2).

Overall, the decentralization of the PCA is contributing to the regional convergence in the consumption of calories – where provinces and districts converge slowly towards a zero-net gap in calories. After decentralization, the Peruvian population is consuming calories in a proportion closer to their energy needs. While provincial authorities managed to help increase the consumption of calories in the provinces (excluding Lima) that were suffering more from undernourishment, decentralization in Lima helped to reduce the excess in calorie consumption.

Table 1.5. The impact of decentralizing the PCA on households' probability of undernourishment and over-nourishment

	Provinces (excluding Lima)			Lima districts		
	(1)	(2)	(3)	(4)	(5)	(6)
	Undernutrition	Good-track	Over-nutrition	Undernutrition	Good-track	Over-nutrition
Decentralization policy	-0.0132 (0.0119)	0.0108 (0.0101)	0.00245 (0.00645)	0.0165 (0.00867)	0.0112 (0.00848)	-0.0276*** (0.00636)
<i>Local authority characteristics</i>						
The local authority is a capital	-0.0402*** (0.00251)	0.0361*** (0.00165)	0.00412** (0.00146)	0.0916*** (0.00424)	-0.0550*** (0.00464)	-0.0366*** (0.00367)
Population (in thousands)	-0.000391*** (0.00000527)	0.000224*** (0.00000324)	0.000167*** (0.00000282)	0.000104*** (0.00000573)	-0.0000429*** (0.00000499)	-0.0000608*** (0.00000410)
Government employees per 1 000 inhabitants	-0.0420*** (0.000484)	0.0302*** (0.000312)	0.0118*** (0.000271)	-0.000706 (0.000523)	0.00554*** (0.000477)	-0.00484*** (0.000434)
<i>Household characteristics</i>						
Gross equivalized income	-0.00384*** (0.000491)	0.00149*** (0.000283)	0.00235*** (0.000279)	0.000275 (0.000360)	-0.000351 (0.000280)	0.0000754 (0.000236)
(Gross equivalized income) ²	0.0000141*** (0.00000311)	-0.00000721*** (0.00000168)	-0.00000692*** (0.00000174)	-5.62e-08 (0.00000145)	-0.000000673 (0.000000912)	0.000000729 (0.00000103)
Household size	0.0248*** (0.00161)	0.000732 (0.00220)	-0.0255*** (0.00130)	0.0200*** (0.00293)	0.0234*** (0.00202)	-0.0434*** (0.00186)
Self-consumption	0.0000408*** (0.00000191)	-0.0000293*** (0.00000144)	-0.0000115*** (0.000000582)	0.0000521*** (0.00000365)	-0.0000361*** (0.00000249)	-0.0000160*** (0.00000138)
Main activity: agriculture	0.0863*** (0.00568)	-0.0597*** (0.00410)	-0.0266*** (0.00303)	-0.000912 (0.0347)	-0.0603 (0.0361)	0.0612 (0.0333)
Household head is a woman	-0.0226*** (0.00364)	-0.00111 (0.00271)	0.0237*** (0.00231)	-0.00593 (0.00894)	-0.0322*** (0.00682)	0.0381*** (0.00574)
Primary education	-0.00880* (0.00350)	0.00917*** (0.00271)	-0.000373 (0.00219)	0.0515*** (0.0106)	-0.0146 (0.00929)	-0.0369*** (0.00872)
Secondary education	-0.0170*** (0.00414)	0.0156*** (0.00292)	0.00143 (0.00283)	0.0399*** (0.00869)	-0.00465 (0.00945)	-0.0352*** (0.00822)
Tertiary education	-0.0510*** (0.00612)	0.0264*** (0.00517)	0.0246*** (0.00501)	0.0341** (0.0111)	-0.0196 (0.0121)	-0.0146 (0.00841)
N	239976	239976	239976	22466	22466	22466
R ²	0.180	0.088	0.082	0.040	0.025	0.055
Adjusted R ²	0.180	0.087	0.082	0.038	0.023	0.053
Province/Lima District FE	Yes	Yes	Yes	Yes	Yes	Yes
Post 2003 FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: A household is considered over-nourished if it consumes 150% or more of its calorie needs, while it is considered in good track if its calorie intakes are between 100 and 150% its minimum requirements. Robust standard errors in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001.

1.6. Conclusions

This paper evaluates the causal impact of the decentralization of the Peruvian Complementary Food Program on its effectiveness to bring the consumption of calories closer to the average needs of the population across the country.

Our results highlight a clear heterogeneous effect of decentralization between the districts composing the Province of Lima and the rest of the provinces. While households living in other provinces than Lima see their calorie intakes rise after decentralization, the ones residing in Lima experience a decrease in their average consumption. We explain these differentiated

impacts by two opposite effects associated with the decentralization process: a positive “proximity effect” coming from a better understanding of the local context by subnational authorities, and a negative “capacity effect” that reflects the weaker financial and institutional resources and skills in local authorities in comparison to the national government.

Using complementary measures of food security, we argue that regional convergence in calorie intakes in Peru is welfare improving. While decentralizing the PCA boosted the consumption of calories in provinces with initial high levels of undernourishment, the fall in calorie intake in the districts of Lima is mainly driven from a share of the population shifting from very high levels of calorie consumption (“over-nourished”) to more standard ones.

Our results support the use of bottom-up approaches in policymaking if complemented with the necessary local capacity, in particular in the context of decentralization. While there are gains in decentralization associated to the knowledge of subnational authorities about the local specificities and needs, the lack of capacity of local institutions can offset these positive gains. If decentralization occurs with the right capacity in place or is accompanied by capacity building, its positive effects can be ensured.

Annex 1.A. Robustness checks: different thresholds for over-nourishment

Annex Table 1.1. Robustness checks: using a 120-threshold

	Provinces (excluding Lima)			Lima districts		
	(1)	(2)	(3)	(4)	(5)	(6)
	Undernutrition	Good-track	Over-nutrition (≥120-threshold)	Undernutrition	Good-track	Over-nutrition (≥120-threshold)
Decentralization policy	-0.0132 (0.0119)	0.00552 (0.00679)	0.00772 (0.00962)	0.0165 (0.00867)	0.0135 (0.00688)	-0.0299* (0.00921)
<i>Local authority characteristics</i>						
The local authority is a capital	-0.0402*** (0.00251)	0.0208*** (0.00118)	0.0194*** (0.00210)			
Population (in thousands)	-0.000391*** (0.0000527)	0.0000783*** (0.00000209)	0.000313*** (0.00000467)	0.000104*** (0.00000573)	-0.0000902*** (0.00000360)	-0.0000135* (0.00000563)
Government employees per 1 000 inhabitants	-0.0420*** (0.000484)	0.00992** (0.000215)	0.0321*** (0.000403)	-0.000706 (0.000523)	0.00112** (0.000396)	-0.000413 (0.000571)
<i>Household characteristics</i>						
Gross equivalized income	-0.00384*** (0.000491)	0.000293 (0.000158)	0.00355*** (0.000449)	0.000275 (0.000360)	-0.000261 (0.000203)	-0.0000140 (0.000264)
(Gross equivalized income) ²	0.0000141*** (0.00000311)	-0.00000173** (0.000000626)	-0.0000124*** (0.00000270)	-5.62e-08 (0.00000145)	0.000000294 (0.000000724)	-0.000000238 (0.00000104)
Household size	0.0248*** (0.00161)	0.00525*** (0.00140)	-0.0300*** (0.00119)	0.0200*** (0.00293)	0.0204*** (0.00149)	-0.0404*** (0.00262)
Self-consumption	0.0000408*** (0.00000191)	-0.0000141*** (0.000000673)	-0.0000267*** (0.00000134)	0.0000521*** (0.00000365)	-0.0000167*** (0.00000150)	-0.0000354*** (0.00000248)
Main activity: agriculture	0.0863*** (0.00568)	-0.0267*** (0.00275)	-0.0596*** (0.00471)	-0.000912 (0.0347)	-0.0314 (0.0315)	0.0323 (0.0354)
Household head is a woman	-0.0226*** (0.00364)	0.00141 (0.00182)	0.0212*** (0.00324)	-0.00593 (0.00894)	-0.00604 (0.00516)	0.0120 (0.00895)
Primary education	-0.00880* (0.00350)	0.00708*** (0.00198)	0.00172 (0.00314)	0.0515*** (0.0106)	0.00854 (0.00822)	-0.0600*** (0.0123)
Secondary education	-0.0170*** (0.00414)	0.00800*** (0.00238)	0.00899* (0.00404)	0.0399*** (0.00869)	0.0146* (0.00671)	-0.0545*** (0.0103)
Tertiary education	-0.0510*** (0.00612)	0.0118** (0.00366)	0.0392*** (0.00608)	0.0341** (0.0111)	0.00442 (0.00951)	-0.0385** (0.0120)
N	239976	239976	239976	22466	22466	22466
R ²	0.180	0.029	0.137	0.040	0.017	0.046
Adjusted R ²	0.180	0.028	0.137	0.038	0.015	0.044
Province/Lima District FE	Yes	Yes	Yes	Yes	Yes	Yes
Post 2003 FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: A household is considered over-nourished if it consumes 120% or more of its calorie needs, while it is considered in good track if its calorie intakes are between 100 and 120% its minimum requirements. Standard errors in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001.

Annex Table 1.2. Robustness checks: using a 200-threshold

	Provinces (excluding Lima)			Lima districts		
	(1)	(2)	(3)	(4)	(5)	(6)
	Undernutrition	Good-track	Over-nutrition (≥200-threshold)	Undernutrition	Good-track	Over-nutrition (≥200-threshold)
Decentralization policy	-0.0132 (0.0119)	0.00975 (0.0115)	0.00349 (0.00304)	0.0165 (0.00867)	0.00210 (0.00915)	-0.0186*** (0.00374)
<i>Local authority characteristics</i>						
The local authority is a capital	-0.0402*** (0.00251)	0.0435*** (0.00237)	-0.00327*** (0.000470)			
Population (in thousands)	-0.000391*** (0.00000527)	0.000358*** (0.00000466)	0.0000329*** (0.00000125)	0.000104*** (0.00000573)	-0.0000956*** (0.00000622)	-0.00000816*** (0.00000205)
Government employees per 1 000 inhabitants	-0.0420*** (0.000484)	0.0405*** (0.000454)	0.00151*** (0.000103)	-0.000706 (0.000523)	0.00567*** (0.000572)	-0.00497*** (0.000185)
<i>Household characteristics</i>						
Gross equivalized income	-0.00384*** (0.000491)	0.00317*** (0.000431)	0.000669*** (0.000141)	0.000275 (0.000360)	-0.000659* (0.000318)	0.000383** (0.000136)
(Gross equivalized income) ²	0.0000141*** (0.00000311)	-0.0000136*** (0.00000283)	-0.000000543 (0.00000145)	-5.62e-08 (0.00000145)	0.000000733 (0.00000124)	-0.000000677 (0.000000450)
Household size	0.0248*** (0.00161)	-0.0149*** (0.00191)	-0.00993*** (0.000628)	0.0200*** (0.00293)	0.00113 (0.00284)	-0.0212*** (0.000967)
Self-consumption	0.0000408*** (0.00000191)	-0.0000388*** (0.00000188)	-0.00000201*** (0.00000154)	0.0000521*** (0.00000365)	-0.0000488*** (0.00000338)	-0.00000330*** (0.000000456)
Main activity: agriculture	0.0863*** (0.00568)	-0.0829*** (0.00526)	-0.00340** (0.00117)	-0.000912 (0.0347)	-0.0213 (0.0418)	0.0222 (0.0214)
Household head is a woman	-0.0226*** (0.00364)	0.00503 (0.00403)	0.0176*** (0.00143)	-0.00593 (0.00894)	-0.0221* (0.00953)	0.0281*** (0.00298)
Primary education	-0.00880* (0.00350)	0.00963** (0.00311)	-0.000825 (0.00101)	0.0515*** (0.0106)	-0.0538*** (0.0115)	0.00230 (0.00571)
Secondary education	-0.0170*** (0.00414)	0.0197*** (0.00391)	-0.00269 (0.00138)	0.0399*** (0.00869)	-0.0347*** (0.00932)	-0.00520 (0.00388)
Tertiary education	-0.0510*** (0.00612)	0.0430*** (0.00554)	0.00799*** (0.00239)	0.0341** (0.0111)	-0.0337** (0.0117)	-0.000371 (0.00483)
N	239976	239976	239976	22466	22466	22466
R ²	0.180	0.154	0.035	0.040	0.029	0.045
Adjusted R ²	0.180	0.153	0.034	0.038	0.026	0.043
Province/Lima District FE	Yes	Yes	Yes	Yes	Yes	Yes
Post 2003 FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: A household is considered over-nourished if it consumes 200% or more of its calorie needs, while it is considered in good track if its calorie intakes are between 100 and 2000% its minimum requirements. Standard errors in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001.

Chapter 2. How does Mobility improve Food Security and Diet Diversity? The role of vehicle ownership in Peruvian cities

Co-authored with Emmanuelle Lavallée

Abstract: This chapter explores the linkages between household mobility and food security in cities. More precisely, it assesses the role of both motorized and non-motorized vehicle ownership on different food security outcomes for households living in urban areas of Peru. First, using rich household data (ENAHO, 2004-2016), we build indicators of undernourishment, size of the calorie deficit, and diet diversity to capture both the quantity and the quality of diets. Then, we estimate the effect of vehicle ownership, by type of vehicles, on food security at the household level. In particular, we exploit the panel dimension of our data to control for household heterogeneity by using fixed effects models. Our findings reveal that having a car is not a determinant of food security in Peruvian cities, whereas having a bike or a scooter is statistically significantly associated with households' access to food. Nevertheless, these associations are modest in magnitude and are mainly driven by middle- and upper middle-income families who tend to live in areas closer to the city center. The analysis supports that clean and affordable modes of transport, such as bicycles, are a better option to enhance food security and nutrition in Peruvian cities.

2.1. Introduction

Food insecurity and malnutrition is a complex issue that can take many forms. While undernourishment, stunting and wasting result from not eating enough calories and nutrients (compared to one's needs), excessive food consumption and unbalanced diets can also lead to other forms of malnutrition such as overweight and obesity (WHO, 2020a). Worldwide, more than 820 million people are still suffering from hunger, while almost 2 billion adults are overweight (WHO, 2020b; FAO and WHO, 2018; WHO, 2018a; Dury et al., 2019).

Following global trends of globalization, urbanization, and the rise of the processed food industry, both the forms and structural causes of food insecurity have been reshaping. While six decades ago among the main challenges for food security was the fragile and insufficient global food supply, today – with a massive overproduction and wasting of food, and yet millions of people going hunger – the main food security challenges have shifted from availability to accessibility issues (Dury et al., 2019).

Difficulties to access food due to rampant poverty and inequalities are among the main drivers of food insecurity. Low income, unemployment, social segregation, and volatility in food prices are important sources of the unequal access to sufficient and nutritious food (Sharma, 1992). While the literature reveals prolific studies on the economic and social barriers to food access (see the seminal work by Sen (1981), and the literature on the concept of food poverty, for instance, Greer and Thorbecke, 1986; Dowler, 1998; Pretty et al., 2003), little is known about the role of physical accessibility to food, including through mobility. Yet, besides economic and social constraints, other kinds of barriers might interfere with peoples' ability to access food, including their capacity to physically reach the markets that offer good-quality and diverse products at affordable prices (see a discussion on the evolution of food security issues by Burchi and De Muro (2016)).

Sustaining households' income may not be sufficient to ensure food security. As pointed out by the Food and Agriculture Organization (FAO) at the FAO Committee on World Food Security in 1992, food security depends on both households' economic and physical access to food: *“Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life”* (Sharma, 1992). For people to be able to access food – typically in

markets or with local producers, but also through food aid programs –, effective and affordable modes of transport are needed. While cities with quality transport infrastructure and systems (e.g. well-constructed roads, trams, bike lanes) can enhance mobility, people might also need to invest to access these modes of mobility (e.g. buying a car, a bike, or a pass for the public transport). Previous studies have shown the correlation between transport infrastructure and development (with a particular focus on poverty and health, see for instance van de Walle, 2002; Olsson, 2009; Donaldson, 2018; Djemaï, 2018). However, the independent role of mobility on health and food security has not been widely explored. In fact, the effect of mobility on people’s capacity to get food has been often confounded with the effect income or wealth (richer households tend to be more mobile as they can afford both more food and more vehicles).

The objective of this chapter is to explore the linkages between mobility and food security by assessing the respective role of motorized and non-motorized vehicles in urban households’ calorie intake and diet diversity, while filtering out the effect of income and wealth. The paper also contributes to the current policy debate on the potential trade-offs between Sustainable Development Goals (SDGs), since achieving food security (SDG 2) while meeting the climate and environmental objectives (SDG 13) can be a complex task (De Neve and Sachs, 2020; Liu et al., 2019; Rasul and Sharma, 2016; Fujimori et al., 2019; Beuchelt and Badstue, 2013; Palm et al., 2010). The chapter shows that although increased mobility helps households to access more and diverse food items, the use of motorized and highly pollutant vehicles is not more effective than the use of non-motorized vehicles for food security in urban areas.

The analysis focus on households living in urban areas of Peru¹⁷. Urban areas in the country have been persistently facing problems of malnutrition (e.g. higher consumption of low-nutritious food), while simultaneously dealing with growing air pollution and climate issues predominantly linked to transport. For example, in Lima, which hosts around one-third of Peru’s population, transport alone is responsible for 75% of all CO₂ emissions in the metropolitan area (OECD, 2016; Barbero, 2006), and the average exposure to fine particulate

¹⁷ We follow the rural-urban classification adopted in the ENAHO survey (INEI, 2019), where households are considered urban if they live in cities of more than 2 000 inhabitants.

matter 2.5 (PM_{2.5}) reaches 37 $\mu\text{g}/\text{m}^3$ (a level above the WHO guideline of 10 $\mu\text{g}/\text{m}^3$) (OECD-European Commission, 2020; WHO, 2016).

We make use of rich household panel data from the ENAHO survey (the national households survey on living conditions and poverty) to construct indicators of food security – such as calorie intake and diet diversity – and explore their connection with vehicle ownership at the household level (i.e. if the household has a car, a bike or a scooter). We start by quantifying these associations through simple linear (OLS) and censored regressions (Tobit model), while controlling for income and wealth – among other relevant variables. To mitigate further potential omitted variable bias due to unobserved time-invariant household characteristics, we exploit the panel dimension of our database by including household fixed-effects. Our results reveal that owning a car does not increase food security outcomes in Peruvian cities, whereas owning a bike or a scooter significantly improves both the quantity and the quality of the diets. However, these effects are mainly driven by middle- and high-income households who live closer to the city center. Public policies that promote better access to food through clean and affordable transport could help urban areas in Peru achieve both food security and environmental objectives.

The remaining of the paper is organized as follows. Section 2.2 explores the literature on mobility and access to food and takes a particular look at vehicle ownership and food security in Peruvian cities. Section 2.3 details the sources of data and explains the construction of the food security measures used throughout the analysis. While Section 2.4 explains the empirical strategy, including addressing the potential endogeneity issues, Section 2.5 presents the results and our interpretations. Finally, Section 2.6 concludes and discusses some policy implications of our findings.

2.2. Mobility, food access and food security

Low economic and physical access to food have become the most important drivers of food insecurity in cities. By lowering the costs to physically access food, mobility is a channel towards more diverse and nutritive diets. This section delves into the literature about the links between mobility and food access and provides some insights on the malnutrition and urban mobility challenges that Peruvian cities are facing.

2.2.1. Mobility unlocks access to food, even in situations of scarce or distant food supply

In urban areas, unavailability of food or shortages in the production are not the main causes of food insecurity anymore. Instead, limitations in the access to food generate most of the cases of malnutrition (Battersby, 2011; Riley and Dodson, 2016). Low access to food can be due to economic or physical constraints. Understanding the physical obstacles to food access has gained a significant interest among development and geographical economists, as suggested by the fast-growing literature exploring the phenomenon of urban food deserts (see for instance Eckert and Shetty, 2011; Fitzpatrick et al., 2019; Gordon et al., 2011).

Research on food access shows that in urban areas, it is the lack of individual mobility – particularly of private modes of transport – what threatens food security among residents, rather than the distance that separates people from food shops (Coveney and O’Dwyer, 2009). Limited food access due to low levels of household mobility and low vehicle ownership have been substantially studied in the context of rich economies (mainly in the United States and in Australia) but significantly less in the context of developing countries, where they nonetheless remain utterly relevant (Battersby and Crush, 2014; Dixon et al., 2007).

Mobility is ensured when households can easily use the adequate modes of transport that help them meet their needs, including shopping for food (Zegras and Gakenheimer, 2006). In developing countries, where public transport systems tend to be unsafe, deficient or ageing, many people need to invest on alternative modes of mobility, such as private cars. Yet, cars are expensive and out of reach for poor families. Stark income inequalities and poverty are among the root causes of low mobility in cities with deficient public transport networks (Valenzuela-Levi, 2018; Freedman and Bell, 2009; Ver Ploeg et al., 2009). Valenzuela-Levi (2018) suggests that in places where income concentration is high, elites tend to impose forms of urbanization that rely on private modes of mobility. They spurn investments in public transport and discourage urban planning policies that would ensure more reliant mobility and thus accessibility for all. Such car-based urban development can increase the risk of food insecurity as they prevent a safe constant access to food for everyone, notably the poor, even in the context where food supply is not scarce or far away (Coveney and O’Dwyer, 2009).

A limited physical access to food can have disastrous short- and long-term consequences on individuals' food security outcomes and well-being. Most research on the topic – which focuses on food shop availability within the neighborhood of residence while controlling for household capacity to displace to these stores (by type of transport) – shows that a low level of mobility and thus food access increases food insecurity through two channels. For some groups of the population living far from most food shops, lower mobility is associated with lower nutrient intakes and greater odds of undernutrition cases. Whereas for households with access to a limited number of food items (reduced diversity), low mobility can lead to an unbalanced diet, excessive calorie intake, and a higher risk of overweight or obesity (Bodor et al., 2010, Dixon et al., 2007).

To address both issues of undernutrition and overweight, researchers and international organizations call for renewed public interventions targeted at improving public transport systems, redesigning urban forms, and enhancing household mobility and accessibility. However, naive solutions that would only incentivize and subsidize the use of private cars (see Clifton, 2004) must be avoided. Relying on private motorized vehicles to ensure food access is both risky and counterproductive since it results in severe social and environmental issues including air pollution (PM2.5) and greenhouse gas (GHG) emissions, which threaten people's lives today and for future generations (Bhat, Sen and Eluru, 2009; Litman, 2002; Giles-Corti et al., 2016). Finding solutions to food access in cities should not stand in the way of the climate objectives. Integrated solutions that allow fighting against food insecurity while preserving the environment must be undertaken. This paper documents some of the linkages between vehicle ownership, mobility, and food security to inform policymakers in the implementation of policies towards cycling, investments in green public transport and compact cities, while disincentivizing the use of pollutant vehicles (OECD, 2012).

2.2.2. Food security and mobility in Peruvian cities

Peruvian cities are impacted by similar global trends as other developing cities across the world. On the one hand, the population is increasingly facing obesity issues due to poor access to nutritious food. On the other hand, given the deficient public transportation system, households' physical access to sufficient and good-quality food products heavily depends on their capacity to buy a private vehicle.

A double burden of malnutrition

Over the past decades, Peru has experienced one of the greatest economic and social progress compared to its Latin American neighbors. Taking advantage of its democratic transition and rapid economic growth, the country redefined its policy objectives by leaning towards more decentralized interventions (see Chapter 1) and intensified its fight against food insecurity – more precisely undernourishment – across the territory (Marini et al., 2017; OECD-FAO-UNCDF, 2016). As a result of these increased efforts, undernourishment among the Peruvian population successfully fell from 22.6% in 2003 to 7.9% in 2015, while progress was also made among children for whom rates of stunting decreased and undernourishment dropped from 28% in 2008 to 13% in 2016 (World Bank, 2018).

Despite notable progress, undernourishment remains an issue for more than two million Peruvians, including for those living in urban areas, and might be on the rise due to the COVID-19 pandemic and its socio-economic consequences (SMIA, 2020). At the same time, the country is seeing an increase in the prevalence of overweight and obesity among the population (Pia Chaparro and Estrada, 2012; McCloskey et al., 2017; Smith Torres-Roman et al., 2018). For instance, while 7.6% of children (below the age of five) in urban areas are still in a situation of chronic undernourishment, more than 25% of women in urban areas suffer from obesity (INEI, 2019c; INEI, 2018).

As explained by Pia Chaparro and Estrada (2012), most urban areas in Peru deal with this double burden (or polarization) of food insecurity (i.e. high shares of both undernourishment and over-nourishment), as they might enter a new phase of malnutrition transition, where more diets typically shift towards less healthy products – generally processed, high in sugar and fat (e.g. oils, animal, and sweetened products) (McCloskey et al., 2017). Causes of food insecurity are diverse and intertwined. In Peru, inequalities, poverty, globalization and trends in changing lifestyles, climate change, and rapid urbanization are among the main determinants of the persistence of undernourishment and the rise of over-nourishment (OECD-FAO-UNCDF, 2016; SMIA, 2020; WHO, 2018c).

In Peru, urbanization – through rural-urban migration – has been mostly triggered by the poor quality of public services and opportunities available in rural areas (OECD-FAO-UNCDF, 2016). Today, around 72% of the Peruvian population live in cities, distributed between the city

centers and the corresponding suburban areas. Since rural-to-urban migrant families and low-income households tend to reside far from the city center (Ortegon-Sanchez and Oviedo-Hernandez, 2016), and because in Peru the costs of urban transports are high (OECD-FAO-UNCDF, 2016), most of urban households have limited access (both economic and physical) to sufficient and healthy food. In addition, with the significant growth in built-up area due to urbanization, agricultural lands in cities have been sharply reduced in the past years, giving few opportunities to people in cities to grow their own food, and thus making them more dependent on travelling to the city center to access food.

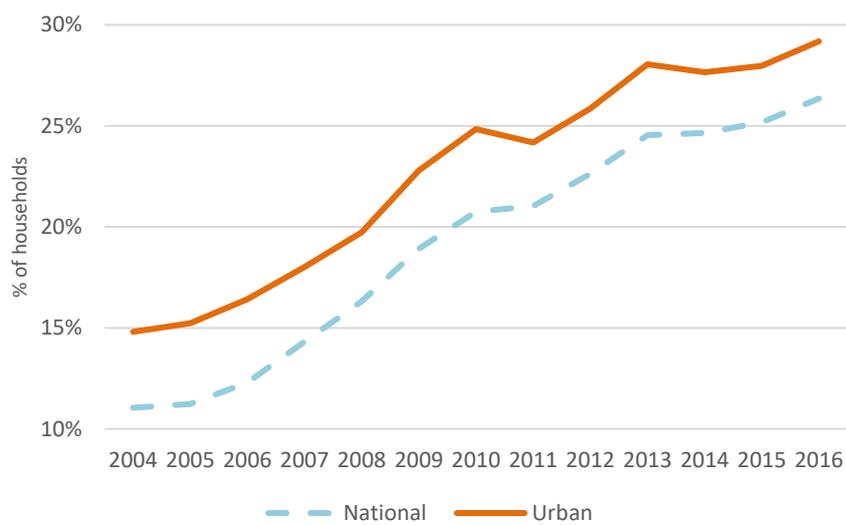
Which mobility for Peruvians in urban areas?

For the past thirty years, cities in developing regions around the world have been experiencing rapid growth in private vehicle ownership. “Motorization rates” of low- and high-income households in Latin America have been growing faster than the ones observed in more industrialized countries (OECD, 2016; OECD, 2015; Zegras and Gakenheimer, 2006; Roque and Masoumi, 2006; Button et al., 1993). Peru has been no exception to this phenomenon. Rising incomes and falling prices for motorized vehicles have contributed to this trend, together with urban planning programs favoring cars over cycling, including the national and local governments highly investing in road infrastructure rather than in public transport (which has now become inefficient and of low-quality) (OECD, 2016).

Despite lower motorization levels in Peru than in other Latin American countries (OECD, 2016; Ortegon-Sanchez and Oviedo Hernandez, 2016), motorized-vehicles ownership in Peruvian cities almost doubled between 2004 and 2016. More precisely, the percentage of urban household having at least one motorized vehicle grew from 14.8% to 29.2% over the period (Figure 2.1). In 2016, the stock of motorized vehicles in the country reached over 160 vehicles per 1 000 inhabitants (OECD, 2016). In the metropolitan area of Lima – the most dynamic center of the country – the number of vehicles soared from more than 775 000 in the year 2000 to 1.4 million in 2012, and the number of motorized trips per capita doubled over the same period (OECD, 2016). When breaking down vehicle ownership by type of vehicle, we note that the growth in motorization rates is mainly driven by the rise in scooter ownership (Figure 2.2), an affordable alternative compared to cars. The percentage of households having a scooter tripled in twelve years, while car ownership grew by 43% on average. The rise in scooters

ownership may have come at the expense of bikes ownership, which has been progressively decreasing since 2008. If policies to support more sustainable transport systems are not put in place, mobility trends will keep favoring the use of private motorized vehicles in the future (OECD, 2015).

Figure 2.1. Motorization rates in Peru



Source: Authors' elaboration based on INEI (2019) data.

Figure 2.2. Rates of vehicle ownership among urban households in Peru



Source: Authors' elaboration based on INEI (2019) data.

Although private vehicles increasingly support household mobility in cities, public transportation remains the predominant mode of transport, especially for low- and middle-income families (OECD, 2016). In the early 1990s, the national government decided to liberalize the public transport sector, a decision that has had long-lasting repercussions on the quality of urban mobility. The sector split between a large number of small firms offering a service based on buses, often too small in capacity to meet the demand. With little to no regulation on travel prices, quality of the service, vehicle checks and safety, nor urban planning coherence, the routes of the different bus lines are often overlapping and thus the urban transport system results to be inefficient, on top of generating negative externalities on people's lives and significantly increasing pollution (see OECD (2016) for a detailed description of Peru's urban public transport system).

Deficient public transport and car-based urbanization can hamper people's well-being in cities for several reasons. First, it prevents many people from accessing services and amenities that matter for all dimensions of well-being (e.g. schools, hospitals, green spaces), including for basic needs such as food shopping. In addition, limited mobility exacerbates social exclusion, segregation and inequalities, while motorization of cities increases pollution and climate-related issues.

While mobility is key to improve access to basic services and amenities such as food shops, transport must not be increased at all costs. Policymakers at the national and local levels need to design comprehensive interventions to enhance both urban mobility and food security, while minimizing the impact on the environment. If no improvements are made to the urban transportation system in Peru, and private motorized vehicles trends are not reversed, CO₂ emissions in Peruvian cities are expected to increase to 40-50 million of metric tons (Mtons) in 2050 (compared to 6.3 Mtons emitted in 2010) (OECD, 2015).

2.3. Data

2.3.1. Main sources of data

To investigate the linkages between mobility and food security in Peruvian cities, we combine several sources of data, listed below:

- The *National Households Survey on Living Conditions and Poverty (ENAHO)*¹⁸ (2004-2016) from the Peruvian Institute of Statistics (INEI);
- The *Peruvian Tables of Food Composition*¹⁹ (2009) prepared by the National Center for Food and Nutrition (CENAN);
- The *Energy Requirements of the Peruvian Population*²⁰ (2012) constructed by the CENAN;
- The *National Record of Municipalities (RENAMU)*²¹ (2005, 2015) from the INEI;
- The *National Census of Markets*²² (CENAMA) by the INEI (2016);
- *OpenStreetMap Points of Interest in Peru*²³ (2020);
- *GHS Functional Urban Areas* spatial dataset²⁴ from Schiavina, Moreno-Monroy, Maffenini and Veneri (2019) and the *GHS Urban Centre Database*²⁵ from Florczyk et al. (2020).

The ENAHO is a household survey representative at the smallest administrative division in Peru that provides annual, exhaustive, and geo-referenced household panel data from 2004 to 2016 on numerous topics including vehicle ownership by type of vehicle, income and wealth, and household food purchases by food item and frequency of consumption (up to 507 food

¹⁸ INEI (2019a), “Encuesta Nacional de Hogares sobre Condiciones de Vida y Pobreza” (database), <http://iinei.inei.gob.pe/microdatos/>.

¹⁹ CENAN (2009), “Tablas Peruanas de Composición de Alimentos” (database), <http://www.ins.gob.pe/insvirtual/images/otrpubs/pdf/Tabla%20de%20Alimentos.pdf>.

²⁰ CENAN (2012), “Requerimientos de Energía para la Población Peruana” (database), <https://fr.scribd.com/document/140295535/Requerimiento-de-energia-para-la-poblacion-peruana-pdf>.

²¹ INEI (2019b), “Registro Nacional de Municipalidades” (database), <http://iinei.inei.gob.pe/microdatos>.

²² INEI (2016), “Censo Nacional de Mercados de Abastos” (database), <http://iinei.inei.gob.pe/microdatos/>.

²³ OpenStreetMap (2020), “Points of Interest in Peru” (GIS database), available for download at: <https://www.openstreetmap.org/#map=5/-10.279/-76.644>.

²⁴ Schiavina, M., A. Moreno-Monroy, L. Maffenini and P. Veneri (2019), GHS-FUA R2019A - GHS functional urban areas, derived from GHS-UCDB R2019A, 2015, European Commission, Joint Research Centre (JRC) (database), <https://doi.org/doi:10.2905/347F0337-F2DA-4592-87B3-E25975EC2C95>.

²⁵ Florczyk et al. (2020), GHS Urban Centre Database GHS-UCDB R2019A, European Commission, Joint Research Centre (JRC) (database), https://ghsl.jrc.ec.europa.eu/ghs_stat_ucdb2015mt_r2019a.php.

products are listed). The ENAHO, coupled with the Peruvian Tables of Food Composition and the Energy Requirements of the Peruvian Population, provides us with adequate information to build our outcome variables on food security and diet diversity (namely undernourishment, size of the calorie deficit and diversity of the diet). While the ENAHO provides complementary information on other household characteristics and controls, we also use the National Record of Municipalities and the National Census of Markets to build controls at the district level. Additionally, we use geo-referenced information on the location of food shops that we extract from OpenStreetMap shapefiles “Points of Interest”, and Peru’s Functional Urban Areas (FUA) and urban centers’ spatial boundaries that we obtain through the work of Schiavina Moreno-Monroy, Maffenini and Veneri (2019) and Florczyk et al. (2020).

2.3.2. Measuring food security and diet diversity at the household level

This chapter investigates whether more mobile households (i.e. those who own private means of transportation) are more food secure than less mobile families. As food security is a multidimensional issue that can take many forms, it can be measured in different ways. However, considering the long history of undernourishment in Peru and the growing issue of overweight in urban areas, we decide to focus on three specific indicators at the household level, namely the probability of being undernourished, the size of the deficit in calorie intake, and a diet diversity score.

While measuring nutrition and diet diversity is a complex and relatively new challenge in the literature, undernourishment indicators are among more standard measures of food security. They have been widely used by academics, international organizations, and governments – including the Peruvian authorities – to set common objectives in the fight against hunger. Beyond undernourishment, Peru is also growingly vulnerable to other forms malnutrition such as inadequate intakes of macro- and micro-nutrients associated with low-quality diets (Pia Chaparro and Estrada, 2012; McCloskey et al., 2017; Smith Torres-Roman et al., 2018) that generate deficiencies in vital nutrients (e.g. vitamins, minerals, proteins), endanger the development of the body and foster overweight and obesity. Yet, malnutrition and its devastating consequences could be prevented through a safer and continuous access to nutritious and diversified foods.

Could mobility be one of the factors helping households access more food and more diversified food products? By reducing the distance, the time and the costs between households and markets, mobility may increase the number and the variety of shops accessible by households. Families with a private vehicle might be able to travel more easily outside their neighborhood to reach a more diversified supply of food, at lower prices. To investigate this question, the chapter includes as measure of household diet diversity (as a score). This indicator is increasingly used in the literature (see Hirvonen et al., 2017; Harou, 2018; Ali et al., 2013; McDonald et al., 2015). Contrary to more traditional measures of nutrition such as anthropometrics, a score of diet diversity allows to capture more short-term variations in the quality of the diet. It also avoids typical biases generated by other measures of nutrition such as nutrient intakes (which are sensitive to autocorrelation in the consumption of specific nutrients) (Kant, 1996). Several authors (see for instance Hirvonen et al., 2017) validated diet diversity scores as reliable proxy indicators for nutrient intake and diet quality, since a balanced consumption of the main food groups should provide all types of nutrients required for a healthy functioning of the body. Note that with this indicator, we aim to account for the quality of food available to households, but that we do not pretend to measure “household nutrition” as we do not have information about the intra-household repartition of food (see Verger et al., 2019 for a discussion on the use of diet diversity as a measure of nutrition).

Details on the construction of our outcome variables for food security and diet diversity are explained as follows:

The probability of being undernourished is a dummy variable indicating 1 if the household is undernourished. We define undernourishment when available calories at the household level are below the aggregated energy needs of the household members. To build this indicator, we first convert household food consumption into kilocalories by using the Peruvian Tables of Food Composition which provide the content in kilocalories for each food product listed in the ENAHO survey. Then, we compare these calorie intakes to the household minimum energy requirements, the latter are obtained by summing individual energy requirements of each household member. If calorie intakes are lower than calorie requirements, we consider the household to be undernourished. Since estimated energy requirements depend on age, gender, and place of residence, our indicator already accounts for heterogeneity in

household composition. The indicator is constructed at the household level and it does not make any assumptions on the potential intra-household inequalities in the repartition of food.

The size of the calorie deficit measures the depth of food insecurity within undernourished households. We build this indicator as a censored variable – while it equals 0 for all non-undernourished households, its continuous part is the value of the gap between household calorie consumption and calorie needs. The lower the calorie intakes compared to the calorie needs, the larger is the size of the deficit in calories.

The household diet diversity score represents the capacity of households to access diversified food products on a regular basis. We use a methodology developed by the World Food Program (2008)²⁶ to construct a score of the frequency of consumption (per two weeks) of products belonging to eight fundamental food groups and use specific weights to account for the nutritional value of each type of group. In the sample, the score ranges between 8 (low diversity) and 240 (high diversity) and is computed as follows:

Diet Diversity Score

$$\begin{aligned} &= (starches_{frequency} * 2) + (pulses_{frequency} * 3) + vegetables_{frequency} \\ &+ fruits_{frequency} + (animal_{frequency} * 4) + (dairy_{frequency} * 4) \\ &+ (fats_{frequency} * 0.5) + (sugar_{frequency} * 0.5) \end{aligned}$$

2.3.3. Measuring mobility, household income and wealth, food availability, and other explanatory variables

To measure mobility, we use household vehicle ownership data from the ENAHO annual survey. More specifically, we construct a dummy variable that indicates, for each year and household, the possession of at least one vehicle (of any type). To uncover the relative importance of motorized and pollutant vehicles against more sustainable means of transportation, we also break down the status of vehicle ownership by type of vehicle and create dummy variables for the three following possibilities: possession of at least one car, possession of at least one scooter, and possession of at least one bike.

²⁶ World Food Program (2008), “Food consumption analysis. Calculation and use of the food consumption score in food security analysis”, Vulnerability Analysis and Mapping, Technical Guidance Sheet, February, Rome, Italy, https://documents.wfp.org/stellent/groups/public/documents/manual_guide_proced/wfp197216.pdf.

Since access to food also depends on other modes of transport not available through the survey (e.g. public transport) and on the availability and quality transport infrastructure (e.g. roads), we use data from the RENAMU to control for the number of public transport vehicles per capita by district and by year, and also add a variable indicating whether the district of residence is connected to a paved road (potentially improving connectedness to local food markets within the city or in other close cities). Besides mobility and transport infrastructure, the quantity of the local food supply also determines the capacity of households to get enough food. To control for local food availability, we include a variable stating if the district of residence hosts a food market. We also account for the accessibility to the local food supply by using geo-referenced data from OpenStreetMap. More precisely, we compute the number of food shops²⁷ within a 1 km radius from the households' place of residence.

Because richer families are more likely to own a private vehicle than poorer households, we control for household income and wealth using data from the ENAHO. If we follow the “entitlement approach” of Devrèz and Sen (1989), considering household endowments is key to capture household capabilities to access food (Burchi and De Muro, 2016). While income levels are better for understanding the current economic situation of the households, wealth variables allow controlling for long-term trends and initial endowments (Burchi and De Muro, 2016). For income levels we use the equivalized gross household income per year, we measure wealth through a series of dummy variables reflecting the quality of housing (e.g. number of rooms per capita) and the possession of specific assets (e.g. refrigerator, washing machine, computer)²⁸. These variables are typically used in the literature to measure household material conditions and well-being (see the International Wealth Index of Smits and Steendijk (2015); and the wealth indices used in the Demographic and Health Surveys (2020)).

While high- and middle-income households are more likely to have a vehicle, they are also more likely to live closer to the city center – where quality services and amenities are more

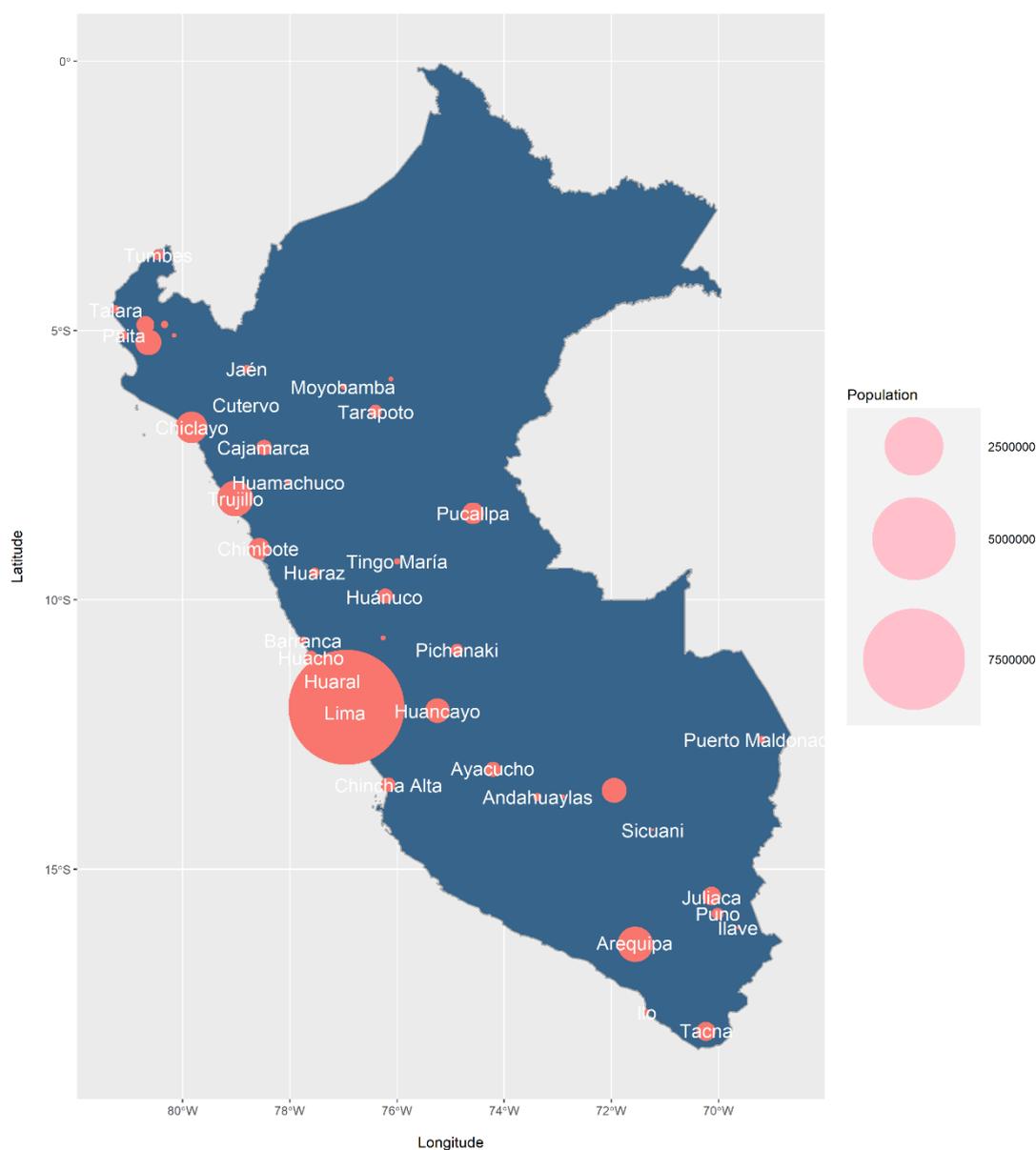
²⁷ Food shops include restaurants, supermarkets, bakeries, department stores, convenience stores, malls, grocery stores, and marketplaces, but also fast-food shops.

²⁸ The full list of wealth dummies is as follows: Refrigerator, Internet at home, Number of rooms per capita, Good water supply quality, Good sanitation quality, Good floor quality, Good walls quality, Good roof quality, Electricity for lighting, Electricity for cooking, Mobile phone, Fixed phone, Cable TV, Radio, Computer, Blender, Microwave, Washing machine.

concentrated. We take into account these spatial inequalities in the distribution of households across the urban space by computing a variable of the distance between households' residence (coordinates) and the city center (centroid of the polygon). We make use of the GHS Functional Urban Areas (FUA) database and the GHS Urban Centre Database to extract the spatial boundaries of the Peruvian cities as defined by their functional urban areas. FUAs – a concept conceived by the OECD and the European Commission – allow defining cities through a functional approach based on density and commuting flows. Going beyond the idea of administrative boundaries of municipalities, FUAs consist of a high-density core (gathering most of the economic activity) and a surrounding hinterland (i.e. a commuting zone) (see Dijkstra, Poelman and Veneri, 2019 for more detailed information). Combining the boundaries of the high density cores of the FUAs with the GPS coordinates of households surveyed by the ENAHO, we calculate the Euclidean distance (in kilometers) between households and the centroid of the closest FUA core (hereafter city center). To a certain extent, this variable should account for the proximity of households to most public services, infrastructure, and amenities, including food markets (which tend to be more concentrated in the city center). Note that the household distance to the FUA center does not vary in time. Figure 2.3 shows the relative population size and the location of the Peruvian FUAs across the country.

Other household characteristics that might influence mobility and food security, and therefore we take into account are the educational attainment and the sex of the household head, as well as the size of the household (i.e. the number of members). All these variables are extracted from the ENAHO database.

Figure 2.3. Peruvian FUAs' location and population size



Sources: Authors' elaboration based on data from Schiavina, Moreno-Monroy, Maffeni and Veneri (2019), Florczyk et al. (2020) and GADM (2018).

2.3.4. Household characteristics by vehicle ownership: key descriptive statistics

Mobility facilitates access to food in cities (Coveney and O'Dwyer, 2009). Basic descriptive statistics based on our sample of urban households in Peru seem to confirm this statement. Table 2.1 reveals that overall, households with at least one vehicle (whatever the type) record significantly better food security outcomes than households who do not possess any vehicle. First, while 56% of urban households with no private means of transportation suffer

from undernourishment, this number falls to 49% among households who possess at least one vehicle (motorized or not). Besides, the average size of calorie deficit is lower among more mobile households, although only by 70 kcal per household. Finally, families with at least one vehicle seem to enjoy slightly more diversified diets, as the score of food diversity is 5% higher for households that own at least one vehicle compared to households that lack any form of private vehicle (Table 2.1).

Although statistically significant, these differences in food security are not large in magnitude and might be partly explained by the significant divergence in income and wealth between the two groups. As shown in Table 2.1, in urban areas, households that own vehicles tend to be significantly richer – with an average annual income around 7 000 Soles (USD 1 900) higher than for the rest of households. Additionally, the percentage of households with assets (e.g. refrigerator, good-quality housing, etc.) is significantly higher among vehicle-owners.

Table 2.1. (1/2) Household characteristics for households without any vehicle vs. households with at least one vehicle (urban households)

(1/2) Theme	Variables	<i>No vehicle</i> (<i>N</i> = 114 510)		<i>At least one vehicle</i> (<i>N</i> = 89 566)		<i>Difference</i>	
		Mean	sd	Mean	sd	Coefficient	t-stat
Food security	Being undernourished	0.56	0.5	0.49	0.5	0.07***	29.6
	Size of the deficit in calories	1795.92	2602.10	1722.49	2669.28	73.43***	6.2
	Food diversity Score	153	38	160	34	-7.80***	-49.1
	Equivalentized gross income (thousands of Soles)	13.46	13.27	20.32	21.44	-6.86***	-84.0
Household income and wealth controls	Having a refrigerator	0.42	0.49	0.62	0.48	-0.20***	-92.8
	Having Internet	0.11	0.32	0.22	0.42	-0.11***	-64.7
	Having a mobile phone	0.65	0.48	0.81	0.39	-0.16***	-82.3
	Having a fix phone	0.24	0.43	0.34	0.47	-0.10***	-48.5
	Having cable TV	0.22	0.42	0.37	0.48	-0.15***	-74.4
	Number of rooms per household member	1.17	0.97	1.04	0.76	0.13***	32.9
	Good water quality in the house	0.76	0.43	0.82	0.38	-0.06***	-33.7
	Good toilets quality in the house	0.67	0.47	0.74	0.44	-0.07***	-35.9
	Good floor quality in the house	0.14	0.35	0.21	0.41	-0.07***	-40.9
	Good walls quality in the house	0.53	0.5	0.63	0.48	-0.10***	-47.2
	Good roof quality in the house	0.45	0.5	0.49	0.5	-0.04***	-16.2
	Using electricity for lightning	0.96	0.21	0.99	0.12	-0.03***	-41.3
	Using electricity for cooking	0.05	0.22	0.08	0.28	-0.03***	-27.9
	Having a radio	0.59	0.49	0.61	0.49	-0.02***	-7.4

Table 2.1. (2/2) Household characteristics for households without any vehicle vs. households with at least one vehicle (urban households)

(2/2) Theme	Variables	<i>No vehicle</i> (<i>N</i> = 114 510)		<i>At least one vehicle</i> (<i>N</i> = 89 566)		<i>Difference</i>	
		Mean	sd	Mean	sd	Coefficient	t-stat
	Having a computer	0.23	0.42	0.44	0.5	-0.22***	-95.3
	Having a blender	0.58	0.49	0.79	0.41	-0.21***	-102.7
	Having a microwave	0.12	0.32	0.23	0.42	-0.11***	-67.3
	Having a washing machine	0.14	0.35	0.29	0.46	-0.15***	-81.2
Other household characteristics	Household head works in agriculture	0.16	0.37	0.09	0.29	0.07***	40.7
	Household size	3.61	1.99	4.36	1.86	-0.75***	-88.2
	Household head reached primary education	0.27	0.45	0.25	0.43	0.03***	13.1
	Household head reached secondary education	0.3	0.46	0.33	0.47	-0.04***	-18.0
	Household head reached superior education	0.15	0.35	0.21	0.41	-0.06***	-37.3
	Household head is a woman	0.39	0.49	0.27	0.44	0.12***	60.0
	Number of public transport vehicles per 1 000 inhabitants in the district	0	0.01	0	0.01	-0.00***	-4.9
Local characteristics	District of residence is connected to a paved road	0.91	0.29	0.94	0.23	-0.03***	-23.2
	Food market in the district of residence	0.98	0.13	0.99	0.11	-0.00***	-6.2
	Number of food shops within 1 km of the house	16	33	15	29	0.63***	4.1
	Distance to FUA center (km)*	40.8	71.1	39.3	75.6	1.44***	3.5

Note: * *N* are household-year observations. For the distance to FUA center, the number of observations for households without vehicles and with vehicles are respectively 73 173 and 58 559. sd stands for standard deviation.

Sources: Authors' elaboration based on data from INEI (2019), CENAN (2012, 2019), OpenStreetMap (2020) and Schiavina, Moreno-Monroy, Maffeni and Veneri (2019).

2.4. Empirical strategy

This section details our empirical strategy to estimate the role of private vehicles (differentiated by type of vehicles) on three food security outcomes at the household level (namely undernourishment, size of calorie deficit, and diet diversity). Our main identification strategy exploits the panel dimension of our database by including household fixed effects to control for household unobserved characteristics. The analysis also explores potential heterogeneous effects of vehicle ownership by types of urban households.

2.4.1. Baseline model

The first step of our analysis is to investigate whether there is a relationship between mobility (as measured by vehicle ownership) and food security and nutrition for households living in Peruvian cities. Using the panel of urban households from ENAHO, we estimate simple linear (OLS) and Tobit regressions for the general specification described by Equation 2.1, where $FSN_{h(t)}$ represents the food security and nutrition outcome for household h in year t , namely i) the probability of being undernourished, ii) the size of the food deficit, and iii) the diversity of the diet. While the first and last dependent variables are estimated through OLS, the variable size of the food deficit requires using a Tobit model as this variable is censored at 0 (for households who are not undernourished).

$$FSN_{h(t)} = vehicle_{h(t)}\beta_1 + X_{h(t)}A + Z_{m(t)}B + \varphi_p + \tau_t + \varepsilon_{hm(t)} \quad 2.1$$

The variable $vehicle_{h(t)}$ describes whether household h owns a vehicle (overall or by type of vehicle) in year t . $X_{h(t)}$ is a set of household controls – mainly household characteristics such as educational attainment and sex of the household head, as well as household size. $Z_{m(t)}$ is a group of municipality characteristics that might influence food security at the local level, such as the presence of food markets in the district, the connection to a paved road, and the availability of public transport. Finally, φ_p , τ_t and $\varepsilon_{h(t)}$ stand for province fixed-effects, time fixed-effects and the error term, respectively.

Throughout the chapter, standard errors are corrected for heteroskedasticity and clustered at the provincial level to account for the non-random distribution of households across the country. All estimations are run on the subsample of urban households belonging to the panel survey to ensure comparability across results²⁹. OLS and Tobit regressions are weighted using the weights provided by the ENAHO survey.

2.4.2. Addressing sources of endogeneity

Although the baseline provides a first quantification of the association between vehicle ownership and food security outcomes, it does not allow identifying a causal relationship between mobility to food security. While we do not expect reverse causality to be among the

²⁹ Results hold when using the complete set of urban households.

main sources of endogeneity in our model, the omission of some variables – such as income, wealth and other unobservable household characteristics – is probably upwardly biasing the estimates of the baseline model and thus prevents us from identifying the real magnitude of the association.

Filtering the effects of income and wealth

To control for the fact that richer households are more likely to have both good nutrition and a private vehicle, we add to the baseline model two sets of controls for household income and household wealth. Put differently, owning a vehicle could have an effect on food security and nutrition mainly through two channels, namely a mobility effect and a wealth effect (note that owning a car or scooter can also serve as collateral to borrow). Therefore, including an exhaustive set of income and wealth controls to the model is key to disentangle the vehicle's mobility effect from the vehicle's wealth effect.

We run simple linear (OLS) and Tobit models for the subsample of urban households on the model described by Equation 2.2, where $FSN_{h(t)}$ represents the food security and nutrition dependent variables (previously defined in Equation 2.1).

$$FSN_{h(t)} = vehicle_{h(t)}\beta_1 + income_{h(t)}\beta_2 + wealth_dummies_{h(t)}\beta_3 + X_{h(t)}A + Z_{m(t)}B + \varphi_p + \tau_t + \varepsilon_{hm(t)} \quad 2.2$$

The variable $vehicle_{h(t)}$ describes whether household h owns a vehicle (overall or by type of vehicle depending on the specification) in year t . The variable $income_{h(t)}$ represents the gross income of household h annualized for year t and equivalized per member of the household. $wealth_dummies_{h(t)}$ is a set of dummy variables taking the value 1 if household h possesses a specific asset in year t (e.g. refrigerator, Internet, a roof of good quality, etc.; see Table 2.1 for full list). The rest of the variables are the same as in the baseline model (see Equation 2.1); standard errors are clustered at the provincial level and corrected for heteroskedasticity.

Main specification: exploiting panel data with a household fixed-effects model

Although controlling for household income and wealth helps separating the mobility effect of owning a vehicle from its wealth effect, there might be other household characteristics

that we do not observe and yet influence both mobility and food security. For instance, risk averse households might prioritize both food and mobility-related investments over other products (e.g. leisure, clothing). It is also likely that more health-conscious households will prefer nutritious food and active mobility such as walking or biking. In the presence of these unobserved household features, our estimates could be upwardly biased.

To control for household heterogeneity in our sample, we exploit the panel dimension of our database (ENAH0) and run a household fixed-effects model while controlling for income and wealth over time, as described by Equation 2.3 where FSN_{ht} represents either the probability of being undernourished, the size of the food deficit, or the diversity of the diet for household h in year t .

$$FSN_{ht} = vehicle_{ht}\beta_1 + income_{ht}\beta_2 + wealth_dummies_{ht}\beta_3 + X_{ht}A + Z_{mt}B + F_h + \tau_t + \theta_{dt} + \varepsilon_{hmt} \quad 2.3$$

The variable $vehicle_{ht}$ describes whether household h owns a vehicle (overall or by type of vehicle depending on the specification) in year t . $income_{ht}$ and $wealth_dummies_{ht}$ stand for household income and wealth indicators over time, respectively. X_{ht} and Z_{mt} are households and municipality time-varying controls, F_h are the households fixed effects, and τ_t and θ_{dt} stand for the time and department-time fixed effects. ε_{hmt} denotes the error term, standard errors are robust (corrected for heteroskedasticity).

Since this specification captures variations in mobility (vehicle ownership) within households over time, while controlling for unobserved household characteristics, we argue that its coefficients might be closer to capture the causal impact of vehicle ownership on food security and nutrition.

2.4.3. Heterogenous effects by level of income and distance to city center

This section further explores the heterogeneous effects of mobility across population groups (by income and distance to the city center) and its implications for the role of vehicles in food access and food security.

Income inequality is a clear source of heterogeneity across households in our sample. To investigate whether the effect of vehicle ownership on food security is homogenous across all levels of income, we estimate our main specification on two different subsamples. More

precisely, we split the sample between low- and middle-income households (being below the median income and between the median and the 90th percentile, respectively – based on the income of the first year in which the household is observed). The richest 10% are excluded from this part of the analysis as undernourishment is not an issue among this group and to avoid issues of income outliers in such reduced subsample. These estimations can be understood as in Equation 2.3 (main specification), but applied separately to the two subsamples mentioned above.

The location of households across the urban space mirrors to some extent the level of income inequalities and segregation – in particular, households with higher incomes are more likely to live closer to the city center. Here, we examine whether the distance from households' place of residence (based on geographical coordinates) to the city center modifies the mobility impact (given by vehicles) on food access. To do so, we estimate the main fixed-effects specification (given by Equation 2.3) on three different subsamples. The first one gathers urban households living within a radius of 7 km from the center of the high-density core (hereafter city center) of the functional urban area (FUA), while the second subsample is restricted to households living between 7 and 30 km from the city center, and the third subsample to households whose residence is between 30 and 100 km from the city center. While the selection of distance thresholds for the last two groups is based on a trade-off between using meaningful travel distances (for the studied types of vehicles) and keeping a significant number of observations within each subsample, the threshold for the first group is defined by the average radius of a Peruvian FUA (around 7 km)³⁰.

2.5. Results

This section summarizes the main results of the different models and robustness checks through which we quantify and analyze the mobility-food security nexus. The section closes with our interpretation of the heterogenous effects of vehicle ownership by level of income and distance to the city center.

³⁰ Own calculations based on FUAs' area data from Schiavina, Moreno-Monroy, Maffeni and Veneri (2019) and assuming FUAs are circular-shaped.

2.5.1. Baseline model

The results of the baseline model – presented in Table 2.2 – provide the first assessment of the association between household mobility (proxied by vehicle ownership) and household food security and nutrition. More precisely, columns 1 and 2 display the OLS coefficients for the probability of being undernourished, columns 3 and 4 the Tobit coefficients for the size of the food deficit, and columns 5 and 6 the OLS coefficients related to the diet diversity score.

Table 2.2. Results: Baseline model

	(1) OLS Undernutrition <i>Urban</i>	(2) OLS Undernutrition <i>Urban</i>	(3) Tobit Calorie deficit <i>Urban</i>	(4) Tobit Calorie deficit <i>Urban</i>	(5) OLS Diet diversity <i>Urban</i>	(6) OLS Diet diversity <i>Urban</i>
<i>Mobility</i>						
Vehicle	-0.07*** (0.006)		-545.4*** (81.8)		3.0*** (1.0)	
Bike		-0.07*** (0.008)		-580.0*** (87.2)		3.0*** (0.5)
Car		-0.03*** (0.009)		-240.6* (123.1)		-1.5 (1.6)
Scooter		-0.03* (0.02)		-349.4*** (125.6)		4.5*** (0.8)
<i>District characteristics</i>						
Public transport vehicles per 1 000 inhab.	1.1 (1.0)	1.1 (1.0)	11224.3 (6951.2)	11443.0* (6944.5)	8.2 (58.7)	11.7 (57.2)
Connected to paved road	-0.002 (0.04)	-0.003 (0.04)	-35.3 (192.5)	-43.7 (192.2)	2.9 (1.8)	3.0 (1.9)
Food market in municipality	-0.009 (0.03)	-0.005 (0.03)	-358.4 (443.7)	-329.6 (444.9)	10.7 (6.6)	10.5 (6.7)
Number of food points within 1 km	-0.0002 (0.0001)	-0.0002 (0.0001)	-2.3* (1.2)	-2.3* (1.2)	-0.02** (0.008)	-0.02* (0.008)
<i>Household characteristics</i>						
Main activity: agriculture	0.06*** (0.02)	0.06*** (0.02)	782.2*** (143.4)	779.0*** (143.8)	-7.4*** (1.9)	-7.4*** (1.9)
Household size	0.02*** (0.004)	0.02*** (0.004)	539.4*** (22.6)	545.7*** (22.6)	3.2*** (0.4)	3.2*** (0.3)
Primary education	0.03** (0.01)	0.03** (0.01)	202.6* (112.5)	201.2* (112.6)	1.0 (0.7)	1.0 (0.7)
Secondary education	0.02 (0.01)	0.02 (0.01)	37.4 (108.8)	38.0 (109.1)	1.8** (0.9)	1.8** (0.9)
Tertiary education	-0.03 (0.02)	-0.03 (0.02)	-306.9** (126.0)	-286.6** (126.6)	-1.8 (2.4)	-1.6 (2.2)
Household head is a woman	-0.002 (0.01)	-0.002 (0.01)	-1.1 (90.0)	-3.9 (90.0)	-3.6*** (0.8)	-3.7*** (0.7)
N	16037	16037	16037	16037	16037	16037
R ²	0.06	0.06	-	-	0.11	0.11
Adjusted R ² or Pseudo R ²	0.05	0.05	0.01	0.01	0.10	0.10
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Category of reference for education of head is No Education; Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The baseline model reveals that households that own at least one vehicle generally have better food security and diet diversity outcomes than families who do not own any vehicle

(columns 1, 3 and 5). When breaking down vehicle ownership by type of vehicle, we find that households having a car have a lower probability of being undernourished and a smaller food deficit, but do not necessarily eat more quality and diversified diets. On the contrary, households with a scooter or a bike record better quantity but also quality of their diets than households without these types of vehicles.

Although these results suggest that being more mobile and being food secure usually go hand in hand, they do not inform on the causal relationship between mobility and food security and nutrition. More precisely, the coefficients of the baseline model might be biased due to household financial capacity to both own vehicles and buy sufficient food.

2.5.2. Filtering out income and wealth effects

To isolate the mobility effect conferred by vehicles from the socio-economic effects, we include an exhaustive set of income and wealth variables in our regressions. Results of these estimations are presented in Table 2.3. The distribution of the columns is identical to the one in the previous section.

When controlling for income and wealth, we verify that more mobile households (i.e. those that own vehicles) are significantly more food secure and enjoy more diversified diets than non-mobile families (columns 1, 3 and 5). However, if analyzing by type of vehicle, results suggest that having a car is not associated with better food security outcomes (columns 2 and 4). This implies that the positive role of cars found in the baseline model was mainly picking up the household income and wealth effect, as richer households have a higher probability to buy a car (a relatively expensive vehicle compared to bicycles and scooters). Nonetheless, the two other types of vehicles – bikes and scooters – are still significantly associated with better outcomes of food security (columns 2, 4 and 6). Families with a scooter or a bike tend to be more able to access food, consume a number of calories closer to their needs, and enjoy more balanced diets.

Table 2.3. (1/2) Results: Filtering out income and wealth effects

(1/2)	(1) OLS Undernutrition <i>Urban</i>	(2) OLS Undernutrition <i>Urban</i>	(3) Tobit Calorie deficit <i>Urban</i>	(4) Tobit Calorie deficit <i>Urban</i>	(5) OLS Diet diversity <i>Urban</i>	(6) OLS Diet diversity <i>Urban</i>
<i>Mobility</i>						
Vehicle	-0.03*** (0.006)		-296.4*** (83.6)		3.8*** (0.7)	
Bike		-0.04*** (0.007)		-352.6*** (87.6)		3.3*** (0.5)
Car		-0.004 (0.009)		-69.5 (130.4)		1.0 (1.0)
Scooter		-0.02 (0.02)		-255.2** (125.1)		4.1*** (0.8)
<i>Income and wealth</i>						
Gross equivalized income (thousands of Soles)	0.002*** (0.0008)	0.002** (0.0008)	23.2*** (6.2)	23.0*** (6.2)	0.02 (0.05)	0.02 (0.04)
(Gross equivalized income) ²	-0.00001*** (0.000003)	-0.00001*** (0.000003)	-0.1*** (0.04)	-0.1*** (0.04)	-0.0002 (0.0002)	-0.0002 (0.0002)
Refrigerator	-0.04** (0.02)	-0.04** (0.02)	-119.1 (100.3)	-116.1 (100.3)	-2.1** (0.9)	-2.2** (0.9)
Internet at home	0.005 (0.009)	0.004 (0.009)	-54.9 (145.7)	-60.2 (145.6)	-1.6* (0.9)	-1.5 (0.9)
Number of rooms per capita	0.01 (0.01)	0.01 (0.01)	-66.0 (109.6)	-62.9 (109.6)	1.6 (1.5)	1.6 (1.5)
Good water supply quality	-0.04*** (0.010)	-0.04*** (0.010)	-359.8*** (103.8)	-361.3*** (103.9)	-1.6 (1.3)	-1.6 (1.3)
Good sanitation quality	-0.05*** (0.008)	-0.05*** (0.008)	-434.0*** (102.9)	-435.5*** (102.9)	1.2 (0.9)	1.2 (0.9)
Good floor quality	0.06*** (0.009)	0.06*** (0.009)	452.3*** (55.1)	446.7*** (55.0)	-2.0*** (0.7)	-1.9*** (0.7)
Good walls quality	0.03** (0.01)	0.03** (0.01)	196.5 (119.9)	194.8 (119.9)	-1.4 (1.3)	-1.4 (1.3)
Good roof quality	-0.008 (0.01)	-0.007 (0.01)	-40.2 (117.5)	-33.6 (117.4)	1.7 (1.1)	1.7 (1.1)
Electricity for lighting	-0.010 (0.02)	-0.01 (0.02)	-51.5 (125.5)	-57.5 (125.7)	-5.3*** (0.9)	-5.3*** (0.9)
Electricity for cooking	-0.02 (0.02)	-0.02 (0.02)	-49.3 (104.1)	-46.9 (104.1)	2.9** (1.2)	2.8** (1.2)
Mobile phone	0.04*** (0.01)	0.04*** (0.01)	357.5*** (101.7)	348.2*** (101.7)	0.5 (0.9)	0.7 (0.9)
Fixed phone	-0.07* (0.04)	-0.07* (0.04)	-588.2** (240.9)	-579.2** (240.6)	7.5* (4.0)	7.4* (4.0)
Cable TV	-0.08*** (0.03)	-0.08*** (0.03)	-481.8*** (164.9)	-488.3*** (164.6)	-1.1 (0.9)	-1.0 (0.9)
Radio	0.007 (0.010)	0.008 (0.010)	94.1 (80.1)	99.0 (80.2)	-2.2*** (0.4)	-2.2*** (0.4)
Computer	0.02* (0.01)	0.03* (0.01)	94.4 (114.9)	111.9 (114.7)	-0.3 (0.8)	-0.5 (0.8)
Blender	-0.1*** (0.01)	-0.1*** (0.01)	-1144.6*** (96.8)	-1131.7*** (96.9)	0.9 (0.9)	0.8 (0.9)
Microwave	-0.04*** (0.01)	-0.04*** (0.01)	-246.5* (127.9)	-245.7* (127.9)	-1.5** (0.7)	-1.4* (0.7)
Washing machine	-0.05*** (0.02)	-0.05*** (0.02)	-427.8*** (124.8)	-423.8*** (125.0)	0.9 (1.3)	0.9 (1.3)

Table 2.3. (2/2) Results: Filtering out income and wealth effects

(2/2)	(1) OLS Undernutrition <i>Urban</i>	(2) OLS Undernutrition <i>Urban</i>	(3) Tobit Calorie deficit <i>Urban</i>	(4) Tobit Calorie deficit <i>Urban</i>	(5) OLS Diet diversity <i>Urban</i>	(6) OLS Diet diversity <i>Urban</i>
<i>District characteristics</i>						
Public transport vehicles per 1 000 inhabitants	0.7 (0.9)	0.7 (0.9)	8784.0 (6882.0)	8805.0 (6879.1)	12.6 (54.8)	13.6 (53.7)
Connected to paved road	-0.02 (0.03)	-0.02 (0.03)	-150.1 (190.0)	-154.0 (189.9)	2.1 (2.2)	2.2 (2.2)
Food market in municipality	0.01 (0.03)	0.02 (0.03)	-192.3 (431.2)	-179.4 (431.8)	10.1 (6.5)	9.9 (6.6)
Number of food points within 1 km	0.00006 (0.0001)	0.00005 (0.0001)	-0.7 (1.2)	-0.8 (1.2)	-0.004 (0.010)	-0.004 (0.010)
<i>Household characteristics</i>						
Main activity: agriculture	0.04** (0.02)	0.04** (0.02)	630.8*** (145.7)	630.1*** (146.0)	-6.4*** (1.8)	-6.4*** (1.8)
Household size	0.04*** (0.003)	0.04*** (0.003)	690.0*** (27.0)	692.8*** (26.9)	2.8*** (0.3)	2.7*** (0.3)
Primary education	0.04*** (0.01)	0.04*** (0.01)	270.9** (111.5)	270.1** (111.6)	0.8 (0.7)	0.8 (0.7)
Secondary education	0.04*** (0.01)	0.04*** (0.01)	241.2** (109.3)	238.4** (109.5)	1.8** (0.8)	1.8** (0.8)
Tertiary education	0.005 (0.02)	0.006 (0.02)	-91.8 (134.5)	-86.8 (134.5)	-0.04 (1.4)	-0.1 (1.4)
Household head is a woman	0.0005 (0.02)	0.0008 (0.01)	26.4 (89.5)	24.4 (89.4)	-3.3*** (0.9)	-3.4*** (0.8)
N	16037	16037	16037	16037	16037	16037
R ²	0.092	0.092			0.118	0.118
Adjusted R ² or Pseudo R ²	0.082	0.083	0.014	0.014	0.108	0.109
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Category of reference for education of head is No Education; Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

2.5.3. Main specification: panel model with household fixed-effects

We now use within-household variations in vehicle ownership (i.e. changes over time) to investigate the causal relationship between mobility and food security. Using panel data models with household fixed-effects allows us to account for unobservable time-invariant household characteristics that could be driving both the probability to own a vehicle and to be more food secure and thus minimizes our concerns of potential omitted variable bias. Results of the household fixed-effects model are presented in Table 2.4, where the first column displays the coefficients for the probability of undernourishment, the second column the coefficients for the size of the calorie deficit, and the third column the coefficients for the diet diversity score.

Table 2.4. Main specification: panel model with household fixed-effects

	(1) FE Undernutrition <i>Urban</i>	(2) FE Calorie deficit <i>Urban</i>	(3) FE Diet diversity <i>Urban</i>
<i>Mobility</i>			
Bike	-0.03* (0.02)	-86.7 (82.5)	1.2 (1.1)
Car	0.05 (0.03)	153.5 (172.0)	2.5 (2.2)
Scooter	-0.02 (0.03)	-225.2 (137.1)	3.8* (2.0)
<i>Income and wealth</i>			
Gross equivalized income (thousands of Soles)	0.00008 (0.0010)	7.2* (4.3)	0.2** (0.07)
(Gross equivalized income) ²	0.0000006 (0.000004)	-0.02 (0.01)	-0.0006* (0.0003)
Wealth assets dummies	Yes	Yes	Yes
<i>District characteristics</i>			
Public transport vehicles per 1 000 inhabitants	2.1 (2.0)	-41.3 (8038.6)	-136.3 (129.3)
Connected to paved road	-0.04 (0.04)	-81.8 (186.6)	1.9 (2.7)
Food market in municipality	-0.2 (0.1)	525.2 (526.0)	-4.7 (8.7)
<i>Household characteristics</i>			
Main activity: agriculture	0.03 (0.03)	286.0** (140.6)	-1.7 (2.0)
Household size	0.06*** (0.007)	638.0*** (46.9)	3.4*** (0.5)
Primary education	0.04** (0.02)	184.7** (91.8)	-1.3 (1.3)
Secondary education	0.02 (0.02)	35.5 (92.6)	-0.3 (1.3)
Tertiary education	0.009 (0.02)	65.0 (112.1)	1.4 (1.6)
Household head is a woman	0.002 (0.02)	53.6 (91.9)	-1.8 (1.4)
N	16037	16037	16037
R ²	0.057	0.104	0.050
Adjusted R ²	0.048	0.095	0.041
Department*Year FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: Category of reference for education of head is No Education; Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

We confirm that acquiring a bike significantly improves household food security over time by decreasing the probability to face undernourishment (column 1). Similarly, when families acquire a scooter, they can access more types of food products and diversify their diets (column 3). Nevertheless, the magnitude of these effects is relatively modest – for an average household, having a bike decreases the probability of being undernourished by 3 percentage points, while having a scooter improves diet diversity by around 3.8 points (in terms of the diet diversity score, whose standard deviation is around 38). This suggests that although mobility is

important, other factors (including wealth and unobserved household characteristics) contribute more to enhance access to food among urban households in Peru.

While bikes and scooters may nevertheless facilitate households' access to different food shops, our identification strategy suggests that – beyond its related wealth effects – getting a car does not significantly improve household food security or diet diversity in urban Peru (Table 2.4, columns 1, 2 and 3). Given today's tremendous challenges of inequalities, climate change, and pollution in Peruvian cities (and in most cities in the world), establishing that less pollutant forms of transport such as bikes and scooters are better enablers of mobility and access to food within the urban space than cars can help governments in the design of social and environmental policies.

Robustness checks: subsample of households who experienced a change in vehicle ownership over the observed period

A possible concern in the panel model (above) is the potential limited variability in vehicle ownership over time. ENAHO surveys are designed as rotated panels where households are followed over maximum 5 years (70% of the sample is followed over 2 to 4 years). To verify the robustness of our results, we run the household fixed-effects model only on the subsample of urban households who either acquired or lost at least one vehicle over the period of observation (i.e. exclude households who did not experience any change in vehicle ownership). As expected, we obtain similar results than those of the main specification (Table 2.5). While acquiring a bike significantly reduces the probability to fall into undernourishment (column 1), getting a scooter improves households' diet diversity and (compared to the main specification) reduces the size of the deficit in calories (columns 2 and 3). These results confirm that while bikes and scooters are useful means for households to access more and diverse foods in cities, having a car is not significant driver of food security.

Another issue that could arise when looking at changes in vehicle ownership over time is that households might underreport their income in the year where they buy the vehicle (i.e. they subtract the value of the vehicle from their income). To mitigate this potential source of bias in our estimates, we run the main specifications (on the whole sample and the subsample of households who changed vehicle status) using the income declared in the year previous to the acquisition of the vehicle, rather than using the current income (only for the years where

households have a variation in their vehicle status). We obtain practically identical results than our main estimations (see Annex 2.A: Annex Table 2.1 and Annex Table 2.2).

Table 2.5. Robustness check: subsample of households who experienced a change in vehicle ownership

	(1) FE Undernutrition <i>Urban</i>	(2) FE Calorie deficit <i>Urban</i>	(3) FE Diet diversity <i>Urban</i>
<i>Mobility</i>			
Bike	-0.03** (0.02)	-106.3 (84.3)	1.5 (1.1)
Car	0.04 (0.03)	148.7 (174.6)	3.1 (2.2)
Scooter	-0.03 (0.03)	-246.3* (142.7)	3.8* (2.0)
<i>Income and wealth</i>			
Gross equivalized income (thousands of Soles)	0.003* (0.001)	15.3** (6.7)	0.1 (0.1)
(Gross equivalized income) ²	-0.00002** (0.000007)	-0.06* (0.03)	-0.0001 (0.0005)
Wealth assets dummies	Yes	Yes	Yes
<i>District characteristics</i>			
Public transport vehicles per 1 000 inhabitants	2.0 (3.3)	-6475.9 (13703.2)	-195.2 (196.5)
Connected to paved road	-0.06 (0.06)	97.0 (304.4)	-0.9 (4.1)
Food market in municipality	0.08 (0.2)	1186.3* (665.3)	-15.4 (9.6)
<i>Household characteristics</i>			
Main activity: agriculture	0.02 (0.04)	318.2* (188.6)	-6.6** (2.8)
Household size	0.05*** (0.01)	585.8*** (61.7)	3.3*** (0.8)
Primary education	0.07** (0.03)	121.2 (130.1)	1.3 (1.8)
Secondary education	0.04 (0.03)	29.9 (131.6)	1.0 (1.8)
Tertiary education	0.04 (0.04)	-229.1 (162.9)	3.7 (2.3)
Household head is a woman	0.02 (0.03)	115.0 (130.9)	-4.0** (1.9)
N	5479	5479	5479
R ²	0.087	0.126	0.077
Adjusted R ²	0.060	0.101	0.049
Department*Year FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

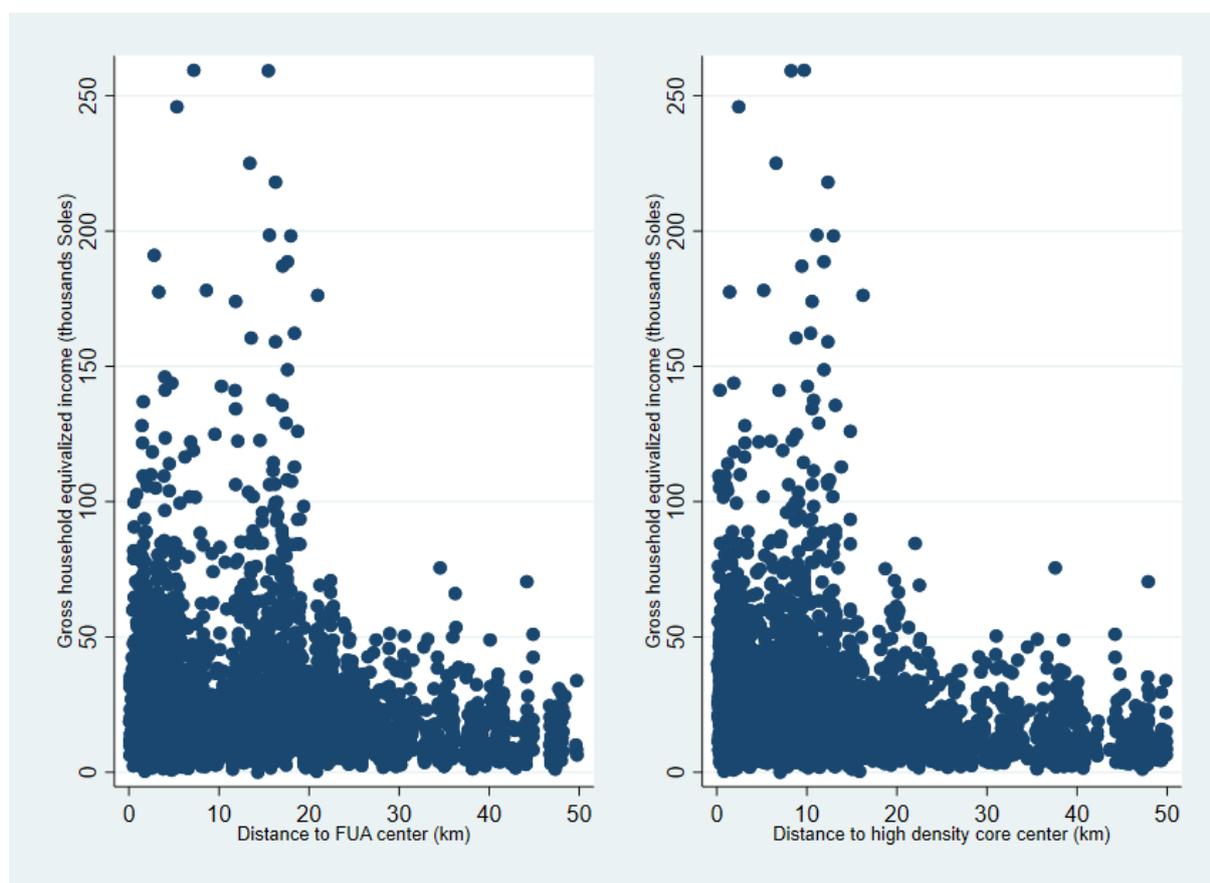
Notes: Category of reference for education of head is No Education; Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

2.5.4. Heterogeneous effects by income and distance to the city center

Our analysis reveals that while cars do not provide significant benefits in terms of access to food, the possession of a bike or a scooter seems to make a difference in household food security. This section explores if this relation holds across the whole spectrum of households

of our sample. Research has indeed demonstrated that non-motorized modes of transportation might only benefit to people living inside or close to the cores of the cities (see for instance Ortegón-Sánchez and Oviedo Hernández, 2016). Due to the higher cost of living in city centers, these areas are typically populated by middle- and high-income households (OECD-FAO-UNCDF, 2016). In Peruvian cities, as in other cities in the world, household incomes tend to decrease with distance to the city center (see Figure 2.4). Therefore, we explore the heterogeneous effects of vehicle ownership on food security along both the income and the distance to the city center gradients.

Figure 2.4. Correlation between household income and distance from the place of residence to the city center (2016)



Notes: FUA refers to Functional Urban Area (see definition in Section 2.3.3).

Source: Authors' elaboration based on INEI (2019a), Schiavina, Moreno-Monroy, Maffeni and Veneri (2019) and Florczyk et al. (2020) data.

We apply our main fixed-effects specification on two different subsamples composed by low- and middle-income households (being below the median income and between the median

and the 90th percentile, respectively). The richest 10% is excluded from this part of the analysis as undernourishment is not an issue among this group and to avoid issues of income outliers in such reduced subsample. Our results reveal that the benefits of scooters on food access are limited predominantly among the low-income households (who are more likely to live in the periphery of cities); whereas bikes seem to improve food security outcomes among the middle- and upper-middle class (who tend to live closer to the city center) (Table 2.6)

Table 2.6. Heterogenous effects of household mobility by income

	<i>Low-income households</i>			<i>Middle-income households</i>		
	(1) FE Undernutrition	(2) FE Calorie deficit	(3) FE Diet diversity	(4) FE Undernutrition	(5) FE Calorie deficit	(6) FE Diet diversity
<i>Mobility</i>						
Bike	-0.01 (0.02)	-92.3 (110.6)	0.5 (1.5)	-0.05* (0.03)	-54.6 (132.4)	1.3 (1.8)
Car	0.04 (0.05)	114.1 (300.3)	3.3 (3.2)	0.05 (0.05)	172.7 (228.4)	1.3 (3.1)
Scooter	-0.05 (0.04)	-480.1** (197.8)	4.3* (2.6)	-0.008 (0.04)	25.9 (211.2)	3.6 (3.2)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
N	8257	8257	8257	6810	6810	6810
R ²	0.08	0.14	0.07	0.10	0.13	0.09
Adjusted R ²	0.06	0.12	0.05	0.08	0.11	0.06
Department	Yes	Yes	Yes	Yes	Yes	Yes
*Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Controls include all the other variables as in previous estimations, (e.g. showed in Table 2.4), i.e. income and wealth, district characteristics, and other household characteristics. Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

To further verify if the benefits of bikes and scooters on food access progressively vanish with greater distances from the city center, we estimate our preferred model on three subsamples of households according to their distance to the city center. Results are presented in Table 2.7 and should be interpreted carefully given the small sample sizes (as we excluded households in “urban areas”, as defined by the INE, who were located 100 km or further away from a high density cluster, the latter being preferred definition of a city center).

Our findings confirm that, compared to other types of vehicles, cars are not a significant mean to improve food security outcomes in Peruvian cities. They also suggest that when households live in or close to the city center (no more than 7 km away), food security and diet diversity are not significantly affected by vehicle ownership (Table 2.7, columns 1 to 3). This may be explained by the fact that city centers are usually more pedestrian-friendly and have larger options in terms of food shops and markets which are easily accessible by walking. For

households living within the periphery of cities (between 7 km and 30 km from the urban center), we find that bikes significantly decrease the risk of households to fall into undernourishment (Table 2.7, column 4), however the benefits of having a bike to access food disappears when living further away than 30 km from a city center. Indeed, households with a residence between 30 and 100 km from a city center cannot rely on bikes to improve their food security. On the other hand, for these households, the use of scooters is significantly contributing to a reduction in calorie deficits and risks of undernourishment (Table 2.7, columns 7 and 8).

Table 2.7. Heterogenous effects of household mobility by distance to the city center

	<i>0 to 7 km from urban center</i>			<i>7 to 30 km from urban center</i>			<i>30 to 100 km from urban center</i>		
	(1) FE Undern trition	(2) FE Calorie deficit	(3) FE Diet diversity	(4) FE Undernu trition	(5) FE Calorie deficit	(6) FE Diet diversity	(7) Undernu trition	(8) Calorie deficit	(9) Diet diversity
<i>Mobility</i>									
Bike	0.02 (0.02)	64.3 (112.6)	-0.9 (1.7)	-0.07* (0.04)	-222.4 (177.8)	3.5 (2.5)	-0.07 (0.05)	-142.9 (225.6)	3.5 (2.9)
Car	0.05 (0.05)	21.8 (255.8)	4.3 (3.4)	0.1 (0.07)	239.7 (353.6)	1.4 (4.6)	-0.1 (0.08)	-135.1 (412.2)	7.6 (5.9)
Scooter	-0.005 (0.04)	-185.5 (210.7)	2.9 (2.8)	0.01 (0.06)	-21.7 (253.4)	1.5 (4.6)	-0.1* (0.06)	-917.2*** (328.8)	1.2 (4.4)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	6508	6508	6508	3646	3646	3646	2445	2445	2445
R ²	0.09	0.13	0.06	0.09	0.13	0.10	0.17	0.25	0.17
Adjusted R ²	0.07	0.11	0.05	0.07	0.11	0.08	0.13	0.21	0.13
Department									
*Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Controls include all the other variables as in previous estimations, (e.g. showed in Table 2.4), i.e. income and wealth, district characteristics, and other household characteristics. Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

2.6. Conclusions

In Peru, cities are affected by two main challenges of food security and nutrition: persistent undernourishment and fast-growing cases of overweight and obesity. Beyond economic factors, physical accessibility to food markets could play an important role in shaping calorie consumption and diet diversity in urban Peru.

The objective of this chapter was to assess the role of private vehicles as enablers of mobility (both motorized and non-motorized) in enhancing access to food and therefore better nutrition. This question has been little studied in the literature, as the mobility effect of vehicles

in food security can be easily confounded with the related income and wealth effects. This chapter fills this gap in the literature through a series of linear, censored and panel models.

The analysis conducted in this chapter suggests that pollutant vehicles such as cars are not a necessary condition to food security in Peruvian cities. On the contrary, we show that cleaner and cheaper transport modes – such as bicycles – have higher and significant potential to enhance households' access to food.

By exploring the heterogeneity in the effects of vehicle ownership along the income and proximity to the city center gradients, we provide evidence on the limited effects of bikes across certain population groups. Indeed, the benefits of bikes for better food accessibility remain locked for many low-income households who live far from the city center. Planning for more bike-friendly cities, including their peripheries, and extending the perimeter of cycling infrastructure in Peruvian urban areas could be welfare improving as it would help more households reach better food products, while contributing to climate and environmental objectives.

Although the current spread of motorized vehicles among Peruvian cities denotes a raise in incomes, on average, this trend in motorization involves many risks and is not necessarily welfare improving. Reversing the current urban planning trend that tends to favor cars over more sustainable modes of transportation (OECD, 2016; OECD 2015; Gallego et al., 2013; Chavez-Rodriguez, 2018) could actually contribute to improving food security and nutrition. The Peruvian national and local governments should integrate the role of sustainable mobility in enhancing food access, when designing policies and programs to tackle undernourishment and malnutrition in Peruvian cities. For example, they could consider transforming urban design on the periphery of cities to extend the use of bikes and the practicability of cycling. Subsidies to incentivize food shops to locate in low-mobility or far-from-the-city areas could also be implemented. Recently, Peru has adopted the “Promovilidad Plan” that defines significant steps towards more sustainable mobility in large cities across the country (Gobierno del Perú, 2019). In the metropolitan area of Lima, for instance, authorities have created two new subway lines and established a publicly managed Bus Rapid Transit system that has begun to reduce the current pressure on urban transport (Ortegon-Sanchez and Oviedo Hernandez, 2016).

In the current context of COVID-19 crisis, Peruvian authorities should also consider that better nutrition among the population will also contribute to the country's health resilience in the face of the current pandemic and future risk disasters. Incorporating the objective of better food security and nutrition into transversal projects in urban planning is essential to improve people's well-being today and for future generations.

Annex 2.A. Robustness check: change in income captured by change in vehicle status

Annex Table 2.1. Robustness check: controlling for income of the year preceding the change in vehicle status

	(1) FE Undernutrition <i>Urban</i>	(2) FE Calorie deficit <i>Urban</i>	(3) FE Diet diversity <i>Urban</i>
<i>Mobility</i>			
Bike	-0.03* (0.02)	-86.0 (82.6)	1.3 (1.1)
Car	0.05 (0.03)	159.5 (172.0)	2.6 (2.2)
Scooter	-0.02 (0.03)	-215.6 (136.8)	4.0** (2.0)
<i>Income and wealth</i>			
Previous Gross equivalized income (thousands of Soles)	-0.00002 (0.001)	2.5 (4.6)	0.1* (0.08)
(Previous Gross equivalized income) ²	0.000003 (0.000005)	-0.002 (0.02)	-0.0004 (0.0003)
Wealth assets dummies	Yes	Yes	Yes
<i>District characteristics</i>			
Public transport vehicles per 1 000 inhabitants	2.0 (2.0)	108.4 (8038.8)	-133.3 (129.5)
Connected to paved road	-0.04 (0.04)	-78.4 (186.4)	1.9 (2.7)
Food market in municipality	-0.2 (0.1)	524.8 (528.1)	-4.8 (8.7)
<i>Household characteristics</i>			
Main activity: agriculture	0.03 (0.03)	288.8** (140.7)	-1.6 (2.0)
Household size	0.06*** (0.007)	638.2*** (46.9)	3.4*** (0.5)
Primary education	0.05** (0.02)	184.8** (91.9)	-1.3 (1.3)
Secondary education	0.02 (0.02)	36.5 (92.7)	-0.3 (1.3)
Tertiary education	0.009 (0.02)	69.6 (112.3)	1.5 (1.6)
Household head is a woman	0.002 (0.02)	49.6 (92.0)	-1.9 (1.4)
N	16037	16037	16037
R ²	0.057	0.103	0.050
Adjusted R ²	0.048	0.094	0.040
Department*Year FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: Category of reference for education of head is No Education; Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Annex Table 2.2. Robustness check: controlling for income of the year preceding the change in vehicle status

(subsample of households with a change in vehicle status)

	(1) FE Undernutrition <i>Urban, change in vehicle</i>	(2) FE Calorie deficit <i>Urban, change in vehicle</i>	(3) FE Diet diversity <i>Urban, change in vehicle</i>
<i>Mobility</i>			
Bike	-0.03* (0.02)	-103.5 (84.5)	1.5 (1.1)
Car	0.04 (0.03)	158.0 (174.7)	3.2 (2.2)
Scooter	-0.03 (0.03)	-229.9 (142.1)	4.0** (2.0)
<i>Income and wealth</i>			
Previous Gross equivalized income (thousands of Soles)	0.003* (0.002)	7.9 (8.0)	-0.04 (0.1)
(Previous Gross equivalized income) ²	-0.00002 (0.00001)	-0.03 (0.04)	0.0008 (0.0006)
Wealth assets dummies	Yes	Yes	Yes
<i>District characteristics</i>			
Public transport vehicles per 1 000 inhabitants	2.1 (3.2)	-5748.2 (13706.7)	-187.1 (196.7)
Connected to paved road	-0.06 (0.06)	101.1 (304.0)	-0.9 (4.1)
Food market in municipality	0.08 (0.2)	1172.6* (668.7)	-15.6 (9.6)
<i>Household characteristics</i>			
Main activity: agriculture	0.02 (0.04)	326.9* (189.2)	-6.5** (2.8)
Household size	0.05*** (0.01)	586.2*** (61.5)	3.3*** (0.8)
Primary education	0.07** (0.03)	123.3 (130.4)	1.3 (1.8)
Secondary education	0.05 (0.03)	34.0 (131.9)	1.1 (1.8)
Tertiary education	0.04 (0.04)	-220.1 (163.6)	3.8 (2.3)
Household head is a woman	0.03 (0.03)	108.2 (131.0)	-4.2** (1.9)
N	5479	5479	5479
R ²	0.087	0.125	0.076
Adjusted R ²	0.060	0.099	0.049
Department*Year FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: Category of reference for education of head is No Education; Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Chapter 3. How heavy was the cost of Obesity during the pandemic? Obesity and COVID-19 severity in Mexico

Co-authored with Marcos A. Díaz Ramírez

Abstract: This study provides new evidence on the role of obesity in generating more COVID-19 severe cases and deaths³¹. The paper also estimates the additional health expenditures associated to obesity during the first wave of the pandemic in Mexico. For the analysis, we use the official Mexican register of COVID-19 cases and deaths – containing rich individual data on the different stages of the COVID-19 disease and on key characteristics such as patients' comorbidities – as well as new health resources inventories that provide information on health system capacity at the municipal level. Through a series of logistic regressions, we demonstrate that obesity is a significant driver of COVID-19 severity and death, even when controlling for an exhaustive set of relevant individual and place-based characteristics. Obese patients are around 50% more likely to develop each of the different severe forms of COVID-19 compared to non-obese patients. Given the alarming prevalence of obesity in Mexico, we show that the cost of obesity in terms of the COVID-19's death toll has been very high. Our model predicts that between 8% and 12% of COVID-19 deaths could have been avoided between January and August 9th 2020 if there were no obesity in Mexico. Results also suggest that obesity and its implications on COVID-19 severity stepped up healthcare expenditure by USD 220 to USD 240 million, generating significant pressure on public health budgets. Our findings support the urgent need for more effective policy action to tackle obesity in Mexico.

³¹ Please note that we finalized this version of the chapter in March 2021. Since then, given the fast-growing research on the subject worldwide, knowledge about COVID-19 and its complexity, including in Mexico, may have considerably evolved.

3.1. Introduction

Obesity has become a major public health issue in the world over the past decades. Today, more than 13% of all adults in the world are obese (WHO, 2020a). Yet, as obesity is deeply linked to poverty and inequalities, some places – such as Mexico – are more impacted than others. Mexico is the second most obese country in the world, with more than 36% of its adult population being obese (INEGI, 2018a; OECD, 2019b).

Obesity comes with numerous negative consequences that seriously jeopardizes people's well-being and socioeconomic development. Obese people are more likely to face discrimination in the labor market through lower wages and employment prospects (Böckerman et al., 2018; Finkelstein et al., 2005; Lindeboom et al., 2010; Norton and Han, 2008). From the health perspective, obese people are also at a higher risk of developing other comorbidities such as diabetes and hypertension, which significantly reduce life expectancy and the quality of life-years (Thompson et al., 1999; Bray, 2004; Pi-Sunyer, 2002; Reilly et al., 2003; OECD, 2019b). Overall, obesity makes people more vulnerable, and hence less resilient, to shocks such as the COVID-19 pandemic.

The medical literature shows that obese patients are more likely to develop severe forms of COVID-19 if infected with SARS-CoV-2 (see for example Cai et al., 2020; Sattar et al., 2020; Simonnet et al., 2020). However, such research uses small samples of individuals (generally below a thousand observations, on average). Little research has been conducted on larger populations (e.g. covering a whole country) and with a public health perspective. Exploring the role of obesity as a potential channel to develop more severe COVID-19 is crucial for effective public policy interventions – particularly in Mexico, the second country in the world most affected by obesity and the fourth most affected by the pandemic in terms of COVID-19 deaths per capita (at the time of writing). Identifying risk factors at a larger scale is key to plan the response to COVID-19 and to prepare for future pandemics, which according to scientific research are very likely to emerge (Hughes et al., 2010; Wolfe et al., 2005). This paper is among the first to investigate the role of obesity in COVID-19 severity in Mexico (Hernández-Garduño, 2020; Denova-Gutiérrez, 2020; Bello-Chavolla et al., 2020) and to provide an estimation of the additional healthcare expenditures that it generated during the first wave of the pandemic (here defined as from 1st January 2020 to 9th August 2020).

The objective of this paper is twofold: to shed light on the role of obesity in aggravating the COVID-19 disease at the individual level, and to estimate the health expenditure costs of obesity during the first 8 months of the pandemic in Mexico. For this purpose, we make use of the rich administrative register of COVID-19 cases and deaths published daily by the Secretary of Health of Mexico. These registers contain detailed individual data on COVID-19 test results and other medical information – including comorbidities such as obesity, diabetes, asthma, and hypertension. We measure COVID-19 severity among patients tested positive by creating several dummy variables that reflect the gradual severity of the disease: developing pneumonia (without being hospitalized), developing pneumonia and being hospitalized, being admitted into an Intensive Care Unit (ICU), requiring mechanical ventilation, and or death due to COVID-19. On the side of patients' health pre-conditions, such as obesity, the variables are validated through a medical review conducted by a health professional and are transcribed as dummy variables (i.e. having or not the pre-condition).

One of the main challenges since the outbreak of the pandemic has been the limited health system capacity and resources to respond to the influx of patients (McCabe et al., 2020). One particularity of our paper is that we complement individual level data on COVID-19 with local level information such as health system capacity, socio-demographics, geographical and institutional characteristics. We use the administrative registers of health resources by medical center, published by the Secretary of Health, to measure health capacity by municipality. We also control for other elements at the municipal level that might influence the spread of COVID-19 (e.g. density and multi-dimensional poverty), including determinants of people's behaviors (e.g. educational attainment) and institutional responses (e.g. political alignment across levels of government) during the first wave of the pandemic in Mexico.

Through a series of logistic regressions, and robustness checks mitigating some endogeneity concerns, we demonstrate that obesity is a significant driver of COVID-19 severity at the individual level, even when controlling for all relevant comorbidities. Obese patients are 50% more likely to develop a severe form of COVID-19 compared to non-obese patients, on average. Furthermore, using estimation techniques, we show that the cost of obesity on the COVID-19 death toll in Mexico has been very high. Our model predicts that between 4 200 to 5 900 COVID-19 deaths could have been avoided between January and August 2020 if there

were no obesity at all in Mexico. This means that obesity is responsible from 8% to 12% of all COVID-19 deaths in the observed period. Results also suggest that obesity and its implications on COVID-19 severity stepped up healthcare expenditures by USD 220 to USD 240 million, making many families face colossal expenses and generating pressure on public health budgets since the additional costs represent around 2% of the annual budget dedicated to universal healthcare in Mexico (Gobierno de México, 2020b).

The remainder of the paper is organized as follows: Section 3.2 reviews the epidemic of obesity through its main causes and its devastating consequences for health and economic development in the world and in Mexico. Section 3.3 presents the main data we use for the analysis. Section 3.4 describes our empirical strategy and presents our findings regarding the role of obesity in aggravating the severity of COVID-19 at the individual level, while Section 3.5 delves into the additional health and healthcare costs generated by obesity during the pandemic in Mexico. It first explains the methodology we adopt to estimate these costs and then exposes our findings. Finally, the conclusions of our research are presented in Section 3.6.

3.2. Obesity and COVID-19: two intertwined epidemics

Obesity has become a major public health issue in the world over the past decades. As obesity is deeply linked to poverty and inequalities, some countries – such as Mexico – are more impacted than others. With significant consequences on health and economic development, obesity makes people more vulnerable, and hence less resilient, to shocks such as the COVID-19 pandemic. Overall, in Mexico, places with high prevalence of obesity are also being hardly hit by COVID-19. This section delves into the causes and consequences of obesity with a particular focus on Mexico and explores the linkages between obesity and the severity of COVID-19.

3.2.1. Obesity is a major public health issue across the globe

Manifestations of food insecurity are diverse (e.g. undernourishment, stunting, wasting, and obesity) and can coexist within the same country, region and even families and individuals (WHO, 2018). Among the different consequences of food insecurity, a relatively new, persistent, and fast-growing issue is that of overweight and obesity, which experienced a surge in the 1980s (see Eknayan, 2006; Monteiro et al., 2003; Pi-Sunyer, 2002). Over the past

decades, obesity has spread at a greater pace than undernutrition in most countries and is now virtually present everywhere around the globe – in high- as well as in low- and middle-income countries (Dury et al., 2019, WHO, 2018). The frequent concentration of different forms of food insecurity even within the same, region, city or area (e.g. undernutrition and obesity) tends to generate a complex burden that governments often struggle to address.

In 2017, although more than 800 million people were undernourished, around 2 billion of adults were affected by overweight or obesity, together accounting for 40% of the global adult population (WHO, 2020a; Dury et al., 2019; FAO and WHO, 2018; WHO, 2018). Regarding obesity alone, the prevalence of cases reaches 13% of all world's adults, making it an omnipresent and worldwide public health issue. While obesity has globally tripled since 1975, it has more particularly spread in the youth population of developing countries. More than 38 million children under the age of five and 340 million of adolescents are currently overweight or obese (WHO, 2020a; FAO and WHO, 2018).

The WHO defines overweight and obesity as an “abnormal or excessive fat accumulation that may impair health” (WHO, 2020a). A standard measure to identify overweight and obesity at the individual level is the Body Mass Index (BMI) (i.e. the ratio of the weight in kilograms over the square of the height in meters). For adult populations, the usual classification of BMI indicates overweight when the ratio is above 25 kg/m², and obesity when it exceeds 30 kg/m² (WHO, 2020a), while underweight appears in cases where the BMI is below 18.5 kg/m². A more precise categorization of BMI can also be adopted to differentiate moderate obesity (BMI between 30 and 35 kg/m²) from severe obesity (BMI above 35 kg/m²) (see for instance Simonnet et al, 2020).

The central cause of overweight and obesity lies in an inadequate intake of food (often due to the consumption of energy-dense foods that are highly concentrated in fat, sugar, and salt) compared to the level of physical activity (WHO, 2020a). Whereas some genetic predispositions (Pi-Sunyer, 2002), specific illnesses and certain drugs can lead to obesity, the main cause of the current obesity epidemic is the combination between unbalanced diets and the lack of adequate physical activity (Martinez, 2000). Over the last decades, the growth of the food and beverage industry coupled with the acceleration of globalization, market liberalization, urbanization, and the progress in technology across the world have considerably

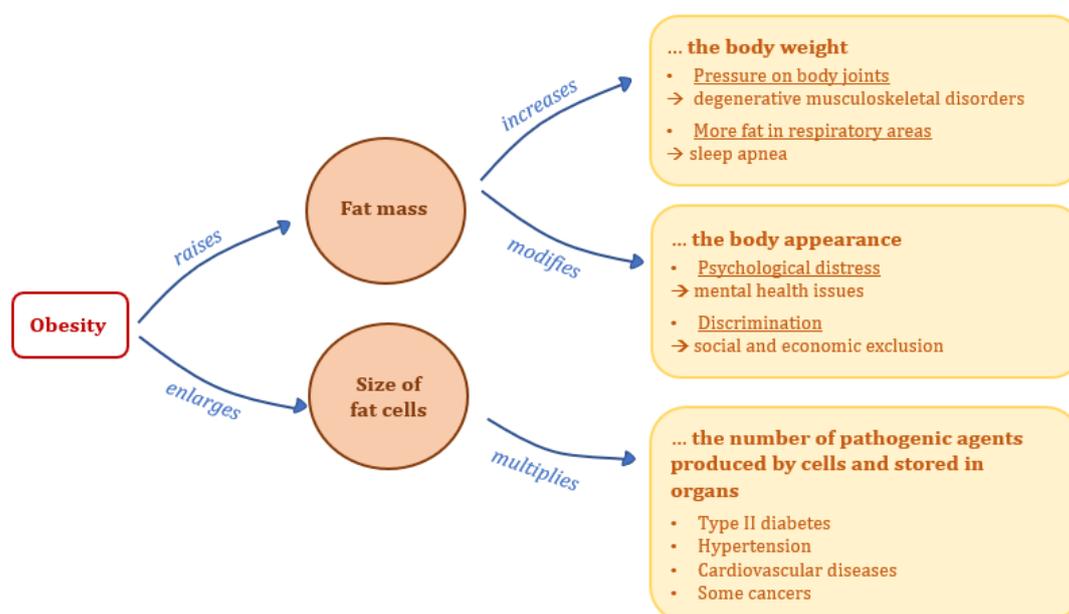
changed the way people live, work, and consume. Together, these global megatrends have reinforced sedentary and unhealthy lifestyles. They have mainstreamed the dependency on motorized modes of transport (thus reducing physical activity), while making a colossal supply of processed (and ultra-processed) food products more accessible to everyone – which are poorly nutritive (e.g. lacking micronutrients such as vitamins and minerals), cheap, and easy to prepare or even ready to consume (WHO, 2020a; Dury et al, 2019; U.S. Department of Health and Human Services, 2010; OECD, 2019b; Monteiro et al., 2013; Pi-Sunyer, 2002). With such transformations of the society, it is difficult to hold people fully accountable for the quality of their diet and other unhealthy behaviors since food choices (and particularly in developing regions) are determined by a conjunction of factors such as household budget and the food availability and supply at the local level (WHO and FAO, 2018), including the influence of the food industry’s marketing strategies. Public information campaigns and educational programs on healthy food habits are not sufficient to slow down the obesity crisis. These programs have to be coupled with an active cooperation between the food industry and the public sector to restructure products and reshape food systems across the world (Monteiro et al., 2013, OECD, 2019b).

Every year, 71% of all adult deaths worldwide are due to non-communicable diseases (NCDs) such as diabetes and cardiovascular disorders (WHO, 2020b). NCDs have become the main killers in the world (FAO and WHO, 2018; GLOPAN, 2016), and their first cause is obesity and overweight. Obesity is a chronic disease that has long-lasting and numerous consequences on health. Besides undermining the ability of the body to combat certain infections such as pneumonia and the COVID-19 (see for instance Cai et al., 2020; Stefan et al., 2020), obesity also generates specific conditions in the tissues of the body that facilitate the development of NCDs, which in turn increase the probability of a premature death and contribute to lowering life expectancy by around 3 years on average in some countries (OECD, 2019b). Dury et al. (2019) suggest that promoting healthier diets could save 11 million lives every year around the globe.

The probability of suffering from NCDs and comorbidities grows with the degree of obesity (Thompson et al., 1999) for two main medical reasons (the following explanations are from Bray, 2004 and Pi-Sunyer, 2002) (see Figure 3.1). Firstly, obesity raises the mass of fat, which transforms both the weight of the body (thus causing pressure on the body joints and

provoking degenerative musculoskeletal disorders such as osteoarthritis; and accumulating fat in the respiratory areas thus increasing the risk of sleep apnea), and the appearance of the body (thus influencing social integration and causing psychological distress). Secondly, obesity translates in an enlargement of the size of the fat cells (that compose the adipose tissue) that intensifies the number of pathogenic agents that they secrete (e.g. acids that will be stored in the liver). While certain types of secretions can trigger insulin resistance which typically leads to type 2 diabetes, other secretions can generate hypertension and cardiovascular distress. Some secretions are also associated to specific types of cancers such as breast, prostate, liver or kidney cancers, for example. Obese children suffer from similar medical consequences, not only during their childhood but also later in life, as obesity is likely to persist in the long-term and contributes to doubling the risks of a premature death in adulthood for obese children (Reilly et al., 2003; OECD, 2019b).

Figure 3.1. Main physiological reactions linking obesity to NCDs and other health issues



Sources: Authors' elaboration based on the work by Bray (2004) and Pi-Sunyer (2002).

Note: This diagram is a simplification of the physiological reactions to obesity; it is used here to help the reader picture the main mechanisms linking obesity to non-communicable diseases.

In addition to serious health issues and comorbidities, obesity is also associated to consequential economic and social inequalities (see for instance Averett, 2019; Böckerman et al., 2018; Rashad, 2003; Lindeboom et al., 2010; Norton and Han, 2008; OECD, 2019b). As

obese individuals are more likely to suffer from health complications and comorbidities such as diabetes and cardiovascular diseases, they are also more likely to face heavier healthcare expenses over their lifetime (Finkelstein et al., 2005). Such pressure on the budget is also reflected in public spending and jeopardizes the capacity of governments to solve the obesity epidemic. Projections reveal that OECD countries will have to spend almost 9% of their annual budget on health in the next 30 years if they want to address the growing issue of obesity and the comorbidities that are associated to it, which represent around USD 400 billion (American dollar) every year (OECD, 2019b).

Beyond the load of potential higher health expenses for obese people, overweight and obesity also come along with significant discrimination on the labor market, especially for women (Rashad, 2003; Lindeboom et al., 2010) – which also relates to healthcare coverage and poverty levels among obese people, particularly when quality healthcare depends on having a formal job (the case of Mexico). A large stream of the labor market literature has highlighted a strong and negative correlation between obesity and labor market outcomes, despite mild evidence regarding the direction of the causality. In general, obesity is associated with lower levels of wages, lower probability of employment, longer periods of unemployment, and fewer chances to occupy a managerial position (Böckerman et al., 2018; Finkelstein et al., 2005; Lindeboom et al., 2010; Norton and Han, 2008). When experienced during childhood, obesity typically affects the formation of human capital because of several social and inclusion factors, which directly jeopardize the capabilities of individuals to integrate the labor market later in life, and thus their lifelong income and their well-being (OECD, 2019b). All economic, health and social consequences of obesity experienced at the individual level, aggregate themselves at the level of the whole society undermining labor productivity and the economic growth potential.

The burden of obesity in Mexico

Although the epidemic of obesity and its related diseases have spread at an impressive pace across the planet during the past decades, populations living in the Americas – and more particularly in the United States and in Mexico – have been the most affected. In the Americas region, 62% and 26% of the population were respectively overweight and obese in 2015, rates

that are significantly more alarming than that of other regions such as Asia, where obesity rates average 5% (OPS-WHO, 2015; OECD, 2019b; Ramachandran et al., 2012).

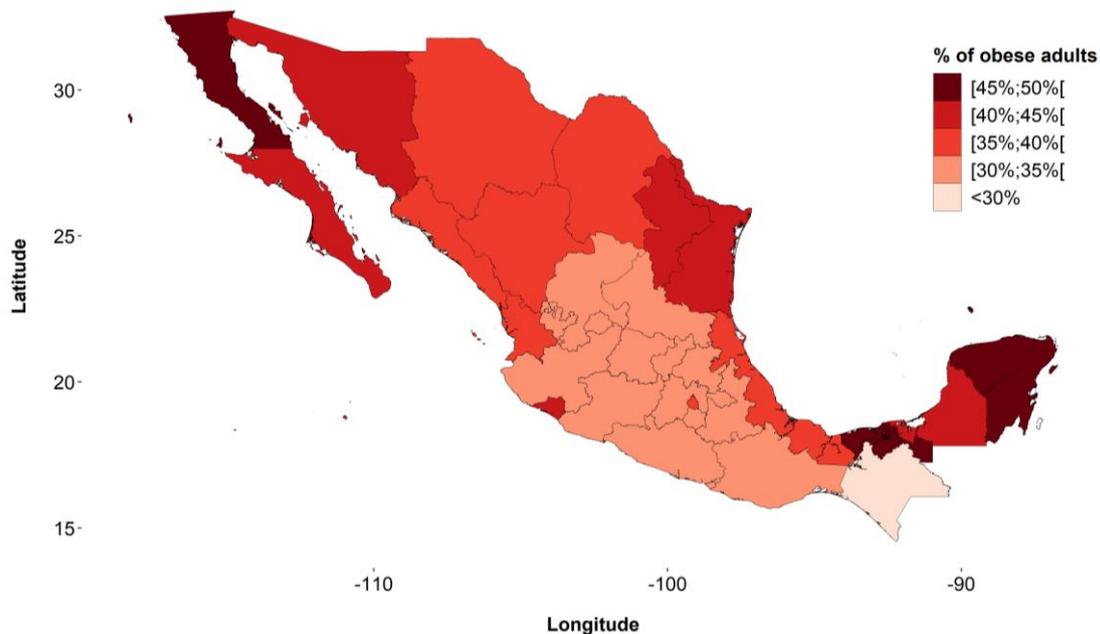
Mexico and the United States (US) are the countries most concerned with overweight and obesity in the world. While the United States record the highest rate of adult obesity, Mexico registers the second highest rate, and suffers from the fourth largest prevalence of child obesity (Dávila-Torres et al., 2015; Gobierno Federal, 2010). Overall, around 8 out of 10 adults in Mexico are either overweight or obese. More precisely, in 2018, 73% of the Mexican population were at least overweight and 36% were obese (OECD, 2019b).

The rise of the obesity epidemic in Mexico has been considerable, with a gain of more than four percentage points in overweight and obesity rates within only six years (2012-2018) (INEGI et al., 2018). Yet, obesity has spread unevenly within the Mexican population as it has been disproportionately affecting certain vulnerable groups, to mirror preexisting social and educational inequalities (INEGI et al., 2018; OECD, 2017a). Such as in most of the middle- and high-income countries, women are significantly more affected by obesity than men are. In Mexico, 40.2% of women are obese, whereas obesity is a condition for 30.5% of men. What is more, while obesity rates for children under the age of 5 have remained stable for several years (around the 8%), adolescents are being outstandingly hit by the disease. The prevalence of obesity among the 12-19 years-old has soared so that it now surpasses obesity rates in adults – close to 39% of all adolescents were obese in 2018.

All Mexican states carry the burden of obesity and overweight; nevertheless, some places are more impacted than others (see Figure 3.2). Close to 20 percentage points pull the least obese regions of Mexico (i.e. states) apart from the most obese ones. The states of Quintana Roo in the southeast and Baja California in the northwest (with close ties with North American markets and tourism) both register the highest prevalence in adult obesity with almost half of all adults being obese in 2018. On the other hand, Chiapas in the south and Guanajuato in the center of the country are the states least affected in relative terms, with around 30% of their adult population suffering from obesity (INEGI, 2018a). At a more granular level, cities and urban areas, as well as some places that share a border or close ties with the US tend to be more at risk of obesity, due to their level of urbanization, their integration in globalization and their

exposure to the influence of the US food markets (INEGI et al., 2018; OECD, 2019b; Gobierno de México, 2019; Rivera et al., 2002).

Figure 3.2. Obesity rates by Mexican state (2018)



Source: Authors 'elaboration based on INEGI (2018a), "Indicadores de Bienestar por entidad federativa" (database), <https://www.inegi.org.mx/app/bienestar/#grafica>.

For several decades, Mexico has experienced important structural changes that have gradually modified the way people eat (Rtveladze et al., 2014). Societal and economic transformations such as the intensification of urbanization and the growing integration of the country into international trade have contributed to the highly obesogenic environment in which the Mexican population is trapped today (Dávila-Torres et al., 2015; Gobierno Federal, 2010). The massive industrialization of food production lowered the prices of processed foods while raising the relative prices of more healthy products such as vegetables. Despite important economic progress, poverty levels are still high in many parts of the country and average levels of GDP per capita are typically low (World Bank, 2020). Such conditions favored the adoption of less expensive diets, therefore based on ultra-processed foods that are highly concentrated in fat and sugar. Mexico is the first consumer of refined carbohydrates and sodas – every person consumes 214 kg of processed foods on average every year (Gobierno de México, 2019; INEGI, 2018a). Sweetened beverages alone account for more than 70% of all calories in an average diet in Mexico (Barrientos-Gutierrez et al., 2016). These products have become the main cause

of malnutrition in the country and are closely associated to many cardiovascular diseases and related mortality (Rivera et al., 2002).

Obesity is an important risk factor for the development of comorbidities such as diabetes, hypertension, and cardiovascular disorders (Thompson et al., 1999; Bray, 2004; Pi-Sunyer, 2002). In Mexico, the surge in overweight and obesity triggered a remarkable rise in NCDs that are now the most important cause of deaths across the country – 75% of all deaths are a consequence of NCDs and obesity (Rtveladze et al., 2012; Rivera et al., 2002). While as high as 18.4% of the population suffer from hypertension, on average, more than 10% (i.e. 9 million people) have diabetes, which is directly linked to obesity – among all cases of diabetes in Mexico, 90% are due to a state of overweight (INEGI, 2018a; Gobierno Federal, 2010). Just as obesity, NCDs affect relatively more women than men, and mostly prevail in the northern states (or closer to the US), where obesity rates tend to be higher (INEGI, 2018a). Consequences of obesity are multiple and far-reaching. If obesity continues rising, the prevalence of NCDs in the Mexican population will double by 2050 and will lower life expectancy by around 4 years before 2030 (OECD, 2019b; Rtveladze et al., 2012). On the other hand, substantial improvements in well-being and health could be attained rapidly since even small reductions in obesity and overweight rates could save millions of lives in the near future (Rtveladze et al., 2012). On top of numerous consequences on health and well-being, the epidemic of obesity is also hampering economic development in Mexico as it captures a significant share of public spending – more than 33% of total public health expenditure are generally allocated each year in health services to address NCDs caused by obesity and their complications (Rivera Dommarco et al., 2018; Rtveladze et al., 2012).

More than being a simple result of individual choices, obesity arises from a complex convergence of economic and societal factors. Poverty, inequality in access to quality food products, quest for excessive profit in the food industry, massive advertising of unhealthy foods, as well as reductions in free time due to working long hours are some examples of social constraints that push people into adopting lower quality diets and sedentary lifestyles. Therefore, reducing the prevalence of obesity and overweight is not only a question of self-motivation, but rather requires the joint efforts of food producers, consumers, and governments.

In Mexico, despite the implementation of a few policies that proved influencing the consumption of ultra-processed food products, a stronger involvement of the public sector into the fight against obesity is needed if the country wants to halt the obesity epidemic. One important step in Mexico's journey towards less obesity is the implementation in 2014 of an excise tax on sugar-sweetened beverages. At that time, consumers faced an increase of 1 peso per liter, representing a rise by 10% in the price of these products. Colchero et al. (2016) found that the policy successfully reduced the consumption of beverages containing added-sugar – which are the main source of excessive calorie consumption in Mexico – and more particularly among less privileged households that decreased their purchase by 9% on average. Such changes in behaviors could translate into a diminution by 2.5% in the prevalence of obesity by 2025 and could potentially prevent around 100 cases of diabetes (Barrientos-Gutierrez et al., 2017). Other public interventions to combat obesity included the obligation for producers to labelling food products on the front of the packaging, as well as mass media information campaigns to encourage people into eating at least five fruits and vegetables every day. While public interventions in the health sector are essential to address obesity and its consequences, transversal policies are also key to develop comprehensive solutions. In Mexico City for instance, a public program financed to build cycling lanes in order to fight climate change and pollution is also helping reduce overweight as it favors physical activity (OECD, 2019b).

Further public policies have yet to be designed in Mexico to address the massive health and economic challenges posed by obesity and overweight, especially as this physical condition is an important risk factor to developing other life-threatening diseases, including severe illness from COVID-19.

3.2.2. Obesity as an independent risk factor for severe forms of COVID-19

Beyond patients' age (see Lighter et al., 2020) or income, there is growing evidence suggesting that comorbidities, and particularly obesity, are critical determinants of COVID-19 severity (see Hernandez-Garduño, 2020; Bello-Chavolla et al., 2020; Cai et al., 2020; Caussy et al., 2020; Dietz and Santos-Burgoa, 2020; Gao et al., 2020; Lighter et al., 2020; Petrilli et al., 2020; Sattar et al., 2020; Simonnet et al., 2020). Early in the pandemic, medical research had highlighted that the elderly, as well as people with pre-existing health conditions such as diabetes, hypertension, and cardiovascular or chronic respiratory diseases, were at higher risks

of developing complications due to the COVID-19 (see for instance Wang et al., 2020; Mueller et al., 2020; Holman et al., 2020; Mehra et al., 2020; Richardson et al., 2020; Gallo Marin et al., 2020). Beyond such factors, new research is now demonstrating that obesity *per se* is also a major – and independent – risk factor for severe forms of COVID-19, including death. Lighter et al. (2020) highlighted that the elderly were not the only groups at high risk of complications and mortality from the COVID-19 in New York City. They discovered that even at a younger age (all ages below 60), patients with a high Body Mass Index (BMI) were 3 times more likely to be admitted in the Intensive Care Unit (ICU) for complications of the COVID-19 compared to non-obese people from the same age range.

New epidemiological literature suggests that being obese has a unique effect in COVID-19 severity and mortality. This goes beyond the fact that obesity increases the risk of other comorbidities (such as diabetes, hypertension, and cardiovascular diseases) that also relate to COVID-19 complications (WHO, 2020b; Sattar et al., 2020; Cai et al., 2020) – an indirect channel through which obesity also impacts COVID-19 severity. For instance, with data from patients (COVID-19 and non-COVID-19) from a hospital in France, Simonnet et al. (2020) show that obesity is an important determinant of COVID-19 complications such as the admission into Intensive Care Unit (ICU) and the need for invasive mechanical ventilation (also referred to as ‘ventilation’), independently from age and other comorbidities such as hypertension or diabetes. The severity of the symptoms increases with the patients’ Body Mass Index (BMI). While 90% of the COVID-19 patients having a BMI superior to 35 kg/m² required invasive ventilation, the authors do not find a large prevalence of obesity in the non-COVID-19 patients having to enter the ICU. Another study in France reveals that people with a BMI superior to 35 kg/m² have seven times more risks to be admitted into ICU for COVID-19 complications compared to non-obese people affected by the COVID-19 (Sattar et al., 2020). Similarly, Gao et al. (2020), by applying a matching technique on data from obese and non-obese patients of a hospital in China, show that the risk of developing severe forms of COVID-19 is three times larger for obese people compared to non-obese, after controlling for gender, age, diabetes, hypertension, and smoking habits, among others. Cai et al. (2020) demonstrate that obesity in itself plays a unique role in shaping the symptoms of COVID-19 in Chinese men patients and show that comorbidities related to obesity (e.g. diabetes, hypertension) only mediated a small part (3%) of the effect of obesity. Using Mexican data,

Denova-Gutiérrez et al. (2020) find that obese patients infected by the SARS-CoV-2 have around 1.4 times more risk to be admitted into ICU and to need mechanical ventilation than non-obese patients. Comparing the role of obesity and diabetes, Bello-Chavolla et al. (2020) show that while both are crucial risk factors, obesity explains almost 50% of the impact of diabetes on the risk of death from COVID-19.

Although the metabolic mechanisms explaining the reasons why obesity is a predisposition factor to severe forms of COVID-19 are still under medical study, previous research suggests that obesity generally jeopardizes individuals' immune response to certain health shocks. For instance, broad research documented that obesity was a predisposition to severe H1N1 infection during the 2009 pandemic (van Kerkhove et al., 2011), and that it typically favors the risk of severe forms pneumonia (Cai et al., 2020; Stefan et al., 2020).

Despite being associated to greater cardiovascular risks (e.g. diabetes, hypertension, insulin resistance, see Stefan et al., 2020) that mediate the impact of obesity on the severity of COVID-19, obesity is also directly responsible for a weakening of the respiratory mechanism. Adiposity forces the body to utilize a significantly larger share (compared to non-obese individuals) of the body oxygen for the functioning of the respiration in the every-day life. Obese people thus have a diminished lung volume capacity and a reduced strength in their respiratory muscles to combat pulmonary infections – even of mild intensity (Sattar et al., 2020; Simonnet et al., 2020; Cai et al., 2020; see Stefan et al., 2020 for a detailed explanation of the potential medical mechanisms). Such predispositions of obese people to respiratory problems may be among the main causes for the more acute symptoms of COVID-19 observed in obese patients.

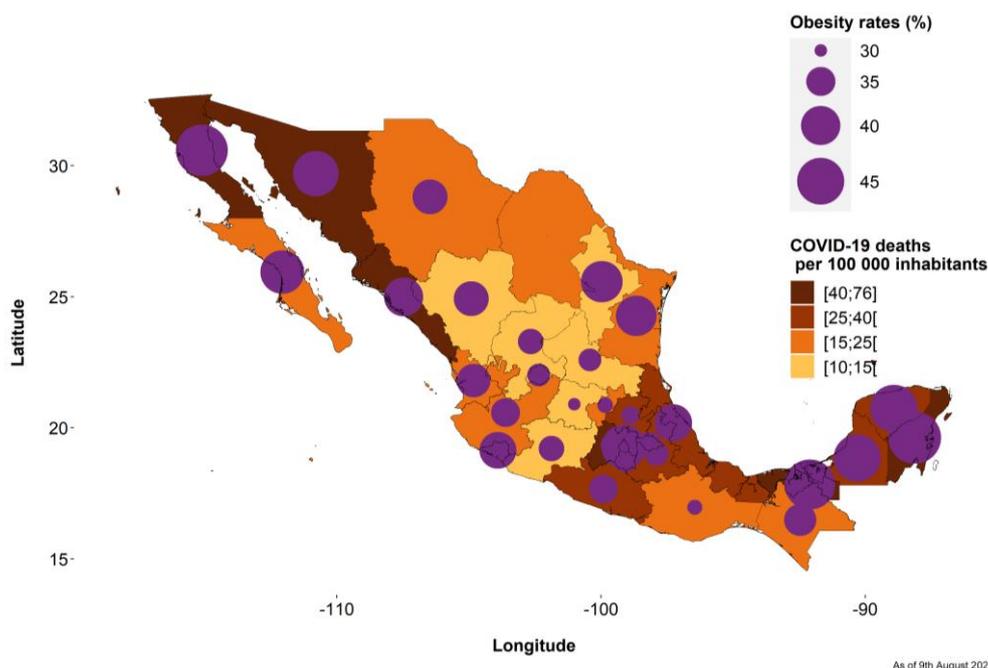
3.2.3. The COVID-19 pandemic in Mexico and its repercussions

Countries that record high levels of inequalities and rampant obesity are also among the most affected by the COVID-19 pandemic in terms of deaths per inhabitant. Whereas Mexico is the fourth country in terms of COVID-19 deaths per 100 000 people, the United States ranks first. At the time of writing, more than 480 000 cases of COVID-19 were registered in Mexico (although testing was very limited), and around 52 000 people have died from the disease (by 9th August 2020). In the US, deaths and deaths per inhabitant have surpassed all other countries,

with 4 million cases and above 145 000 deaths (Gobierno de México, 2020a; Center for Disease Control and Prevention, 2020).

Within countries, sub-national regions are also unequally impacted by the virus. The literature shows that cities and urbanized regions, as well as poor, unequal, densely populated areas, and places with high levels of obesity are among the most vulnerable in the face of the pandemic (OECD, 2020a; Arif and Sengupta, 2020; Coro, 2020; Rubin et al., 2020; Baser, 2021; Patel et al., 2020; Wright et al., 2020). In Mexico, states with higher obesity rates tend to be hit harder by COVID-19 (see Figure 3.3). The states of Baja California, Tabasco, and Sinaloa, as well as Mexico City, record the highest rates of COVID-19 deaths, with more than 60 deaths per 100 000 people (Secretaría de Salud, 2020). While many factors contribute to these results (e.g. limited public health resources and high informality; Baja California's border with the United States; or Mexico City's high population density and urban poverty levels), these states are also among the most obese in Mexico, with obesity rates that exceed 40% on average (INEGI, 2018a).

Figure 3.3. COVID-19 deaths and obesity rates by Mexican state



Sources: Authors' elaboration based on data from Secretaría de Salud (2020), Datos abiertos - Información referente a casos de COVID-19 en México (database), available at: <https://datos.gob.mx/busca/dataset/informacion-referente-a-casos-COVID-19-en-mexico> ; and INEI(2018a), "Indicadores de Bienestar por entidad federativa" (database), <https://www.inegi.org.mx/app/bienestar/#grafica>.

In Mexico, in addition to higher mortality rates, the COVID-19 pandemic has also engendered a major socioeconomic crisis. Due to the international economic slowdown and a large share of the Mexican population being affected by the virus, the country has been experiencing a significant decrease in its economic activity. The International Monetary Fund (IMF) estimates that Mexico's GDP dropped by 10.5% in 2020 (IMF, 2020). More importantly, the crisis has seriously impacted people's lives and well-being. The National Institute of Statistics and Geography (INEGI) estimates that more than 20% of the active population have lost their job because of the pandemic, and around 65% have seen a significant reduction in their income (INEGI, 2020b), leading to an estimate of new 8 million people into poverty (Lustig et al., 2020). In Mexico, more than 60% of the adult population work in the informal sector (INEGI, 2020a) with limited social security or unemployment benefits, which made it impossible to adopt strong lockdowns and social distancing measures. Around 70% of the population has kept commuting to work as usual (INEGI, 2020b), which has nurtured the propagation of the virus and kept adding pressure on medical resources and health expenditures. Consequently, COVID-19 has had a greater impact on the economically vulnerable population who cannot afford to stay home and who tends to suffer more from health issues such as obesity and diabetes. Because it has reduced employment and household income, the pandemic has also increased the prevalence of food insecurity across the country. Gaitán-Rossi et al. (2020) show that since the outbreak of the COVID-19 crisis, Mexican households have more frequently lacked resources to buy food and have consumed cheaper, lower-quality products, both less diverse and less nutritional. The economic, social, and health consequences of the COVID-19 pandemic tend to be exacerbated in Mexico as a large share of the population presents crucial risk factors to the disease (notably obesity and diabetes). What is more, the financial support provided by the government to households and businesses has been moderate and proved insufficient to allow people to stay safely at home. On average, the government has spent only 1.1% of the GDP in the fiscal stimulus package, well below the average of 10% that prevails in the rest of the world (Hannan et al., 2020).

3.3. Data

3.3.1. Main sources of data

To facilitate research on the current COVID-19 pandemic, the Mexican Secretary of Health has given open access to the administrative register of all COVID-19 cases and deaths that have been counted since the first contaminations in Mexico in January 2020. As the register gathers rich individual information – including obesity status – we exploit this database to investigate the role that this form of food insecurity, compared to other comorbidities, plays in the severity of the symptoms of COVID-19. By using supplementary databases about medical capacity at the local level and the costs of hospitalization, we also explore the economic repercussions of obesity as a public health issue during the pandemic. The main sources of data used in this paper are listed below:

- *The administrative register of COVID-19 cases and deaths in Mexico*³² (“Información referente a casos COVID-19 en México”), published by the Secretary of Health (version used in the chapter: 9th August 2020);
- *The administrative register of health resources by medical center in 2018* (“Recursos en Salud, nivel central”), from the Secretary of Health³³;
- *Indicators to measure poverty at the municipal level in 2010 and 2015*³⁴ (“Pobreza a nivel municipio 2010 y 2015”), developed by the National Council for the Evaluation of Social Development Policy (CONEVAL).
- *Unit costs of healthcare services 2020*³⁵ (“Costos Unitarios por Nivel de Atención Médica 2020”), reported by the Mexican Social Security Institute (IMSS) in the Official Journal.

³² Secretaría de Salud (2020), “Datos abiertos - Información referente a casos de COVID-19 en México”, available at: <https://datos.gob.mx/busca/dataset/informacion-referente-a-casos-COVID-19-en-mexico>.

³³ Secretaría de Salud (2018), “Recursos en salud, nivel central”, available at: <https://datos.gob.mx/busca/dataset/recursos-en-salud-nivel-central>.

³⁴ CONEVAL (2015), “Pobreza a nivel municipio 2010 y 2015”, available at: https://www.coneval.org.mx/Medicion/Paginas/AE_pobreza_municipal.aspx.

³⁵ IMSS (2019), “Costos Unitarios por Nivel de Atención Médica actualizados en el año 2020”, *Diario Oficial de la Federación, Acuerdo AS3.HCT.271119/329.P.DF*, 30th December 2019.

The administrative register of COVID-19 cases and deaths is updated daily and provides very detailed information about each patient across Mexico that was tested for COVID-19 in a medical center or a hospital between January 1st and August 9th 2020. The register presents data such as age, gender, municipality of residence of each patient, as well as their medical records for comorbidities (e.g. diabetes, chronic respiratory diseases), including obesity. The database also includes the type of medical center or hospital visited (i.e. public or not), and the date of death if applicable. As of 9th August 2020, 480 278 persons had been tested positive to COVID-19 in a medical center or hospital, which constitute our baseline sample.

The following two databases provide contextual – and very granular – information about hospital capacity and poverty by municipality. The register of health resources – also released to the public to help research and policy responses about COVID-19 – offers exhaustive and valuable data at the hospital level regarding their location, medical staff, and resource capacity, including hospital beds, among others. It contains around 22 500 medical centers, located across all 32 states of Mexico. While the health resources database allows us to control for health system capacity before and at the beginning of the outbreak, the CONEVAL database provides key multidimensional poverty indicators at the municipal level.

The database on unit costs of healthcare services reports the official estimations (by the IMSS) of the average hospitalization unit costs in Mexico for the year 2020, the costs are further disaggregated by type of service (e.g. doctor’s visit, diagnostic tests, surgery, use of bed per day).

3.3.2. Measuring COVID-19 severity

The severity of the symptoms of the COVID-19 varies widely across patients. Some patients are asymptomatic or have mild symptoms (e.g. temporarily losing the senses of smell and taste or being fatigued), while others experience more severe symptoms such as fever, cough, breathing problems and acute pneumonia (Institut Pasteur, 2020). The severity of the symptoms translates into the type of care required to treat the patients. While those with mild symptoms can return home after visiting a medical center, people with severe symptoms must be hospitalized. As the register of COVID-19 cases and deaths gives access to vast information regarding the type of care given to the patients (e.g. admitted to the hospital, being intubated,

entering an ICU), this paper measures the severity of the COVID-19 through the combination of both the medical attention given to the patients and some specific symptoms they experience.

Following the epidemiological and economic literature that seizes the progression of the disease at the individual level (see for instance Cai et al., 2020; Lighter et al., 2020), we create dummy variables for each of the following events, that we argue mirror the different degrees of severity of the disease (see for instance Simonnet et al., 2020):

- Were the patients who were tested positive to COVID-19 diagnosed with pneumonia? (event described by the variable *pneumonia*),
- Were they admitted to the hospital? (variable *hospital*),
- If so, did they enter the Intensive Care Unit (ICU)? (variable *icu*),
- Did they require invasive mechanical ventilation after their admission in the ICU (hereafter also referred to as intubation or ventilation)? (variable *intubation*),
- Did the patients die from the consequences of COVID-19 (variable *death*)?

Besides considering each of these events separately, we also construct a categorical variable (*severity*) that gathers the degrees of severity into seven categories, from the lightest expression of COVID-19 (tested positive but asymptomatic) to death (Table 3.1).

Table 3.1. Construction of the categorical variable *severity*

<i>severity</i>	COVID-19 positive	Pneumonia	Hospitalization	ICU	Mechanical ventilation	Death
Category 1	Yes	No	No	No	No	No
Category 2	Yes	Yes	No	No	No	No
Category 3	Yes	No	Yes	No	No	No
Category 4	Yes	Yes	Yes	No	No	No
Category 5	Yes	Yes or No	Yes	Yes	No	No
Category 6	Yes	Yes or No	Yes	Yes	Yes	No
Category 7	Yes	Yes or No	Yes or No	Yes or No	Yes or No	Yes

3.3.3. Explanatory variables: obesity and other determinants of COVID-19 severity

The literature suggests that food insecurity – and more specifically under the form of obesity – is an important factor of COVID-19 severity. In addition to being a risk factor in the current pandemic, obesity is also a constant threat to people’s health and well-being, and an

obstacle to their social and economic integration. In this chapter, as we are interested in testing the unique role of obesity in the probability of COVID-19 severity, the main variable of interest is a dummy that indicated individuals' obesity status. Data come from the administrative register of COVID-19 cases and deaths that classifies patients as obese if their BMI is superior to 30 kg/m². It is worth noting that the database does not provide the detailed BMI information, therefore we are not able to study the marginal effect of BMI on COVID-19 severity.

Investigating the impact of obesity on the probability to develop severe forms of COVID-19 requires controlling for individual characteristics that can also influence the capacity of the body to combat the disease, such as age and comorbidities (Wang et al., 2020; Mueller et al., 2020; Holman et al., 2020; Mehra et al., 2020). As the administrative register of COVID-19 cases includes key information at the patient level regarding their medical history, we are able to control – in the form of dummy variables – for the presence of diabetes, hypertension, cardiovascular diseases, respiratory diseases, asthma, immunosuppression, chronic renal disease, and other comorbidities. We complement these controls by adding the age of the patient, as it is also a major determinant of severity and death, as well as gender and pregnancy status.

Beyond comorbidities, other individual characteristics can also determine COVID-19 severity, including the patients' social and economic situation that may constrain early access to health services and thus influence the evolution of the disease (Patel et al., 2020). The database on COVID-19 in Mexico provides individual data on the ethnic origins of the patients (i.e. if they are Indigenous or not), as well as proxies for the type of sector in which they are working (i.e. formal or informal) – these two measures give an indication on the socioeconomic status of the patients (Hauser, 1994; Darin-Mattsson et al., 2017). The variable that allows inferring informality status comes from the type of healthcare and hospitals the patients typically have access to – and where they were tested and or received care for COVID-19. Those can be a private hospital, a public hospital accessible to formal workers (e.g. IMSS or ISSSTE), or a public hospital for people typically working in the informal sector (i.e. INSABI, previously Seguro Popular) – who before the creation of Seguro Popular or INSABI would not have any type of healthcare service. Since informal workers do not benefit from extensive social protection, they are more at risk of poverty and are more likely to be affected by COVID-19 (Narula, 2020). A striking example of their vulnerability could be observed during confinement

measures. Informal workers, who do not have paid sick leave, unemployment benefits and any job security, could not afford to stay home during critical moments of the pandemic, which increased their exposure and risk of infection.

The database on COVID-19 in Mexico does not provide specific information on the economic status of the individuals. However, we include variables that control for the economic environment of each patient (i.e. material conditions, educational attainment). People with higher socio-economic status tend to better trust experts' recommendations and develop more knowledge on the pandemic, while they also adopt less risky behaviors, notably thanks to the type of jobs they have (that can easily be adapted to teleworking) (Díaz Ramírez and Veneri, forthcoming; Zhong et al., 2020; Ajzenman et al., 2020; OECD, 2020c). From the indicators of poverty developed by CONEVAL, we obtain the percentage of people living under the poverty line in each municipality across the country in the year 2015 (more than 2 400 municipalities), as well as complementary measures of poverty that could also explain the spread of the virus and the infection rate, and thus account for the risk of death at the local level. These indicators include the percentage of people living without social security, the percentage of people living without sufficient space in their house, and the percentage of people with low levels of education.

While medical literature papers tend to restrict their analysis to health variables at the patient's level, this chapter aims at providing evidence by adopting a more holistic approach, which also includes other economic, social and political variables at both the individual and place-based level (e.g. municipalities and states). Past public policy decisions regarding the health sector, but also social, political and economic aspects, revealed to be key in the response to the crisis, including the management of medical resources and hospital capacity (e.g. ICU beds and ventilators), which are essential to reduce COVID-19 fatality (Moghadas et al., 2020; COVID-19 APHP-Universities-INRIA-INSERM Group, 2020; COVID-19 APHP Group, 2020).

Since the beginning of the pandemic, countries around the world have been trying to flatten the curve of infections to reduce the pressure on health workers and hospitals and to avoid being in the situation where doctors would have to choose between patients to cure due to lack of beds and other medical resources. In places where medical resources are limited and

where it is more difficult to cope with the soaring number of cases, the probability of dying from COVID-19 is significantly higher (Wood et al., 2020). In this sense, controlling for medical capacity at the local level is essential for our analysis. The administrative register of health resources published by the Secretary of Health provides detailed information on medical resources available in each hospital and medical center across the country, be they public or private. We aggregate these data at the municipal level to match them with the place of residence of each patient tested positive to the COVID-19. We construct control variables for local medical capacity that are relevant to tackle the COVID-19 pandemic. In particular, the database allows us to estimate – at the municipal level – the number of hospitals, doctors, hospital beds, and ICU beds per capita.

As the virus spreads through human’s respiratory droplets, it is more likely to get infected in areas where people are closer to each other (and where social distancing measures are more difficult to meet). For this reason, we also control for population density in the municipality of residence, a potential driver of higher infection rates (Carozzi, 2020; Rashed et al., 2020), everything else being equal³⁶. Areas of high population density are prone to a strong circulation of the virus, which induces a greater pressure on hospital resources, *ceteris paribus*, and thus increases the risk of death (Stier et al., 2020; Díaz Ramírez and Veneri, forthcoming). We compute municipal population density using population data from the National Institute for Federalism and Municipal Development (2015) and municipal surface area from municipal administration divisions shapefiles of the INEGI (2018b).

Recent studies also highlight the role of exposure to air pollution (and in particular to fine particulate matter PM_{2.5}) in aggravating COVID-19 spread and mortality (Comunian et al., 2020; Cocker et al., 2020; Wu et al., 2020b; Díaz Ramírez and Veneri, forthcoming). In our model, we do not control for air pollution at the municipal level as we already control for respiratory and cardiovascular diseases at the individual level (which would among the main channels through which air pollution relates to COVID-19 severity). In addition, our analysis includes population density, which is also highly correlated with exposure to air pollution.

³⁶ Since testing for COVID-19 is not systematic in Mexico (Fowler et al., 2020), we do not include the infection rate at the municipal level, a measure likely to be highly biased.

Finally, we also control for state political alignment with the national government, using the results of the last federal elections (Arista and Badillo, 2019) to create a dummy variable indicating 1 if the state of residence follows the presidential party MORENA. New evidence suggests that multi-level governance (many times associated to political alignment), including coordinated responses across levels of government, is also key to cope with the spread of the virus. In the case of Mexico, there are many examples of the federal and state governments following and communicating different strategies (Infobae, 2020), which is a source of weaker and less effective responses as a country, and of differentiated results across space.

3.3.4. Descriptive statistics: obesity and COVID-19 severity in Mexico

Our statistics on the characteristics of COVID-19 patients in Mexico (those who tested positive) align with what the literature has found until now. Table 3.2 shows that men are slightly more vulnerable to the virus than women (53% of COVID-19 patients are men), and that adults and older people are more affected than younger population groups (the average age of the patients in Mexico is 45). Suffering from additional diseases is also a frequent characteristic – in Mexico, 20% of all COVID-19 patients have hypertension, close to 19% are obese, and 16% have diabetes. The prevalence of people suffering from a cardiovascular disease is relatively low among COVID-19 patients (2%), as found in other studies (see for instance Denova-Gutiérrez et al., 2020). Additionally, we observe that almost 60% of the patients infected by the virus have visited a public hospital that accepts uninsured patients (i.e. informal workers), which suggests that most people with COVID-19 evolves in an informal work environment and belongs to modest socioeconomic groups.

Table 3.2. Summary statistics of COVID-19 patients in Mexico (as of 9th of August 2020)

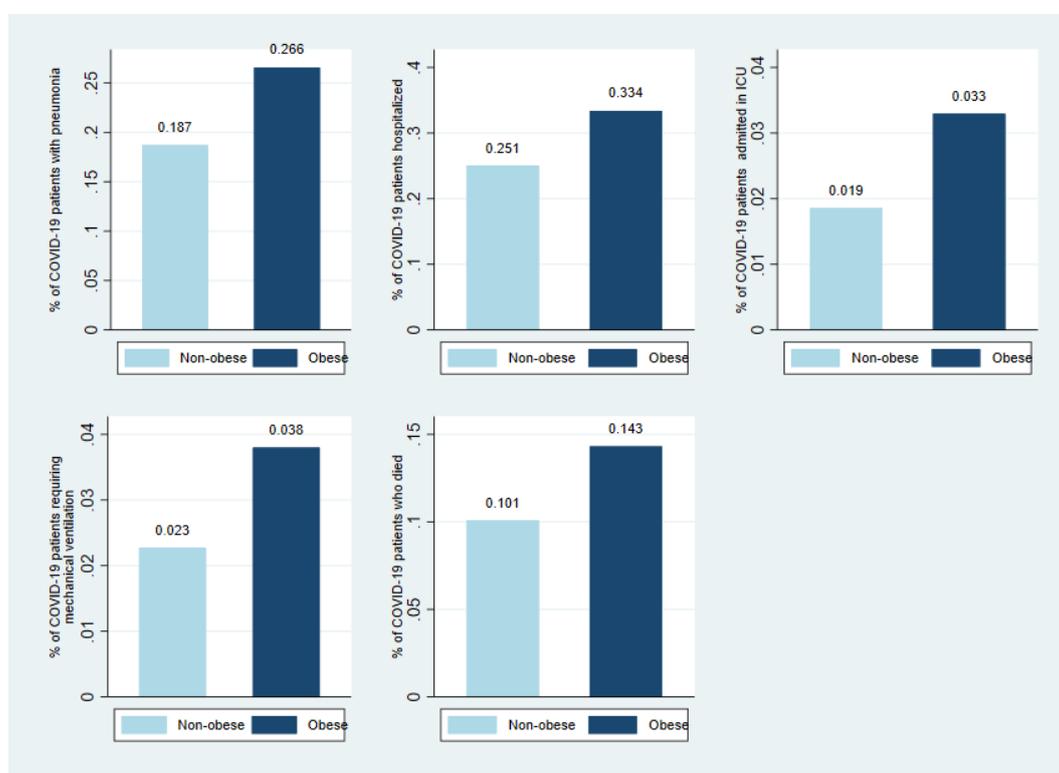
	Variables	mean	sd	min	max
COVID-19 severity	Pneumonia	20.2	0.401	0	1
	Hospitalized	26.6	0.442	0	1
	ICU	2.1	0.144	0	1
	Mechanical ventilation	2.6	0.158	0	1
	Death	10.9	0.312	0	1
Comorbidities	Obesity	18.7	0.390	0	1
	Diabetes	15.9	0.366	0	1
	Hypertension	19.8	0.398	0	1
	Cardiovascular diseases	2.1	0.143	0	1
	Respiratory diseases	1.5	0.123	0	1
	Asthma	2.7	0.161	0	1
	Immunosuppression	1.2	0.108	0	1
	Chronic renal disease	2.0	0.139	0	1
Other comorbidities	2.5	0.157	0	1	
Other individual characteristics	Age*	45.2	16.503	0	118
	Woman	47.0	0.499	0	1
	Indigenous	1.0	0.102	0	1
	Public hospital, formal workers	39.0	0.488	0	1
	Public hospital, informal workers	58.0	0.494	0	1
	Private hospital	3.0	0.170	0	1
	University hospital	0.1	0.025	0	1
<i>Number of observations</i>		480278			

Note: *Age is a continuous variable, its mean indicates that on average the sample is 45.2 years old.

Sources: Secretaría de Salud (2020), Datos abiertos - Información referente a casos de COVID-19 en México (database), available at: <https://datos.gob.mx/busca/dataset/informacion-referente-a-casos-covid-19-en-mexico> (version 9th August 2020).

The prevalence of COVID-19 severity by stage, among obese and non-obese people is depicted in Figure 3.4. It is clear – and confirmed by the statistical tests in Annex 3.A – that the probability of developing severe symptoms is higher for obese people (relative to non-obese) across all the available categories (i.e. pneumonia, hospitalization, ICU, mechanical ventilation and death). For instance, while 25% of non-obese people with COVID-19 were also admitted at the hospital, this is the case for 33% of obese people with COVID-19. The same pattern holds even in more severe and less frequent stages. For example, around 4% of obese patients require invasive mechanical ventilation, two times more than non-obese patients.

Figure 3.4. Prevalence of COVID-19 severity among obese and non-obese patients



Source: Secretaría de Salud (2020), Datos abiertos - Información referente a casos de COVID-19 en México (database), available at: <https://datos.gob.mx/busca/dataset/informacion-referente-a-casos-covid-19-en-mexico> (version 9th August 2020).

Mexico faced the beginning of the outbreak of COVID-19 with relatively low medical equipment and infrastructure (Parr, 2020; Fowler et al., 2020; Olivera et al., 2020) but benefitted from a skilled float of doctors and caregivers. While there are on average 220 doctors by municipality across the country, in many municipalities there is no hospital, and there is an average of two hospital beds by municipality (Table 3.3). The number of beds and physicians per capita in Mexico is among the lowest in the OECD and in the world with 1 hospital beds per 1 000 people on average and 1.6 physicians per 1 000 people (OECD, 2017b; Parr, 2020). As a comparison, the OECD average amounts to 8.6 hospital beds per every 1 000 people (OECD, 2020a). Coping with the sudden and massive influx of patients has been extremely challenging around the world. However, it is important to recognize that some countries and regions were less prepared than others; either by their health resources and capacity or the pre-existing health conditions of their population, among other factors (OECD, 2020a; Gallo Marin et al., 2020).

Table 3.3. Characteristics of municipalities in Mexico

	Variables	mean	sd	min	max
Multidimensional poverty (2015)	Poverty (% inhabitants)	65.5	21.506	2.73	99.9
	Low education (% inhabitants)	27.9	10.071	2.46	60.6
	Lack of space (% inhabitants)	19.8	13.866	0.99	82.66
	No healthcare (% inhabitants)	74.0	15.726	5.9	97.03
Hospital capacity (2018)	Number of hospitals per municipality	0.6	1.428	0	16
	Number of doctors in hospitals per municipality	218.0	554.566	0	6208
	Number of ICU beds per municipality	1.6	10.371	0	200
	Number of hospitals per 1 000 inhabitants per municipality	0.012	0.011	0	0.43
	Number of doctors in hospitals per 1 000 inhabitants per municipality	1.82	1.78	0	29
	Number of ICU beds per 1 000 inhabitants per municipality	0.05	0.07	0	1.17
<i>Number of municipalities</i>		2483			

Sources: CONEVAL (2015), Pobreza a nivel municipio 2010 y 2015 (database), available at: https://www.coneval.org.mx/Medicion/Paginas/AE_pobreza_municipal.aspx ; Secretaría de Salud (2018), Recursos en salud, nivel central (database), available at: <https://datos.gob.mx/busca/dataset/recursos-en-salud-nivel-central>.

3.3.5. Hospitalization costs and health expenditure

Besides its tragic impact in terms of human losses, the pandemic of COVID-19 is also generating exorbitant hospital and healthcare expenses around the world, particularly due to the exponential number of infections and hospital admissions. Hospitalized patients require constant support from doctors, nurses and other health workers, which in turn require more protective equipment than before. For severe cases of COVID-19, patients tend to require costly medical resources such as drugs, oxygen tanks and, in some cases, ventilators. Recent research has found that, depending on the country, medical costs per COVID-19 patient range between USD 2 400 and USD 15 000 on average (Khan et al., 2020; Bartsch et al., 2020). In Mexico where healthcare coverage and reimbursement rates are limited, patients have been facing tremendous difficulties to pay for their testing, treatment and hospitalization.

To estimate the range of expenditure that could have been avoided (for both the patients and the government) if there were no obesity in Mexico, we use IMSS data on the average unit costs of different healthcare services (IMSS, 2019). Using a macro-costing estimation strategy, we calculate an average cost of hospitalization by patient according to the length of stay, the type of hospitalization (simple or ICU), and related services. More precisely, we take into account the costs of the following healthcare services: diagnostic tests, radiology tests, medical treatment visit, and patient-day hospital (either simple hospitalization or ICU admission coupled with mechanical ventilation). Each of those services' costs already include physicians'

fees, medication, medical equipment, and maintenance costs. We calculate that being hospitalized costs between USD 5 700 and USD 22 000 per patient (considering they stay between 11 and 13 days at the hospital – the average length of stay for COVID-19 hospitalizations in Mexico, see Ojino Sosa-Garcia et al. (2020) and Ñamendys-Silva et al. (2021) for the data). Even though these calculations might underestimate the costs relative to personal protective equipment, they concur with other findings of the literature on COVID-19 costs (Khan et al., 2020; Bartsch et al., 2020; Kaier et al., 2020; Steuart et al., 2020; VerLee et al., 2014).

3.4. Is obesity a direct and independent risk factor for severe COVID-19 in Mexico?

This section delves into the first objective of this paper and confirms that obesity is a direct and independent risk factor for more severe forms of the disease COVID-19 among the Mexican population.

3.4.1. Empirical strategy

To investigate the effect of obesity in aggravating the health consequences of the COVID-19 pandemic in Mexico, we first define a baseline model to explore the role of obesity in generating severe forms of the disease. Second, we address potential endogeneity issues in the baseline model and define our preferred empirical model (main specification).

Baseline model: the role of obesity in COVID-19 severity

The first objective of our empirical methodology is to assess the role of obesity in the probability of developing severe forms of COVID-19. First, we define a baseline model that consists of a series of logistic regressions where the dependent variable (dummy) indicates the severity of COVID-19 and where the explanatory variables – including obesity – are a rich set of individual and local characteristics.

These logistic regressions, performed on a sample of COVID-19 patients, can be interpreted as horse races between obesity and other comorbidities, including diabetes, asthma, hypertension, and cardiovascular and respiratory diseases, among other relevant health pre-conditions. Estimates associated to obesity inform us on the unique role played by obesity, in comparison to other health factors. The empirical specification also takes into account

individual characteristics (e.g. age, gender), the health system capacity in the municipality of residence, and other relevant characteristics at the local level (e.g. poverty rate, percentage of people with low education, political alignment).

The baseline model is described by Equation 3.1, where $severity_dummies_{im}$ is the set of dummy variables representing the fact of being or not in the different severity stages of COVID-19 (i.e. $pneumonia_{im}$, $hospital_{im}$, icu_{im} , $intubation_{im}$, or $death_{im}$) contracted by individual i who lives in municipality m .

$$severity_dummies_{im} = obesity_{im}\beta + X_{im}A + Z_mB + H_mC + \varepsilon_{im} \quad 3.1$$

$obesity_{im}$ is the dummy variable indicating whether the patient i is obese or not – therefore β is our coefficient of interest. X_{im} is the set dummy variables denoting several comorbidities (see Section 3.3.3 for the whole list of comorbidities) and other individual characteristics (i.e. age and gender). While Z_m is the group of variables controlling for multidimensional poverty in the municipality of residence m before the outbreak of the virus, H_m represents the variables of health system capacity at the local level just before the outbreak. ε_{im} is the error term. In this specification and through all the paper, standard errors are corrected for heteroskedasticity.

Going beyond dummy variables, and to explore the role of obesity in experiencing a gradual intensification of symptoms, we also run an ordered logit regression using the categorical variable $gradual_severity_{im}$ as a dependent variable. This variable describes the gradual evolution (maximal severity) of the disease among COVID-19 patients – i.e. being asymptomatic, being diagnosed with pneumonia, being hospitalized, being admitted into ICU, requiring ventilation, and or death.

Preferred model: the probability of COVID-19 severity associated to obesity

Although our baseline model sheds some light on the association between obesity and the development of severe forms of COVID-19, it is very likely that those first estimates are endogenous. The COVID-19 outbreak being a clear exogenous shock (the virus originated outside Mexico and virtually reached every major country in the world within a couple of months), we exclude the possibility that reverse causality or simultaneity issues (at least in the short term) are affecting our estimates. However, there might be other sources of bias that could

affect our baseline results, including self-selection, and endogeneity due to omitted variables. Some variables that we did not include in the baseline model (mainly due to lack of data) may explain both the probability of being obese and the probability of developing more concerning forms of COVID-19. Similarly, unobserved characteristics might determine both the probability of being in our sample (going to a medical testing center after suspicion of being infected) and the probability of developing severe COVID-19. We mitigate each of those potential biases as follows:

- *Patients' socioeconomic status.* Poorer individuals may face higher risk of obesity due to insufficient budget to buy nutritious food, and a higher risk of severe COVID-19 due to limited access to health care. To minimize this issue – in the absence of income data at the individual level – we add fixed effects for the type of hospital the patient is admitted in (i.e. private hospitals, public hospitals for households in the formal sector, or public hospitals for households in the informal sector), which is highly correlated with individual socioeconomic status in Mexico (see Section 3.3.3). As Indigenous populations are disproportionately more affected by poverty than non-Indigenous (Barbary, 2015; Servan-Mori et al., 2014), we also control for the ethnic origin of the patient (i.e. if he or she is Indigenous). Additionally, we cluster the standard errors at the municipal level, since people living in the same area are likely to experience similar contextual conditions (e.g. access to services and local responses to the pandemic).
- *Patients' decision to delay medical consultation.* The timing of consultation after the appearance of symptoms may depend on several individual characteristics, including nature of work, level of education and even obesity. As the medical registers include the dates of different events during the disease, we are able to calculate and include as a control the number of days between the first symptoms and the date of medical consultation.
- *Capacity to undergo medical consultation or test for COVID-19.* Unfortunately, a limit in our analysis is that we are unable to observe individuals who were infected by the virus but did not visit a health center to get tested. These individuals who might have developed a symptomatic form of the disease may present specific characteristics that determine both their behavior regarding medical consultation and the severity of their

symptoms. Nevertheless, this potential selection in COVID-19 patients should only downwardly bias our estimates of interest regarding obesity, since the prevalence of obese patients in the database (18.7%) is lower than the average obesity rate among the Mexican population (36%). We potentially observe fewer obese patients because of the greater difficulties they face to go to the hospital (e.g. mobility issues, financial constraints).

- *Local institutional responses to the COVID-19 pandemic.* Mexico is a federal country where states and municipalities have different attributions and areas of responsibility, as well as financial and human resources, which can significantly shape their capacity to manage the COVID-19 crisis, and thus influence the probability of people being infected and or recovering from the disease. To take some of these differences into account, we add state fixed effects in our model as well as the state's political alignment with the national government to isolate the role of local institutional responses more specifically. Political alignment has been important since the beginning of the pandemic in Mexico, as some states and municipalities decided unilaterally to impose more or less restrictive measures (e.g. confinement, curfew, obligatory masks) relative to the national level (federal government), which could significantly influence the spread of the virus. As political responses and medical supplies vary across states but also in time depending on the local spread of the virus, we perform robustness checks by including state-time fixed effects – the interaction between the states and two-month periods (January-February, March-April, etc.).

After adjusting for these confounder effects, two potential issues might remain. The first issue relates to the question: After being tested for COVID-19, could the probability of having a false positive or a false negative result be correlated with the obesity status? Based on available evidence, COVID-19 tests' sensitivity and efficacy (i.e. their capacity to correctly detect positive and negative cases) are equivalent among obese and non-obese individuals; therefore we assume no biases due to testing. The second issue relates to the question: Could the probability of being infected with SARS-CoV-2 depend on the obesity status? To our knowledge based on existing literature, the probability of being infected with the SARS-CoV-2 is most likely independent of the obesity status *per se*, everything else being equal. In general, the medical literature suggests that infection does not depend on intrinsic individual

characteristics³⁷ but rather on the degree of exposure to the virus (e.g. through the type of activities or social interactions). Although we include some controls for the probability of being infected that might also be correlated to the probability of being obese (e.g. population density which correlates with living in large urban areas and thus the probability of being obese; or the type of healthcare which relates to job quality), we do not have sufficient data to fully address this potential selection bias. The probability of appearing in our database, everything else being equal, (i.e. being infected) might thus be different between obese and non-obese individuals.

Equation 3.2 summarizes our modifications to the baseline model and describes our main specification (preferred model), where $severity_dummies_{im}$ is the set of dependent dummy variables representing the existence or not of different severity stages of COVID-19 for patient i who lives in municipality m . We run the estimations only on the subsample of patients who tested positive to the SARS-CoV-2 virus (i.e. COVID-19 patients).

$severity_dummies_{im} = obesity_{im}\beta + X_{im}A + typehosp_{im} + nbdays_{im} + Z_m B + H_m C + politics_s + F_s + \varepsilon_{im}$	3.2
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$obesity_{im}$ the dummy variable that indicates if patient i living in municipality m is obese or not, and thus β is our coefficient of interest that translates the probability of having severe COVID-19 for obese versus non-obese patients, conditional on being tested positive to SARS-CoV-2 in a health center. X_{im} is the set of dummy variables for pre-existing health conditions of individual i , $typehosp_{im}$ is the type of hospital in which patient i was taken care of (i.e. public hospital for formal workers, public hospital for informal workers, private hospital, and few university hospitals which became available for the general public), $nbdays_{im}$ is the number of days patient i took to visit the medical center after the first COVID-19 symptoms. While Z_m and H_m are respectively municipality poverty and hospital capacity controls, $politics_s$ is a dummy indicating 1 if the patient lives in a state led by the same political party

³⁷ The medical literature suggests that infections does not depend on intrinsic individual characteristics, except for some new findings suggesting that women and O blood-type individuals might have lower probability of infection, *ceteris paribus* (see Groban et al., 2020; Wu et al., 2020a). If results are confirmed, it would be that our estimates are only downwardly biased (the real effect of obesity being larger) since women and O blood groups are more likely to be obese (OECD, 2017a; Jawed et al., 2018).

as the national government. F_s are state fixed effects and ε_{im} is the error term. Standard errors are clustered at the municipal level and corrected for heteroskedasticity.

3.4.2. Results

This section presents the results of the baseline model and the main specifications on the role of obesity in COVID-19 severity at the individual level. We show the results of the baseline model and the main specifications in Table 3.4 and Table 3.5, respectively. In those tables, columns 1 to 5 display the exponentiated coefficients of the logistic estimations for each of the COVID-19 severity stages in the following order: the probability of having pneumonia when infected with SARS-CoV-2 (column 1), the probability of being hospitalized (column 2), the probability of being admitted into Intensive Care Unit (column 3), the probability of requiring artificial ventilation (column 4), and the probability of death (column 5). Column 6, on the other hand, shows the odds ratios of the ordered logistic regressions that estimate the probability of escalating degrees of COVID-19 severity.

These logistic regressions, performed on the sample of observed COVID-19 patients, can be interpreted as horse races between obesity and other comorbidities, since the model is also controlling for diabetes, hypertension, cardiovascular diseases, among other relevant health pre-conditions. Our results of the baseline model and the main specification reveal that in Mexico, obesity is a decisive and direct risk factor for the development of more severe forms of COVID-19 (Table 3.4 and Table 3.5). We show that obesity is a significant driver of COVID-19 severity at the individual level, as coefficients associated to obesity remain significant even when controlling for all other relevant comorbidities and characteristics that affect patients' vulnerability to the virus. On average, the probability to develop each of the degrees of COVID-19 severity is between 40% to 70% higher for obese patients compared to non-obese ones (Table 3.5, columns 1 to 5). Furthermore, the probability of escalating in severity is also around 40% higher for obese people relative to non-obese people (Table 3.5, column 6). The results hold even when controlling for state-time fixed effects (the interaction between states and two-month periods), to control for potential differences in states governments' political responses to COVID-19 over time (see Annex 3.B). As a way of example, the strong impact of obesity on COVID-19 death seems to be driven by obesity in men rather than in women, and by obesity among workers of the formal sector who benefit from a public health insurance rather

than obesity among workers of the informal sector (see examples of heterogenous effects in Annex 3.C).

Table 3.4. Baseline model: Obesity and COVID-19 severity (odds ratios)

	(1) <i>Logit</i> Pneumonia	(2) <i>Logit</i> Hospitalized	(3) <i>Logit</i> ICU	(4) <i>Logit</i> Intubation	(5) <i>Logit</i> Death	(6) <i>Ordered logit</i> Severity
Obesity	1.48*** (0.01)	1.37*** (0.01)	1.66*** (0.04)	1.61*** (0.03)	1.47*** (0.02)	1.39*** (0.01)
<i>Comorbidities</i>						
Diabetes	1.73*** (0.02)	1.95*** (0.02)	1.59*** (0.04)	1.60*** (0.04)	1.70*** (0.02)	1.88*** (0.02)
Hypertension	1.19*** (0.01)	1.28*** (0.01)	1.12*** (0.03)	1.17*** (0.03)	1.28*** (0.02)	1.27*** (0.01)
Cardiovascular diseases	1.03 (0.03)	1.09*** (0.03)	1.12* (0.06)	1.07 (0.05)	0.96 (0.03)	1.08*** (0.02)
Respiratory diseases	1.21*** (0.03)	1.38*** (0.04)	1.06 (0.06)	0.99 (0.05)	1.24*** (0.04)	1.38*** (0.03)
Asthma	0.93** (0.02)	0.89*** (0.02)	0.90 (0.06)	0.84** (0.06)	0.86*** (0.03)	0.90*** (0.02)
Immunosuppression	1.69*** (0.06)	2.08*** (0.07)	1.71*** (0.1)	1.53*** (0.10)	1.59*** (0.06)	1.90*** (0.06)
Chronic renal disease	1.75*** (0.05)	2.69*** (0.08)	1.11 (0.06)	1.31*** (0.06)	2.43*** (0.07)	2.53*** (0.06)
Other comorbidities	1.37*** (0.03)	2.00*** (0.05)	1.11 (0.06)	1.17** (0.06)	1.78*** (0.05)	1.86*** (0.04)
<i>Other individual characteristics</i>						
Age	1.05*** (0.0003)	1.05*** (0.0003)	1.03*** (0.0008)	1.04*** (0.0007)	1.07*** (0.0004)	1.06*** (0.0003)
Woman	0.34*** (0.03)	0.22*** (0.02)	0.31*** (0.1)	0.63* (0.1)	0.24*** (0.04)	0.21*** (0.02)
Pregnancy	0.99*** (0.001)	0.99*** (0.001)	0.99* (0.003)	1.00 (0.002)	0.99*** (0.002)	0.99*** (0.001)
<i>Municipality characteristics (2015)</i>						
Poverty rate	1.02*** (0.0007)	1.02*** (0.0007)	1.00 (0.002)	1.01*** (0.002)	1.02*** (0.0009)	1.02*** (0.0006)
% people with low education	0.97*** (0.001)	0.99*** (0.0010)	1.00 (0.003)	0.97*** (0.002)	0.98*** (0.001)	0.98*** (0.0009)
% people lacking space	1.00** (0.0008)	1.00 (0.0008)	1.01*** (0.002)	1.01*** (0.002)	1.01*** (0.001)	1.00 (0.0007)
% people lacking social security	1.01*** (0.0006)	0.99*** (0.0005)	1.01*** (0.001)	1.01*** (0.001)	0.99*** (0.0008)	0.99*** (0.0005)
Population (thousands of inhabitants)	1.00*** (0.000008)	1.00*** (0.000008)	1.00*** (0.00002)	1.00*** (0.00002)	1.00*** (0.00001)	1.00*** (0.000007)
Population density (inhabitants/km ²)	1.00*** (0.00000001)	1.00*** (0.00000001)	1.00 (0.00000003)	1.00 (0.00000003)	1.00*** (0.00000002)	1.00*** (0.00000001)
<i>Health system capacity in municipality</i>						
Number of hospitals per 1 000 inhabitants	0.0039*** (0.002)	0.00066*** (0.0003)	0.89 (1.1)	0.00083*** (0.001)	0.00095*** (0.0007)	0.0026*** (0.001)
Number of doctors in hospitals per 1 000 inhabitants	0.97*** (0.006)	0.96*** (0.006)	0.93*** (0.02)	0.99 (0.02)	0.99 (0.008)	0.97*** (0.005)
Number of ICU beds per 1 000 inhabitants	1.66*** (0.2)	1.70*** (0.2)	2.35* (0.9)	2.06* (0.6)	0.99 (0.2)	1.41** (0.2)
N	479975	479975	479975	479975	479975	479975
Pseudo R ²	0.14	0.18	0.06	0.09	0.22	0.12
State FE	No	No	No	No	No	No
Clustering	No	No	No	No	No	No

Notes: Exponentiated coefficients; Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3.5. (1/2) Main specification: Obesity as a direct risk factor for severe forms of COVID-19 in Mexico
(odds ratios)

(1/2)	(1) <i>Logit</i> Pneumonia	(2) <i>Logit</i> Hospitalized	(3) <i>Logit</i> ICU	(4) <i>Logit</i> Intubation	(5) <i>Logit</i> Death	(6) <i>Ordered logit</i> Severity
Obesity	1.47*** (0.04)	1.37*** (0.03)	1.67*** (0.06)	1.60*** (0.06)	1.46*** (0.03)	1.39*** (0.03)
<i>Comorbidities</i>						
Diabetes	1.72*** (0.02)	1.97*** (0.03)	1.64*** (0.05)	1.62*** (0.04)	1.67*** (0.03)	1.86*** (0.02)
Hypertension	1.16*** (0.01)	1.22*** (0.02)	1.19*** (0.03)	1.21*** (0.03)	1.20*** (0.02)	1.21*** (0.02)
Cardiovascular diseases	1.04 (0.03)	1.11** (0.04)	1.10 (0.06)	1.06 (0.05)	0.98 (0.03)	1.10*** (0.03)
Respiratory diseases	1.18*** (0.04)	1.30*** (0.05)	1.10 (0.08)	1.01 (0.06)	1.19*** (0.04)	1.33*** (0.04)
Asthma	0.94* (0.03)	0.88*** (0.03)	0.90 (0.06)	0.85* (0.06)	0.86*** (0.03)	0.90*** (0.02)
Immunosuppression	1.64*** (0.06)	2.04*** (0.10)	1.75*** (0.2)	1.50*** (0.1)	1.54*** (0.07)	1.83*** (0.07)
Chronic renal disease	1.73*** (0.05)	2.46*** (0.1)	1.23*** (0.07)	1.41*** (0.07)	2.22*** (0.07)	2.35*** (0.07)
Other comorbidities	1.17*** (0.04)	1.41*** (0.05)	1.25* (0.1)	1.27*** (0.07)	1.34*** (0.04)	1.36*** (0.04)
<i>Socioeconomic status</i>						
Public hospital, informal sector	0.66*** (0.06)	0.34*** (0.02)	2.27*** (0.3)	1.65*** (0.1)	0.35*** (0.02)	0.37*** (0.03)
Private hospital	0.97 (0.1)	0.50*** (0.09)	5.40*** (0.9)	2.11*** (0.2)	0.20*** (0.02)	0.53*** (0.08)
University hospital	0.40*** (0.09)	0.38*** (0.06)	2.43 (1.2)	3.09*** (0.6)	0.42*** (0.05)	0.40*** (0.07)
Indigenous	1.60*** (0.1)	1.52*** (0.1)	1.11 (0.2)	1.14 (0.1)	1.37*** (0.08)	1.52*** (0.09)
<i>Other individual characteristics</i>						
Age	1.05*** (0.0008)	1.05*** (0.0009)	1.03*** (0.001)	1.04*** (0.0010)	1.07*** (0.0007)	1.06*** (0.0007)
Woman	0.35** (0.1)	0.29*** (0.10)	0.27*** (0.10)	0.48* (0.2)	0.35** (0.1)	0.28*** (0.10)
Pregnancy	0.99 (0.003)	0.99* (0.004)	0.99* (0.004)	1.00 (0.004)	1.00 (0.004)	0.99* (0.004)
Number of days between first symptoms and consultation	1.03*** (0.004)	1.01* (0.005)	1.06*** (0.005)	1.05*** (0.005)	0.99* (0.003)	1.01** (0.004)
<i>Municipality characteristics (2015)</i>						
Poverty rate	1.00 (0.004)	1.00 (0.004)	0.99 (0.006)	1.00 (0.004)	1.01** (0.003)	1.00 (0.003)
% people with low education	1.02* (0.007)	1.04*** (0.007)	1.01 (0.01)	1.01 (0.007)	1.02*** (0.005)	1.03*** (0.006)
% people lacking space	1.00 (0.005)	1.00 (0.005)	1.02 (0.009)	1.01 (0.005)	1.00 (0.004)	1.00 (0.004)
% people lacking social security	1.00 (0.004)	1.00 (0.003)	1.01 (0.005)	1.01 (0.004)	0.99** (0.003)	1.00 (0.003)
Population (thousands of inhabitants)	1.00 (0.000005)	1.00 (0.000005)	1.00 (0.000008)	1.00* (0.000006)	1.00* (0.000005)	1.00 (0.000005)
Population density (inhabitants/km ²)	1.00 (0.00000007)	1.00 (0.00000005)	1.00 (0.0000001)	1.00 (0.00000007)	1.00 (0.00000004)	1.00 (0.00000004)
Political alignment	1.23 (0.1)	1.13 (0.1)	2.49*** (0.6)	1.61* (0.3)	1.59*** (0.2)	1.25* (0.1)

(to be continued)

Table 3.5. (2/2) Main specification: Obesity as a direct risk factor for severe forms of COVID-19 in Mexico
(odds ratios)

(2/2)	(1) <i>Logit</i> Pneumonia	(2) <i>Logit</i> Hospitalized	(3) <i>Logit</i> ICU	(4) <i>Logit</i> Intubation	(5) <i>Logit</i> Death	(6) <i>Ordered logit</i> Severity
<i>Health system capacity in municipality</i>						
Number of hospitals per 1 000 inhabitants	0.028* (0.05)	0.037 (0.07)	0.083 (0.2)	0.0078* (0.02)	0.0051*** (0.007)	0.045* (0.07)
Number of doctors in hospitals per 1 000 inhabitants	1.02 (0.02)	1.00 (0.02)	0.97 (0.04)	0.99 (0.03)	1.01 (0.02)	1.01 (0.02)
Number of ICU beds per 1 000 inhabitants	1.04 (0.5)	1.22 (0.5)	1.68 (1.4)	1.55 (0.8)	1.00 (0.4)	1.05 (0.4)
N	479975	479975	479975	479975	479975	479975
Pseudo R ²	0.18	0.24	0.12	0.11	0.26	0.16
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Clustering	Municipality	Municipality	Municipality	Municipality	Municipality	Municipality

Notes: Exponentiated coefficients; The category of reference for the socioeconomic status is Public hospital for formal workers; Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Our results are in line with recent studies that explore the role of obesity in aggravating symptoms of COVID-19. For instance, both Denova-Gutiérrez et al. (2020) and Bello-Chavolla et al. (2020) find that obese patients in Mexico have around 1.4 times the risk to develop severe forms of the disease or die than that of non-obese people – although the former authors only look at ICU admission in cases of pneumonia, and the latter authors at COVID-19 lethality. Similar to them, but contrary to Hernández-Garduño (2020) whose analysis highlights obesity as the main comorbidity that determines severe COVID-19 the most, we also find that other comorbidities– that are largely prevalent in Mexico – also are crucial risk factors. In particular, we find that obesity and diabetes have a similar impact in magnitude across COVID-19 severity stages. Patients with obesity, diabetes, chronic renal disease, or immunosuppressed are between 50% and 100% more likely to experience severe COVID-19 than patients who do not suffer from these comorbidities (Table 3.5). Both obesity and diabetes weaken the immune response in people infected by viruses of bacteria (Denova-Gutiérrez, 2020), while immunosuppressant treatments typically increase the risk of infections (Thng et al., 2020). Although obesity, diabetes, renal chronic disease, and immunosuppression appear as the most critical risk factors for severe COVID-19 in Mexico, all other comorbidities – except asthma (see Broadhurst et al., 2020) – significantly widen the odds of COVID-19 severity (Table 3.5).

With the inclusion of individual and municipal controls (Table 3.5), we verify foundational results of the recent literature about the determinants of COVID-19 severity. Everything else being equal, men are three times more likely to develop each of the COVID-19

severity degrees than women, and the probability of facing severe forms of the disease increases with age and poverty. Patients without access to the formal health care system (i.e. who typically have to visit public hospitals for informal workers or private hospitals) are also the ones more likely to require intensive care and intubation, but are less likely to die from COVID-19 in an hospital. An explanation of this result is that we do not observe individuals who die at home from COVID-19, and who are more likely to be poor individuals without the capacity to consult a doctor at any stage of the disease. Besides, we notice that more hospitals per capita are associated to a greater probability of mechanical ventilation – with more resources and capacity, hospitals should be able to provide the necessary care to patients in need. Finally, results suggest that living in a state politically aligned with the national government is associated with a higher probability of COVID-19 severity.

3.5. Estimating the additional health and healthcare costs of obesity during the pandemic

The second step in our analysis is to estimate the additional health costs and healthcare expenditures (in terms of deaths and USD, respectively) associated to obesity for the Mexican society during the first wave of the pandemic (from January to August 2020). We provide upper- and lower-bound estimates for both mortality and healthcare costs, by simulating different obesity scenarios in the population. This section details the methodology we adopt to estimate these costs and presents our findings.

3.5.1. Empirical strategy

To estimate the additional health costs and healthcare expenditures (in terms of deaths and USD, respectively) associated to obesity for the Mexican society during the first wave of the pandemic, we ask two main questions: 1) How many lives could have been saved if there were no obesity in Mexico? and 2) How much public health expenditures could have been avoided with zero obesity rates during the pandemic?

1) How many lives could have been saved if there were no obesity in Mexico?

Using the logistic regression of the preferred model (main specification), we predict the probability of death assuming nobody in the sample is obese and compare it with the probability of death predicted by the model with the real sample (and original obesity levels). We first

calculate a lower bound for the role of obesity in the death toll due to COVID-19, as we (simplistically) assume a null impact of obesity on increasing other comorbidities that also affect COVID-19 severity. To calculate the upper bound, we take into account the indirect effect of obesity on other comorbidities – more particularly on increasing the risk of diabetes (a pre-existing health condition highly associated to both obesity and COVID-19 severity). Obesity is a crucial risk factor for non-communicable diseases, including diabetes (WHO, 2020a). In Mexico, while 36% of the population is obese, 10.4% suffers from diabetes, a disease that is the second most important cause of death in the country as it accounts for 15% of all deaths (WHO, 2016; Levallant et al., 2019; Barquera and Rivera, 2020). To calculate the larger impact of obesity on COVID-19 deaths while considering the consequences of obesity on diabetes, we generate estimates of the probability of diabetes in obese and non-obese individuals using our own sample.

Estimation method to calculate the lower bound of the role of obesity in aggravating the death toll due to COVID-19:

1. Using the main specification defined by Equation 3.2 (see Section 3.4.1), we predict the probability of death given the real obesity status ($death_{im}$) and the probability of death assuming none of the patients are obese ($death_{noob_{im}}$), everything else being equal:

$$\widehat{death}_{im} = obesity_{im}\beta + X_{im}A + typehosp_{im} + nbdays_i + Z_mB + H_mC + politics_s + F_s + \varepsilon_{im}$$

$$\widehat{death}_{noob_{im}} = 0 * \beta + X_{im}A + typehosp_{im} + nbdays_{im} + Z_mB + H_mC + politics_s + F_s + \varepsilon_{im}$$

2. We assign to each patient i a dummy variable of predicted death if the probability of death computed by our model is superior to 0.3 (see discussion on the choice of the probability cut-off in Annex 3.D), in the original case ($death_{pred}$) and in the case without obesity ($death_{noob_{pred}}$):

$$death_{pred} \begin{cases} = 1 \text{ if } \widehat{death}_{im} \geq 0.3 \\ = 0 \text{ if } \widehat{death}_{im} < 0.3 \end{cases}$$

$$death_{noob_{pred}} \begin{cases} = 1 \text{ if } \widehat{death}_{noob_{im}} \geq 0.3 \\ = 0 \text{ if } \widehat{death}_{noob_{im}} < 0.3 \end{cases}$$

3. We calculate the total number of deaths predicted by our model in the original case (nb_{death}) and in the case assuming no obesity ($nb_{death_{noob}}$), where N is the total number of COVID-19 patients:

$$nb_{death} = \sum_{i=1}^N death_{pred}$$

$$nb_{death_{noob}} = \sum_{j=1}^N death_{noob_{pred}}$$

4. We calculate the number of (predicted) deaths that could have been avoided if there were no obesity in Mexico:

$$diff_{death} = nb_{death} - nb_{death_{noob}}$$

Estimation method to calculate the upper bound of the role of obesity in aggravating the death toll due to COVID-19:

We estimate the probability of having diabetes for obese and for non-obese individuals using the following model, described by Equation 3.3, and based on existing literature (see for instance Jenum et al., 2005; Gupta and Bansal, 2020; Abdullah et al., 2010).

$$diabetes_{im} = obesity_{im}\beta + X_{im}A + smoking_{im} + Z_mB + F_s + \varepsilon_{im} \quad 3.3$$

While $obesity_{im}$ reflects whether patient i is obese or not, $smoking_{im}$ is a dummy variable indicating whether the patient is a smoker. X_{im} is a set of individual characteristics (including age and sex), Z_m regroups controls for the municipality of residence (as in Equation 3.2 while excluding population density), F_s are state fixed effects, and ε_{im} is the error term. Standard errors are corrected for heteroskedasticity. Non-obese have a lower – although not null – probability of suffering from diabetes than obese.

Using the results of Equation 3.3, we predict the probability of having diabetes conditional on not being obese (everything else being equal). We use these probabilities to estimate the upper bound number of lives that could have been saved (from COVID-19 death) if the prevalence of obesity were zero during the first wave of the pandemic.

More precisely, we repeat steps 1 to 4 as for the estimation of the lower bound, with the particularity that step 1 also incorporates a lower chance of having diabetes due to the absence of obesity (through the predicted probability of diabetes from Equation 3.3). We obtain the number of (predicted) deaths that could have been avoided if there were no obesity in Mexico, considering that the eradication of obesity would have also decreased the number of diabetes cases, and therefore the risk for death if infected with COVID-19.

2) How much health expenditure could have been avoided during the pandemic if there were no obesity in Mexico?

Adopting a similar strategy than for the previous question, we use the logistic regression of the preferred model to predict the probabilities of hospitalization (both for simple admissions and for admissions that required ICU and mechanical ventilation) assuming nobody in the sample is obese. We then compare these estimates with the probabilities of hospitalization predicted by the model using the actual obesity levels observed in the sample. While the lower bound health expenditure is estimated assuming nobody in the sample is obese, the upper bound is calculated by adding the indirect effect of obesity on increasing the risk of diabetes.

Calculating the lower bound's predicted health expenditure of the additional COVID-19 hospitalization expenses related to obesity:

1. Using the main specification defined by Equation 3.2, i) we predict the probabilities of hospitalization (simple and ICU with ventilation) given the real obesity status (observed in the sample), and ii) the probabilities of hospitalization assuming none of the patients are obese, everything else being equal.
2. We assign to each patient a dummy variable of predicted simple hospitalization if the probability of simple hospitalization computed by our model is superior to 0.37, and a dummy of predicted ICU hospitalization if the probability of ICU hospitalization computed by the model is superior to 0.5 (i.e. these thresholds generate a distribution of hospitalizations close to the one observed in the real sample, see Annex 3.E), in the original case and in the case without obesity.
3. We compute the total number of hospitalizations predicted by our model in both the real case (observed obesity) and assuming no obesity.

4. We determine the number of (predicted) hospitalizations that could have been avoided if there were no obesity in Mexico (i.e. difference between predicted hospitalization without obesity and predicted hospitalizations with observed obesity).
5. We calculate the additional healthcare expenditure associated to the extra number of hospitalizations due to obesity. We multiply the average hospitalization costs per patient per day by the additional number of patients and the average length of stay associated to obesity.

Calculating the upper bound's predicted health expenditure of the additional COVID-19 hospitalization expenses related to obesity:

We estimate the probability of having diabetes for obese and for non-obese individuals using the model described by Equation 3.3. More precisely, Equation 3.3 allows predicting the probability of having diabetes conditional on not being obese (everything else being equal). We use those probabilities to estimate the upper bound number of hospitalizations that could have been prevented if the prevalence of obesity were zero. We then repeat steps 1 to 5 as for the estimation of the lower bound. The result is the number of (predicted) hospitalizations (both simple and ICU admissions with ventilation) that could have been prevented if there were no obesity in Mexico, considering that the eradication of obesity would have also decreased the number of diabetes cases, and therefore the risk for hospitalization if infected with COVID-19.

3.5.2. Results

This section presents our estimations of the additional COVID-19 mortality and health expenditure due to obesity during the first wave of the pandemic in Mexico (January-August 2020). We find that obesity highly contributed to COVID-19 mortality and additional healthcare expenses in Mexico.

Additional COVID-19 mortality due to obesity

The administrative data of COVID-19 cases and deaths suggest that 10.9% of all COVID-19 patients who visited a hospital died, similar to our model prediction of 10.6%. As of August 9th 2020, 52 298 COVID-19 deaths were registered in Mexico (Gobierno de México, 2020a; Center for Disease Control and Prevention, 2020), making the country one of the most

affected by the pandemic worldwide (in terms of deaths and deaths per 1 000 people). This high death toll from COVID-19 is partly explained by the prevalence of comorbidities in the Mexican population – 36% of the population are obese and 10.4% suffer from diabetes. These figures surpass the OECD average by 16.5 and 4 percentage points respectively (OECD, 2017a; OECD, 2019a) and add an extra risk of death from COVID-19.

The cost of obesity on the COVID-19 death toll in Mexico has been very high. Table 3.6 displays the lower bound estimations of the predictions of deaths, using observed obesity status in a first step and then assuming no obesity in our sample. Our model predicts that around 4 290 deaths from COVID-19 could have been avoided between January and the first week of August 2020 if there were no obesity at all in Mexico. This means that obesity is responsible for around 8% (lower bound estimate) of all COVID-19 deaths predicted by our model in the observed period. When we consider the spillover effects of obesity on the probability of having diabetes (as obesity is a key determinant of diabetes), we find that up to 5 890 lives could have been saved if no one in the sample had suffered from obesity during the first months of the pandemic (Table 3.7). As obesity and diabetes weaken the capacity of the body to combat the infection caused by the virus, they have had a significant weight on the probability of death. Overall, we find that obesity and its consequences on diabetes have been responsible for as much as 11.5% (upper bound estimate) of all predicted COVID-19 death in Mexico. It is worth highlighting that obesity has further repercussions on the probability of getting other comorbidities (beyond diabetes) such as cardiovascular diseases and hypertension, including the indirect effects of obesity on these comorbidities would generate an even larger effect of obesity on COVID-19 severity and deaths across the country.

Table 3.6. Estimated additional COVID-19 mortality due to obesity (lower bound)

Dichotomic logistic model predicted probabilities	Death	Death if no obesity
Obs	479 975	479 975
Mean	0.11	0.10
Std. Dev.	0.15	0.14
Min	0.0021	0.0021
Max	0.96	0.95
Number of deaths predicted	51 018	46 726
Number of deaths avoided if no obesity		4 292
% of deaths avoided if no obesity		8.4

Source: Authors' calculations based on Secretaría de Salud (2020), Datos abiertos - Información referente a casos de COVID-19 en México (database), available at: <https://datos.gob.mx/busca/dataset/informacion-referente-a-casos-COVID-19-en-mexico> (version 9th August 2020).

Table 3.7. Estimated additional COVID-19 mortality due to obesity (upper bound)

Dichotomic logistic model predicted probabilities	Death	Death if no obesity and less probability of diabetes
Obs	479 975	479 975
Mean	0.11	0.10
Std. Dev.	0.15	0.14
Min	0.0022	0.0022
Max	0.96	0.97
Number of deaths predicted	51 018	45 129
Number of deaths avoided if no obesity and less diabetes		5 889
% of deaths avoided if no obesity and less diabetes		11.5

Source: Authors' calculations based on Secretaría de Salud (2020), Datos abiertos - Información referente a casos de COVID-19 en México (database), available at: <https://datos.gob.mx/busca/dataset/informacion-referente-a-casos-COVID-19-en-mexico> (version 9th August 2020).

Additional health expenditure due to obesity and its implications on COVID-19 severity

Just as in other parts of the world, the first wave of the pandemic put tremendous pressure on Mexico's health system and resources, by rapidly reducing hospitals' capacity to provide services to patients with COVID-19, as well as patients with other diseases. As of early August 2020, Mexico had registered around 130 000 cumulated hospitalizations due to COVID-19 infections, of which more than 5 200 required admission into ICU, along with mechanical ventilation. Our previous results revealed that obesity is a direct and significant risk factor for COVID-19 related hospitalization, ICU admission, and intubation (see Section 3.4.2). At the scale of the country, we suggest that the consequences of obesity on the severity of the COVID-19 disease accelerated hospital saturation and contributed significantly to more health spending for both the government and the population.

Table 3.8 presents the lower bound predictions of hospitalizations by our model, using observed obesity status in a first step, and then assuming no one in our sample is obese. Hospitalizations are further disaggregated into simple and ICU with mechanical ventilation. We predict that at least 14 000 hospitalizations (5 500 simple and 8 500 ICU with ventilation) could have been avoided if there were no obesity in Mexico during the first wave of the pandemic. In other words, we estimate that obesity is at least responsible for 4% of all predicted COVID-19 hospitalizations during the first eight months of the pandemic in Mexico. When considering the side-effects of obesity on the emergence of diabetes (upper bound estimations), we find that up to 17 000 hospitalizations could have been avoided if there were no obesity (and cases of diabetes were lower) in the country (Table 3.9). This means that obesity and

obesity-related diabetes explain around 5% of all predicted admissions into hospital for COVID-19. These reductions in hospitalizations are lower than the ones found by Xcenda (2021) in the context of the United States – their study suggests a 7% reduction in COVID-19 hospitalizations if obesity were to drop by 25%.

Table 3.8. Estimated additional COVID-19 hospitalizations and health expenditure due to obesity (lower bound)

Dichotomic logistic model predicted probabilities	Simple hospitalizations	Simple hospitalizations if no obesity	ICU & ventilation	ICU & ventilation if no obesity
Obs	479 975	479 975	479 975	479 975
Mean	0.24	0.23	0.49	0.48
Std. Dev.	0.22	0.22	0.20	0.20
Min	0.002	0.002	0.01	0.01
Max	0.99	0.99	0.93	0.93
Number of hospitalizations predicted	116 227	110 764	235 734	227 197
Number of hospitalizations avoided if no obesity		5 463		8 537
Number of hospitalizations avoided if no obesity				14 000
% of hospitalizations avoided if no obesity				4
Health expenditure avoided if no obesity (USD)				219 024 119

Table 3.9. Estimated additional COVID-19 hospitalizations and health expenditure due to obesity and obesity-related diabetes (upper bound)

Dichotomic logistic model predicted probabilities	Simple hospitalizations	Simple hospitalizations if no obesity	ICU & ventilation	ICU & ventilation if no obesity
Obs	479 975	479 975	479 975	479 975
Mean	0.24	0.23	0.49	0.48
Std. Dev.	0.22	0.21	0.20	0.20
Min	0.19	0.19	0.11	0.11
Max	0.99	0.99	0.93	0.94
Number of hospitalizations predicted	116 227	107 772	235 734	227 018
Number of hospitalizations avoided if no obesity		8 455		8 716
Number of hospitalizations avoided if no obesity and less diabetes				17 171
% of hospitalizations avoided if no obesity and less diabetes				4.9
Health expenditure avoided if no obesity and less diabetes (USD)				240 055 415

Note for Table 3.8 and Table 3.9: “Simple hospitalizations” refer to hospitalizations that did not require an admission into ICU or mechanical ventilation. “ICU & ventilation” refers to hospitalizations that did require an admission into ICU and mechanical ventilation assistance.

Source of Table 3.8 and Table 3.9: Authors’ calculations based on Secretaría de Salud (2020), Datos abiertos - Información referente a casos de COVID-19 en México (database), available at: <https://datos.gob.mx/busca/dataset/informacion-referente-a-casos-COVID-19-en-mexico> (version 9th August 2020).

Since hospitalizations are costly, every admission – including the ones that could have been avoided if obesity rates were lower in the country – also contributes to the degradation of the health system capacity by consuming limited health budgets. Applying a macro-costing estimation using IMSS data (see data in Section 3.3.5 and methodology in Section 3.5.1), we find that obesity and its consequences on COVID-19 severity have raised health expenditure for the Mexican society by USD 220 million to USD 240 million (lower and upper bounds respectively) between January and August 2020. The details of all hospital and health expenditure costs estimations are presented in Annex 3.F.

In Mexico, national and local governments take care of a relatively small share of hospital costs compared to other OECD countries. In practice, access to quality healthcare is limited and patients' out of pocket payments cover, on average, 41% of total health spending (OECD, 2019a) – while health expenditure can go up to 100% for those going to private hospitals due to the saturation of the public system. The estimated 14 to 17 thousand people at risk of hospitalization for COVID-19 because of obesity are thus potentially facing tremendous healthcare expenses – between USD 2 300 to USD 9 000, the equivalent of 3 to 11 months of the average monthly national income of USD 825 (INEGI, 2018c). On the other side, additional expenses caused by obesity and supported by the government represent up to 2% of its annual budget dedicated to universal healthcare (Gobierno de México, 2020b).

While our results reveal the additional burden of obesity in the context of the pandemic, it has been largely documented that overweight and obesity trigger significant health expenditure and economic costs for the society. OECD research in Mexico reveals that obesity and overweight represent around 9% of all public health expenditure and lowers the Mexican GDP by 5% every year (e.g. through loss in employment and labor market productivity) (OECD, 2019b). Although policies to tackle obesity come with a significant cost of implementation, research finds that they tend to be highly cost-effective. Among other policies (e.g. food labelling, school or workplace nutrition programs), mass media campaigns to influence physical activity and good nutrition in Mexico could make the government save up to USD 50 million annually on public health expenditure.

3.6. Conclusions

This paper explores the role of obesity in aggravating COVID-19 symptoms at the individual level in Mexico and is among the first ones to estimate the related health and economic costs on the Mexican society in the first wave of the pandemic.

Using administrative registers of COVID-19 cases and deaths while controlling for relevant individual and local characteristics, including the local health system capacity, we demonstrate that in Mexico, obesity is a key and direct risk factor for the development of more severe forms of COVID-19. We show that obesity is a significant driver of COVID-19 severity at the individual level, even when controlling for all relevant comorbidities and available hospital resources. Obese patients are around 50% more likely to develop each of the different stages of COVID-19 severity compared to non-obese patients, on average; and the probability of escalating in severity is around 40% higher in obese individuals than in non-obese ones.

The high prevalence of obesity in Mexico – affecting 36% of the population on average – contributes to make COVID-19 more deadly than in other places of the world. The cost of obesity on COVID-19 death toll in Mexico has been very high. Our model predicts that between 4 200 and 5 900 COVID-19 deaths could have been avoided between January and August 9th 2020 if there were no obesity in Mexico. This means that obesity is responsible for around 8% to 12% of all predicted COVID-19 deaths in the observed period.

Since quality healthcare and medical resources are limited in Mexico, obesity and its implications on COVID-19 severity come with high risks for the population and for the overall health system. Our results suggest that obesity and its implications on COVID-19 severity stepped up healthcare expenditure by USD 220 to USD 240 million.

The consequences of obesity on the pandemic of COVID-19 may be even larger than that suggested in our paper. For instance, our data does not allow us to observe people with potentially severe COVID-19 who could not – or chose not to – visit a hospital or a medical center. Since obese people might be more likely not to go to the hospital than non-obese – for mobility and or financial reasons – our estimates might be slightly downwardly bias. While this element is one of the main limitations of our analysis, it only underestimates the role of obesity in COVID-19 severity as the prevalence of obesity in our sample (18.7%) is significantly lower

than the one of the Mexican population (36%). Another limit of our analysis is that we ignore the actual effectiveness of COVID-19 tests (Bisoffi et al., 2020; Vandenberg et al., 2020) and more particularly the ones applied to patients in our sample.

Our paper is among the first to highlight the direct and significant role of obesity in aggravating COVID-19 symptoms in Mexico (for many stages of COVID-19 severity, including death) (see Denova-Gutiérrez et al., 2020; Bello-Chavolla et al., 2020; Hernández-Garduño, 2020), and among the first to our knowledge to provide estimations of the health and economic costs of obesity (in terms of additional deaths, and health system expenditure) during the first wave of the COVID-19 pandemic in Mexico.

This paper reveals that people with obesity belong to the most vulnerable populations in the face of COVID-19, since they are more likely to develop a severe form of the disease. As of March 2021 in Mexico, the vaccine against COVID-19 was principally available to healthcare workers and people above 60 years old. The national government as well as the authorities in charge of COVID-19 responses should consider obese people among the primary targets for the next steps of vaccination campaign.

More generally, our findings demonstrate the urgent need for more effective policy action to tackle obesity in Mexico. Although in recent years the topic of nutrition and health pre-conditions has gained momentum in Mexico, more efforts are needed to cope with this public health issue. Policies such as taxes on the food industry, and food reformulation to curb the production of foods that contain excessive fats and sugar may be helpful to improve people's health and lives (see OECD, 2019b). Additionally, the government should consider more policies to ensure food security and nutrition in the long term, including the daily provision of nutritive food at schools, and investments in water infrastructure to deliver free drinkable water in every household and disincentivize the alarming high consumption of sweetened beverages in the country. By shedding light on the costs of obesity in Mexico, we hope this work can contribute to support the implementation of policies needed to enhance good nutrition in Mexico.

Annex 3.A. Statistical test

Annex Table 3.1. Statistical test for the difference in the prevalence of COVID-19 severity among obese and non-obese patients

Severity of COVID-19	Obese patients		Non-obese patients		Difference	
	% COVID-19 patients	sd	% COVID-19 patients	sd	t-test	p-value
Pneumonia	26.57	0.442	18.72	0.390	-53.06	0.000
Hospitalized	33.39	0.472	25.05	0.433	-51.09	0.000
ICU	3.30	0.179	1.86	0.135	-26.98	0.000
Mechanical ventilation	3.80	0.191	2.27	0.149	-26.17	0.000
Death	14.32	0.350	10.10	0.301	-36.64	0.000
<i>Number of observations</i>	89229		390449			

Source: Secretaría de Salud (2020), Datos abiertos - Información referente a casos de COVID-19 en México (database), available at: <https://datos.gob.mx/busca/dataset/informacion-referente-a-casos-COVID-19-en-mexico> (version 9th August 2020).

Annex 3.B. Robustness checks

Annex Table 3.2. (1/2) Robustness checks: Inclusion of months-state fixed effects in the main specifications
(odds ratios)

(1/2)	(1) <i>Logit</i> Pneumonia	(2) <i>Logit</i> Hospitalized	(3) <i>Logit</i> ICU	(4) <i>Logit</i> Intubation	(5) <i>Logit</i> Death	(6) <i>Ordered logit</i> Severity
Obesity	1.45^{***} (0.04)	1.36^{***} (0.03)	1.64^{***} (0.06)	1.57^{***} (0.06)	1.44^{***} (0.03)	1.38^{***} (0.03)
<i>Comorbidities</i>						
Diabetes	1.72 ^{***} (0.02)	1.97 ^{***} (0.03)	1.63 ^{***} (0.05)	1.61 ^{***} (0.04)	1.67 ^{***} (0.03)	1.86 ^{***} (0.02)
Hypertension	1.17 ^{***} (0.01)	1.23 ^{***} (0.02)	1.19 ^{***} (0.03)	1.22 ^{***} (0.03)	1.21 ^{***} (0.02)	1.22 ^{***} (0.02)
Cardiovascular diseases	1.03 (0.03)	1.10 ^{**} (0.04)	1.09 (0.06)	1.05 (0.05)	0.96 (0.03)	1.09 ^{**} (0.03)
Respiratory diseases	1.16 ^{***} (0.04)	1.27 ^{***} (0.05)	1.06 (0.07)	0.98 (0.06)	1.15 ^{***} (0.04)	1.31 ^{***} (0.04)
Asthma	0.92 ^{**} (0.03)	0.86 ^{***} (0.03)	0.88 [*] (0.06)	0.84 [*] (0.06)	0.84 ^{***} (0.03)	0.88 ^{***} (0.02)
Immunosuppression	1.61 ^{***} (0.06)	2.03 ^{***} (0.10)	1.73 ^{***} (0.2)	1.48 ^{***} (0.1)	1.50 ^{***} (0.07)	1.81 ^{***} (0.07)
Chronic renal disease	1.72 ^{***} (0.05)	2.45 ^{***} (0.1)	1.20 ^{**} (0.07)	1.39 ^{***} (0.07)	2.23 ^{***} (0.08)	2.35 ^{***} (0.07)
Other comorbidities	1.15 ^{***} (0.04)	1.39 ^{***} (0.05)	1.21 [*] (0.1)	1.25 ^{***} (0.07)	1.32 ^{***} (0.04)	1.35 ^{***} (0.04)
<i>Socioeconomic status</i>						
Public hospital, informal sector	0.68 ^{***} (0.06)	0.35 ^{***} (0.02)	2.32 ^{***} (0.4)	1.68 ^{***} (0.1)	0.35 ^{***} (0.02)	0.37 ^{***} (0.03)
Private hospital	0.91 (0.1)	0.47 ^{***} (0.08)	4.92 ^{***} (0.7)	1.88 ^{***} (0.2)	0.18 ^{***} (0.01)	0.49 ^{***} (0.07)
University hospital	0.34 ^{***} (0.08)	0.29 ^{***} (0.05)	1.63 (0.9)	2.18 ^{***} (0.4)	0.30 ^{***} (0.03)	0.32 ^{***} (0.06)
Indigenous	1.55 ^{***} (0.10)	1.47 ^{***} (0.1)	1.03 (0.2)	1.10 (0.1)	1.31 ^{***} (0.08)	1.47 ^{***} (0.08)
<i>Other individual characteristics</i>						
Age	1.05 ^{***} (0.0008)	1.05 ^{***} (0.0010)	1.03 ^{***} (0.002)	1.04 ^{***} (0.001)	1.07 ^{***} (0.0007)	1.06 ^{***} (0.0008)
Woman	0.35 ^{***} (0.1)	0.28 ^{***} (0.10)	0.28 ^{***} (0.09)	0.49 [*] (0.2)	0.35 ^{**} (0.1)	0.28 ^{***} (0.09)
Pregnancy	0.99 [*] (0.003)	0.99 [*] (0.004)	0.99 [*] (0.004)	1.00 (0.004)	0.99 (0.004)	0.99 [*] (0.004)
Number of days between first symptoms and consultation	1.03 ^{***} (0.004)	1.01 [*] (0.005)	1.06 ^{***} (0.005)	1.05 ^{***} (0.005)	0.99 ^{**} (0.003)	1.01 [*] (0.004)

(to be continued)

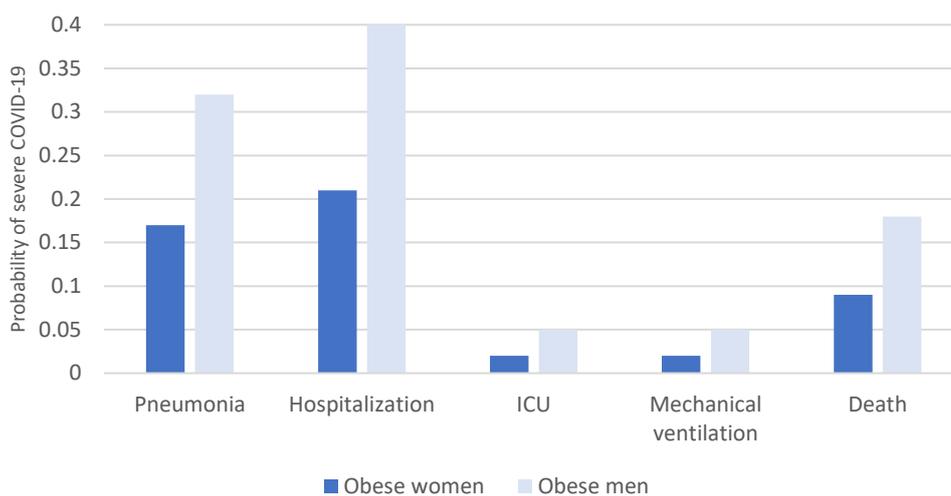
Annex Table 3.2. (2/2) Robustness checks: Inclusion of months-state fixed effects in the main specifications
(odds ratios)

(2/2)	(1) <i>Logit</i> Pneumonia	(2) <i>Logit</i> Hospitalized	(3) <i>Logit</i> ICU	(4) <i>Logit</i> Intubation	(5) <i>Logit</i> Death	(6) <i>Ordered logit</i> Severity
<i>Municipality characteristics (2015)</i>						
Poverty rate	1.00 (0.004)	1.01 (0.004)	0.99 (0.007)	1.00 (0.004)	1.01** (0.003)	1.01 (0.003)
% people with low education	1.02* (0.007)	1.04*** (0.007)	1.01 (0.01)	1.01 (0.007)	1.02*** (0.005)	1.03*** (0.006)
% people lacking space	1.00 (0.005)	1.00 (0.005)	1.02 (0.009)	1.00 (0.005)	1.00 (0.004)	1.00 (0.004)
% people lacking social security	1.00 (0.004)	1.00 (0.003)	1.01 (0.005)	1.01 (0.004)	0.99** (0.003)	1.00 (0.003)
Population (thousands of inhabitants)	1.00 (0.00005)	1.00 (0.00004)	1.00 (0.00007)	1.00 (0.00006)	1.00* (0.00004)	1.00 (0.00004)
Population density (inhabitants/km ²)	1.00 (0.0000007)	1.00 (0.0000005)	1.00 (0.000001)	1.00 (0.0000007)	1.00 (0.0000003)	1.00 (0.0000004)
Political alignment	0.85 (1.1)	0.25 (0.2)	0.17 (0.3)	0.16 (0.2)	0.061* (0.08)	0.34 (0.3)
<i>Health system capacity in municipality</i>						
Number of hospitals per 1 000 inhabitants	0.040* (0.06)	0.042 (0.07)	0.14 (0.4)	0.013 (0.03)	0.0094*** (0.01)	0.060 (0.09)
Number of doctors in hospitals per 1 000 inhabitants	1.02 (0.02)	1.00 (0.02)	0.97 (0.04)	0.99 (0.02)	1.01 (0.02)	1.01 (0.02)
Number of ICU beds per 1 000 inhabitants	1.06 (0.5)	1.22 (0.5)	1.69 (1.2)	1.68 (0.8)	1.06 (0.4)	1.07 (0.4)
N	479963	479963	479963	479963	479963	479963
Pseudo R ²	0.19	0.25	0.14	0.13	0.28	0.16
State FE	No	No	No	No	No	No
2 months*State FE	Yes	Yes	Yes	Yes	Yes	Yes
Clustering	Municipality	Municipality	Municipality	Municipality	Municipality	Municipality

Notes: Exponentiated coefficients; The category of reference for the socioeconomic status is Public hospital for formal workers; Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

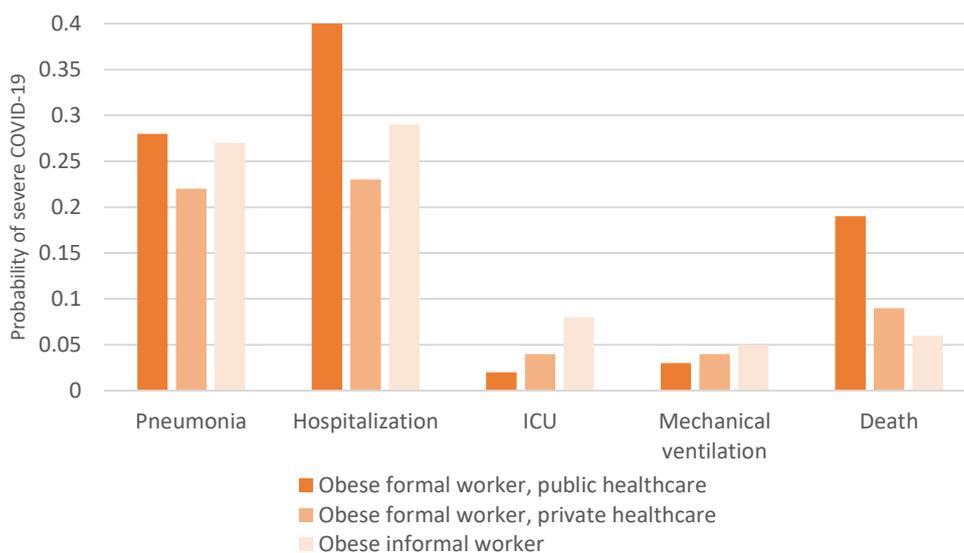
Annex 3.C. Heterogenous effects of obesity by sex and type of healthcare

Annex Figure 3.1. Probability of severe COVID-19 for obese men and obese women (adjusted predictions)



Source: Authors' elaboration based on Secretaría de Salud (2020), Datos abiertos - Información referente a casos de COVID-19 en México (database), available at: <https://datos.gob.mx/busca/dataset/informacion-referente-a-casos-COVID-19-en-mexico> (version 9th August 2020).

Annex Figure 3.2. Probability of severe COVID-19 for obese formal workers and obese informal workers (adjusted predictions)

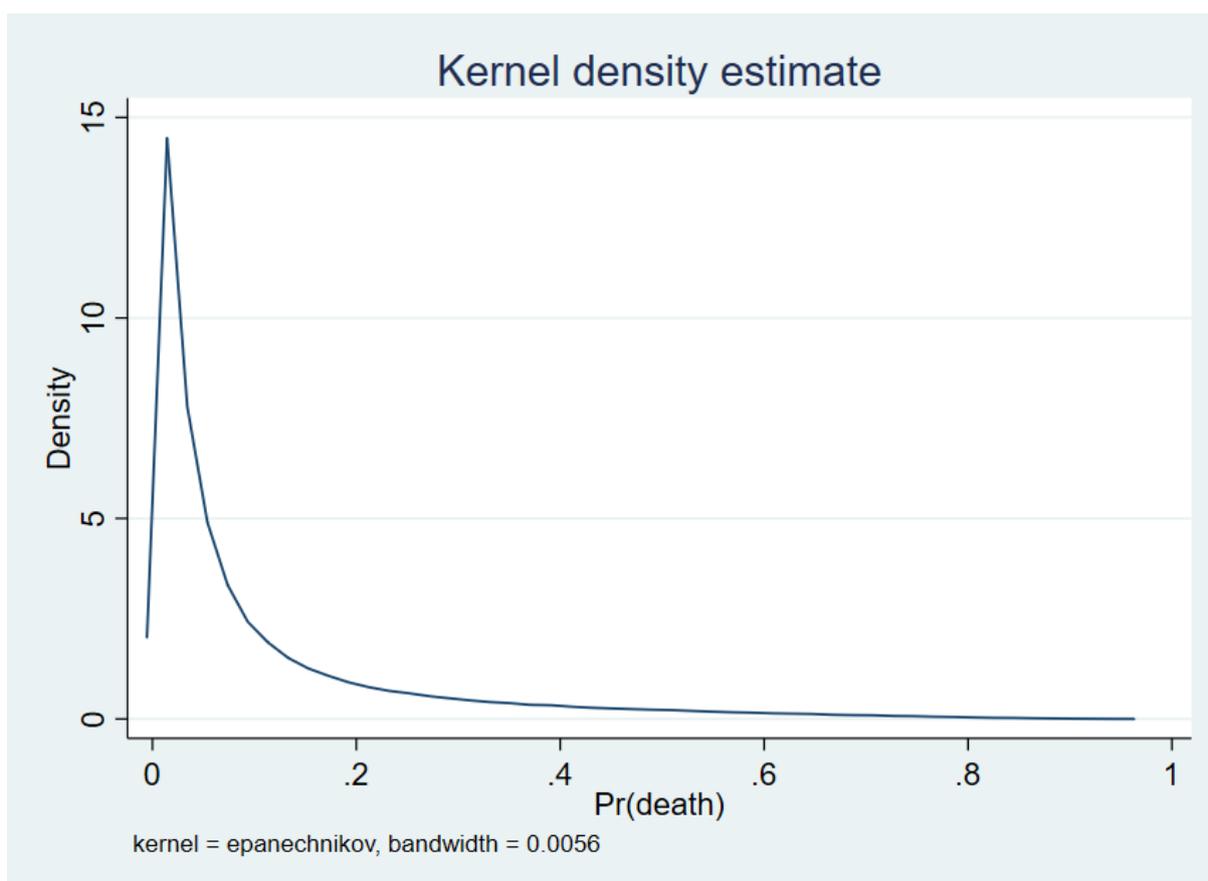


Source: Authors' elaboration based on Secretaría de Salud (2020), Datos abiertos - Información referente a casos de COVID-19 en México (database), available at: <https://datos.gob.mx/busca/dataset/informacion-referente-a-casos-COVID-19-en-mexico> (version 9th August 2020).

Annex 3.D. Choice of the probability threshold to predict COVID-19 deaths

To adjust the goodness of fit of our estimation of COVID-19 death, we determine the probability cut-off that matches the best the number of deaths that we observe in the data. In the sample, 10.9% of COVID-19 patients died. After our estimation, the distribution of the predicted probabilities of death (Annex Figure 3.3) shows that 4% of the sample is concentrated above the threshold of 0.5, while 10.6% is accumulated above the predicted probability of 0.3. As it better fits the observed number of deaths in the sample, we choose to assign $death_{pred} = 1$ or $death_{noob_{pred}} = 1$ when the model predicts death with a probability superior or equal to 0.3 (see Section 3.5.1).

Annex Figure 3.3. Distribution of the predicted probabilities of COVID-19 death

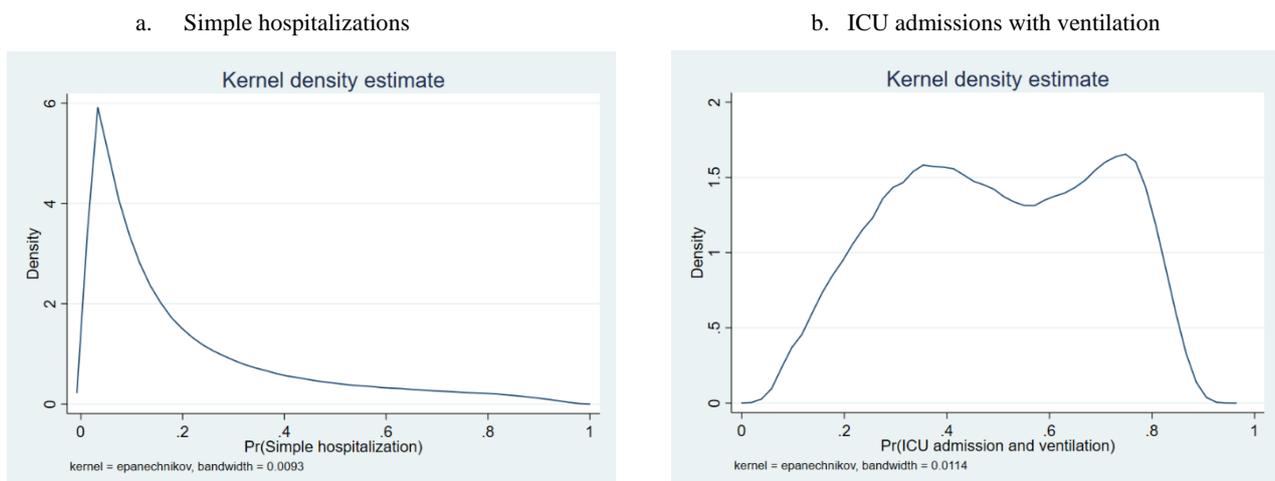


Source: Authors' elaborations based on data from Secretaría de Salud (2020).

Annex 3.E. Choice of the probability thresholds to predict COVID-19 hospitalizations

To adjust the goodness of fit of our estimation of COVID-19 hospitalizations, we determine the probability cut-off that matches the best the number of (simple and severe) hospitalizations that we observe in the data. In the sample, 23.9% of COVID-19 patients experienced simple admissions in the hospital. After our estimation of simple hospitalizations, the distribution of the predicted probabilities (Annex Figure 3.4, panel a) shows that only 15.2% of the sample is concentrated above the threshold of 0.5, while 24.3% is accumulated above the predicted probability of 0.37. As it better fits the observed number of simple hospitalizations in the sample, we choose to assign 1 to the predicted hospitalizations and 1 to the predicted hospitalizations in the case of no obesity when the model predicts hospitalization with a probability superior or equal to 0.37 (see Section 3.5.1). Regarding more severe cases of hospitalizations, we observe that 51.4% of COVID-19 patients required an admission in ICU along with mechanical ventilation. After the estimation, we find that 0.5 is the probability threshold that matches the observed frequency of severe hospitalizations the most (Annex Figure 3.4, panel b).

Annex Figure 3.4. Distribution of the predicted probabilities of COVID-19 hospitalizations



Sources: Authors' elaborations based on data from Secretaría de Salud (2020).

Annex 3.F. Hospitalization costs and health expenditure calculations

Annex Table 3.3. Hospital costs and health expenditure linked to obesity and COVID-19

		Extra number of patients	Hospital costs per patient ^{a, b} (USD)	Extra health expenditure for society (USD)	Extra health expenditure per patient ^c (USD)	Extra health expenditure for government ^c (USD)
Lower bound	Simple hospitalizations	5 463	5 713	31 210 119	2 342	18 413 970
	ICU & ventilation cases	8 537	22 000	187 814 000	9 020	110 810 260
	Total	14 000		219 024 119		129 224 230
Upper bound	Simple hospitalizations	8 455	5 713	48 303 415	2 342	28 499 015
	ICU & ventilation cases	8 716	22 000	191 752 000	9 020	113 133 680
	Total	17 171		240 055 415		141 632 695

Sources: Authors' calculations based on Secretaría de Salud (2020), Datos abiertos - Información referente a casos de COVID-19 en México (database), available at: <https://datos.gob.mx/busca/dataset/informacion-referente-a-casos-COVID-19-en-mexico> (version 9th August 2020), and on IMSS (2019), "Costos Unitarios por Nivel de Atención Médica actualizados en el año 2020", Diario Oficial de la Federación, Acuerdo AS3.HCT.271119/329.P.DF, 30th December 2019.

Notes:

^a Hospital costs per patients include: diagnostic tests, radiology tests, treatment medical visit, patient-day hospitalization cost (either simple or ICU) – as well as all physicians' fees, medication, medical equipment and maintenance associated to the abovementioned services.

^b In IMSS Official Journal data, costs were provided in Mexican peso. We converted them in USD using the MXN-USD exchange rate on 28th December 2020: $MXN\ 1 = USD\ 0.05$.

^c Using data from OECD (2019a), we assumed the average repartition of healthcare costs between the government and the patients: the government takes care of 59% of all health expenses, while the remaining 41% are at the charge of the patients.

General Conclusion of the Thesis

Ensuring food security and nutrition for all is a major challenge of our time. For the last decade, undernourishment and obesity have been on the rise worldwide, while the ongoing COVID-19 pandemic has put the world at risk of a new global food emergency. This thesis studied food security and nutrition in the contexts of Peru (Chapters 1 and 2) and Mexico (Chapter 3) to help design better policies against hunger and malnutrition and to demonstrate the crucial role of good nutrition as a source of health resilience.

The first chapter estimated the impact of decentralizing the Peruvian Complementary Food Program on its efficacy to increase calorie consumption at the household level. Using a difference in difference approach, the analysis showed that due to opposing proximity and capacity effects, the decentralization policy generated heterogeneous outcomes across the territory that, overall, led to a positive regional convergence in calorie consumption. These findings revealed that decentralization policies should always consider the capacity of local authorities.

The second chapter assessed the effect of urban mobility, through vehicle ownership, on food security and diet diversity in Peruvian cities. Using panel data models to control for unobserved household characteristics, the results revealed a significant positive association between mobility and food security outcomes. More precisely, the analysis supports that clean and affordable modes of transport, such as bicycles, are a better option to enhance food security and nutrition.

Finally, the third chapter shed light on the essential role of good nutrition as a source of health resilience, particularly in the context of the COVID-19 pandemic. Through a series of logistic regressions applied to detailed official registers of COVID-19 cases in Mexico, this study demonstrated that obesity has been a significant and direct driver of COVID-19 severity. The results also showed that obesity substantially worsened the impact of the pandemic in terms of human losses and healthcare expenditure. Overall, the chapter highlights the urgent need for more effective policies to tackle obesity and improve nutrition.

Policy implications and recommendations

The findings of this thesis have policy implications that can be regrouped into three broad recommendations to improve food security and nutrition policies and outcomes. First, policies should be designed and implemented through a local and bottom-up approach, which requires better coordination and support between local and national governments. Second, they should take into account the interconnectedness of food security and nutrition with other sustainable development objectives, finding synergies between objectives can result into reinforced long-term progress. Third, policies should promote and incentivize transformative change particularly in reshaping production food systems and consumption food patterns across the world.

Localizing objectives, policies, and actions for food security and nutrition

The risk of food insecurity and malnutrition is unequally distributed across the world, with regions and cities within the same country being exposed to different forms and levels of food insecurity. Therefore, supporting the need for more localized policies and actions that could help design solutions adapted to local populations' characteristics, needs, and challenges.

Indeed, this thesis supports the use of bottom-up approaches in policymaking to allow a more active participation of all levels of government, private organizations, NGOs and citizens, to design more realistic and effective actions towards a durable reduction in hunger and in obesity at a larger scale. Local policymaking should nevertheless always be in coordination and cooperation with the national government, including the co-creation of local capacity and financial resources needed to manage the devolved responsibilities.

While policies and programs to eradicate food insecurity require applying the local lens, international cooperation remains key to share resources, good practices, data and knowledge on the localization of policymaking towards sustainable development. In particular, this work supports the UN and OECD call for a more localized approach to the SDGs, including through decentralized cooperation, to enhance our chances to achieve the global goals of the 2030 agenda (OECD, 2020a; United Nations, 2016).

Considering the interdependence of food security and nutrition with other Sustainable Development Goals

Long-term food security and good nutrition for all human beings cannot be achieved at the expense of other dimensions of sustainable development. Numerous trade-offs and synergies can be identified between the 17 Sustainable Development Goals (SDGs). However, achieving one SDG at the expense of other SDGs would result in a fragile and short-term solution as all SDGs are interconnected and imbalances in one part of the system will sooner or later break the whole system. In this sense, finding long-term solutions for food security and nutrition implies considering positive synergies with other SDGs.

With the analysis proposed in Chapter 2, this thesis underlines some potential synergies in policymaking to overcome the dual issue of food insecurity and environmental risks in cities. The economic literature has shown for a long time that urbanization and economic growth go hand in hand, as cities foster labor productivity, innovation, and increase the supply of goods (including food), services, infrastructure, and amenities (Duranton and Puga, 2020). Across countries and regions of the world, the higher the level of GDP, the larger the share of the population living in cities, and more precisely in large metropolitan areas (OECD, 2021). Although urbanization favors economic growth, it can also lead to poor sustainable development (OECD, 2018). Indeed, unplanned urbanization can come with tremendous negative repercussions, such as rampant inequalities, congestion, safety issues, as well as high levels of air pollution – which all contribute to reduce life quality and notably good nutrition, while aggravating the risk of morbidity and premature death (OECD, 2021; Duranton and Puga, 2020).

The COVID-19 pandemic provides another relevant example of interdependencies between food security objectives and other sustainable development goals. The way the world produces, consumes and trades food is directly affecting the biosphere and the environment, and therefore determines the risk of emergence of new infectious diseases (particularly zoonotic diseases, i.e. bacterial, viral or parasitic pathogens jumping from animals to humans), such as the SARS-CoV-2 virus that causes the COVID-19 disease. According to existing evidence, around 60% of emerging infectious diseases come from zoonotic infectious agents (Jones et al., 2008), which is directly related to poor protection and management of the natural environment

(e.g. deforestation and unsustainable agriculture), low standards for animal care in the livestock farming sector, and low controls on the quality of drinking water (WHO, 2020). The regulation of human activity in areas with wildlife and the adoption of sustainable agriculture practices have an important role to limit future environmental and health risks, and thus to indirectly ensure food security and decrease poverty by preventing the emergence of crises such as the COVID-19 pandemic (OECD, 2020b).

Food security and nutrition in the short- and long-term cannot be achieved if food systems do not ensure environmental protection. By exploiting positive synergies in terms of health, food and the natural environment, the world has the opportunity to developing a new food system that relies more on local production and consumption to ease the access to nutritious food while also safeguarding the planet.

Leveraging lessons from the COVID-19 crisis to reshaping global food systems towards local-based diets

Beyond showing the burden of obesity on health, the COVID-19 pandemic also has revealed numerous caveats in the global food system, including its inability to ensure sufficient and nutritious food for everyone. Policymakers should use the momentum, and the lessons from the ongoing COVID-19 crisis, to push for transformative action on the current way of consuming and producing food. This includes integrating food security and nutrition as an essential pillar in the recovery plans, and supporting small and local producers and consumers.

To make durable progress towards food security and nutrition worldwide, policymakers, citizens but also private companies of the food industry, must work hand in hand to profoundly reshape global food system (United Nations, 2020; Jurgilevich et al., 2016). Currently, the global food system is highly unequal, prevents access to fair-priced food products to millions of people, and push billions into obesity and overweight as it disproportionally offers high-processed and low-nutritious food. Besides its fragility to shocks (which the COVID-19 crisis has made even more visible) (Béné, 2020), the global food system is also one of the most important drivers of climate change – this sector alone generates one third of all greenhouse gas emissions worldwide and threatens biodiversity through deforestation and extensive agriculture (United Nations, 2020). What is more, the food system clearly advantages large

producers, mono-specialized agriculture, and powerful intermediates and distributors, over small, family-owned, and sustainable farming.

Empowering small producers and consumers at the same time through a return to short and local agri-food circuits is key to achieve better food security and nutrition across the world (Chiffolleau and Prevost, 2012; Berti and Mulligan, 2016). In industrialized economies, promoting more local food systems is among the most essential solutions to achieve sustainable food production, thanks to smaller agricultural exploitations that better respect the natural cycle of the biodiversity; and to improve nutrition, through fewer intermediaries between the producers and the consumers, which would enhance the distribution of fresh products at a fairer price.

In developing countries, local agri-food systems should be redirected towards a more diversified subsistence agriculture to exit the current dominant pattern of product specialization for exports (often monoculture, such as cacao or coffee in West Africa) inherited from and imposed by colonial trade policies that profoundly affected the way people, in the former colonies, eat and produce (Lavallée and Lochard, 2015; Christensen, 2014). By reducing the dependency of the populations on expensive and volatile imports of staple food products (e.g. wheat or rice), the promotion and the subvention of local food systems would help develop an agriculture more adapted to local conditions (e.g. droughts and floods) and thus ensure a better access to local quality products at affordable prices.

Reshaping global food systems through governments' interventions and engagement of the private sector in the agri-food industry could significantly be leveraged if the populations were better informed about the long-lasting consequences of malnutrition. Many countries (including Peru and Mexico) already implement public programs to disseminate information on food and nutrition (e.g. through food labelling on packaging) and massive media campaigns to raise awareness on the impacts of nutrition on health at the individual level. Such policies must be reinforced and better adapted to local contexts as they have the power to reduce the risk of morbidity and the economic repercussions of malnutrition (OECD, 2019).

Limitations and future research

This work contributes to the measurement and understanding of the drivers and consequences of food insecurity and malnutrition. However, more efforts are needed in this field to better measure nutrition, as well as to better understand the new challenges posed by the current COVID-19 crisis, particularly for vulnerable and hardly hit groups such as homeless people and the youth population.

Measuring of nutrition

Chapter 1 mainly focuses on a quantitative dimension of food security as it measures undernourishment and over-nourishment on the basis of calorie intakes and their comparison with household energy needs. Chapter 2 goes further and tries to capture nutrition through a measure of diet diversity. Nevertheless, this indicator is limited and does not precisely consider the combinations and quantities that would generate an ideal measure of nutrient intakes adequacy. Further research could consider better measures of nutrition that take into account the content of each product in terms of nutrients, such as proteins, iron, calcium and other nutrients.

Homelessness and the measurement of food insecurity

This thesis heavily builds on household survey data to measure food security and nutrition in Peru (Chapters 1 and 2). While these data are very useful to understand average living conditions in the population, it inevitably excludes vulnerable groups of the population such as homeless people. Homeless people tend to be “invisible” to household surveys (and even censuses), as they do not have a fixed residence that could be part of a household survey design. Yet, homeless people generally suffer from deep food insecurity, hunger, malnutrition, and sometimes even from a “hunger-obesity paradox” as they have sporadic access to very low-nutritive foods (Smith and Richards, 2008; Gundersen et al., 2003; Whitbeck et al., 2006). Homelessness is especially acute in cities (the focus of Chapter 2) as urbanization is associated with high population density and thus with reduced urban space and higher costs of land and housing (Duranton and Puga, 2020). Already affected by high economic and social exclusion, homelessness across the world is about to grow even more due to the COVID-19 pandemic. In

Lima, at least 9 000 people already became homeless due to the pandemic (RT, 2021); in Paris (inner city), almost 3 000 persons were sleeping on the street in March 2021 (Ville de Paris, 2021).

Measuring food security among the homeless population is key to ensure that no one is left behind in the fight against hunger. Yet, surveys conducted in shelters or in the streets and studies about homeless' health and living conditions are scarce and often led at very small scales, while repeated comprehensive analyses would be more useful to scope the issue and to help raise the adequate financial and technical support (Lippert and Lee, 2021). Currently, most of the numbers, trends, and objectives about food security and nutrition simply exclude homeless people, and therefore produce downwardly biased estimations and measures of the real magnitude and repercussions of food insecurity. In high-income countries, the supposed elimination of undernourishment might be hiding the reality experienced by people living on the street or in shelters. More initiatives to measure and understand food security among homeless people are needed to support structural and long-term solutions to this issue.

COVID-19 impact on youth's food security and nutrition

In the context of the COVID-19 pandemic, Chapter 3 sheds light on the crucial role of good nutrition as a source of health resilience. Beyond the direct health impact, the COVID-19 pandemic has also disrupted food supply chains worldwide and pushed millions of people into poverty, putting the world at risk of a new global food emergency (United Nations, 2020) – which will in turn reinforce the health impacts of the pandemic.

While all population groups are somehow impacted by the crisis, the youth population are being particularly affected through the socio-economic repercussions of the COVID-19 pandemic. For children and adolescents, repeated lockdowns and school closures are directly threatening their nutrition by preventing them from programs such as free and affordable meals distributed at schools. Even in the richest cities of the most industrialized countries such as Italy, France and Switzerland, young adults (typically students or new graduates) have been facing increasing difficulties since the outbreak of the pandemic to meet their basic needs, such as paying the rent and buying food. As a result, they increasingly turn to charities and public aid to receive food. In France, several associations such as Linkee and the Order of Malta, or

universities, regularly organize food distributions for students across the country. For instance, at Paris-Dauphine University, the Fondation Dauphine together with the association Le Collectif Solidaire, have started, since March 2021, to distribute free rations of fruits and vegetables to students in need.

Future research could be led to complement the analysis of this thesis regarding food security in the context of the COVID-19 crisis, more precisely to quantify and comprehend the underlying causes of food insecurity and malnutrition among the youth population (e.g. high cost of living, excessive rents, limited job opportunities). Indeed, the immediate consequences on their health (e.g. depression, adoption of riskier behaviors including eating disorders) and socioeconomic outcomes (e.g. increased school dropout, low opportunities for insertion on the labor market) (see for instance Liang et al., 2020; Azevedo et al., 2020; Loades et al., 2020) might all have long-lasting impacts on their health, food security, and well-being. Such research would be key to generate policies to tackle this issue and to minimize the potential negative long-term consequences.

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Trois essais en Economie du Développement : Sécurité Alimentaire et Nutrition

- Résumé de la thèse -

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Soutenue le 5 Juillet 2021

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Résumé de la thèse

La sécurité alimentaire et la saine nutrition relèvent des Droits de l'Homme fondamentaux et sont des conditions essentielles au développement durable (United Nations, 1948 et 2015). Cela implique que chaque personne dans le monde devrait pouvoir accéder à une alimentation suffisante et équilibrée nécessaire pour mener une vie saine et épanouissante. En effet, la sécurité alimentaire et la nutrition dessinent les conditions élémentaires pour permettre une bonne santé, favoriser le développement personnel et assurer le bien-être de chacun tout au long de la vie, permettant ainsi aux sociétés d'être résilientes, prospères et paisibles (FAO, 2016). Une alimentation saine et équilibrée aident les enfants à profiter de leur éducation, les adultes à accéder à de meilleurs emplois plus gratifiants, et chacun à vivre plus longtemps en bonne santé (FAO et WHO, 2018; GLOPAN, 2016; Paciorek et al., 2013).

Et pourtant aujourd'hui, plus de trois milliards d'adultes et d'enfants à travers le monde vivent dans une situation d'insécurité alimentaire ou de malnutrition (FAO et al., 2018; WHO, 2020a), tandis que la pandémie actuelle de COVID-19 expose le monde à une nouvelle crise alimentaire globale, amplifiant l'enjeu de la sécurité alimentaire et de la nutrition comme l'un des défis majeurs de notre temps. Cette thèse étudie la sécurité alimentaire et la nutrition afin d'aider à informer au mieux les choix de politiques publiques contre la faim et de démontrer le rôle crucial de la bonne alimentation comme source de résilience des sociétés.

Sécurité alimentaire et nutrition

La sécurité alimentaire et la nutrition sont assurées lorsque « *toutes les personnes ont, à tout moment, un accès physique, social et économique à une nourriture suffisante, saine et nutritive leur permettant de satisfaire leurs besoins énergétiques et leurs préférences alimentaires pour mener une vie saine et active* » (FAO et al., 2020).

Dans ce sens, la sécurité alimentaire et la nutrition sont une problématique complexe pouvant prendre diverses formes. Tandis que la sous-nutrition (causant un retard de croissance, l'émaciation ou l'insuffisance pondérale) résulte du fait de manger trop peu de calories et de nutriments (par rapport aux besoins de chacun), l'excès de consommation alimentaire ou des

régimes non-équilibrés peuvent mener à d'autres formes de malnutrition comme le surpoids et l'obésité (WHO, 2020b). Tous les types d'insécurité alimentaire et de malnutrition sont souvent interconnectés et tendent à co-exister au sein des mêmes pays, territoires, ménages, et individus (au long de leur vie). Cette thèse couvre certaines des formes d'insécurité alimentaire – notamment la sous-nutrition et l'obésité – et se concentre sur des indicateurs spécifiques parmi les multiples moyens existants pour mesurer la malnutrition.

Bien que le concept de sécurité alimentaire et les enjeux globaux qui lui sont associés soient en constante évolution, l'Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO) reconnaît quatre déterminants clés pour la sécurité alimentaire – à savoir la disponibilité des aliments (i.e. la production et l'offre alimentaire), l'accès aux aliments (i.e. la capacité économique et physique d'obtenir de la nourriture), l'utilisation des aliments (i.e. les conséquences du régime alimentaire sur le fonctionnement de l'organisme) et la stabilité dans le temps des trois dimensions précédentes (FAO, 2008).

Alors qu'il y a soixante ou soixante-dix ans, le principal enjeu pour assurer la sécurité alimentaire concernait les limitations dans la production et l'offre alimentaire, aujourd'hui le monde produit suffisamment pour nourrir chaque être humain sur la planète mais gaspille en déchets plus d'un tiers de la production totale d'aliments (Dury et al., 2019; FAO, 2017). Cela implique que l'obstacle majeur aujourd'hui n'est plus un problème lié à la production alimentaire mais bien à la distribution et aux inégalités d'accès aux aliments (Battersby, 2011; Riley et Dodson, 2016).

En effet, à travers le monde, chaque jour, des millions de personnes rencontrent des difficultés pour accéder à une nourriture qui pourtant existe, est produite et disponible, mais qui finira par être jetée et gâchée. Parce qu'ils sont trop pauvres pour acheter une nourriture suffisante et nutritive, ou bien parce qu'ils ne peuvent pas accéder facilement aux marchés, trop d'individus dans le monde font encore face à la faim et à la malnutrition, alors que – avec les systèmes et les politiques adéquats – cela pourrait être évité. Expérimentés à une plus large échelle, les obstacles à un accès suffisant à la nourriture peuvent engendrer des crises à l'échelle de pays ou de territoires tout entiers. En intensifiant les maladies et les guerres, un manque d'accès généralisé à une alimentation saine et équilibrée peut également mettre en péril la santé publique et la paix.

Sous-nutrition et déficit en nutriments

La sous-nutrition (aussi appelée dénutrition) et le déficit en nutriments sont deux formes de malnutrition qui reflètent une consommation d'aliments insuffisante et peu nutritive (i.e. de petites quantités d'aliments de faible qualité nutritive). La sous-nutrition est causée par une consommation en calories inférieure aux niveaux recommandés correspondant aux besoins et caractéristiques de chacun. Ces besoins sont généralement définis par le sexe, l'âge et le train de vie (e.g. le type d'emploi) des individus. Lorsque la consommation en énergie n'est pas suffisante pour mener une vie en bonne santé et dans des conditions saines, la personne est considérée sous-alimentée. Il existe trois conséquences principales à la dénutrition : le retard de croissance, l'émaciation et l'insuffisance pondérale, qui renvoient respectivement à de faibles rapports taille-âge, poids-taille et poids-âge. Chacune de ces conditions augmente dangereusement la probabilité de maladies et de décès prématuré, et entrave la capacité des individus à développer intégralement leur potentiel cognitif (WHO, 2020b). Parce que la dénutrition correspond à une consommation d'aliments en trop faibles quantités, elle est également souvent associée à un déficit en micronutriments tels que les vitamines et les minéraux (e.g. iode, vitamine A et fer) (WHO, 2020b).

L'extrême déséquilibre des pouvoirs économiques entre pays en développement et économies industrialisées a fortement contribué à la divergence des niveaux de sous-nutrition à travers le monde. Tandis qu'aujourd'hui la dénutrition est (en grande partie) éradiquée dans les pays à revenu élevé, elle reste un défi considérable pour les populations des pays à revenu intermédiaire ou faible. Depuis 2015, la sous-nutrition a même recommencé à croître dans ces pays – principalement à cause de la persistance de la pauvreté, de l'aggravation et de l'émergence de plus de conflits et de guerres, et de l'accélération des catastrophes naturelles dues à la crise climatique (United Nations, 2018a). Aujourd'hui, près de 820 millions de personnes dans le monde – soit près de 10% de la population mondiale – souffrent de dénutrition. Tandis que la sous-nutrition peut toucher tout le monde, elle est particulièrement dangereuse pour les enfants puisqu'environ la moitié des décès d'enfants de moins de cinq ans sont dus à la sous-nutrition. Dans le monde, 144 millions d'enfants de moins de cinq ans présentent un retard de croissance et 47 millions souffrent d'émaciation (WHO, 2020).

Mesurer la sous-nutrition et la malnutrition dans toute leur complexité est essentiel pour suivre les progrès mondiaux vers les objectifs de sécurité alimentaire et pour informer au mieux les choix de politiques. Il existe de nombreux indicateurs et méthodes pour mesurer la dénutrition. La comparaison de l'apport en calories aux besoins énergétiques de chacun figure dans la liste des indicateurs les plus pertinents. Cet indicateur est amplement utilisé par les gouvernements et les organisations internationales dans la conception des objectifs et le suivi des progrès vers une meilleure sécurité alimentaire (voir les indicateurs proposés par les Nations Unies (UN) pour mesurer l'Objectif 2 « Faim Zéro » dans le cadre des Objectifs de Développement Durable (ODD) (FAO et al., 2018; United Nations, 2018b)). Construire un tel indicateur nécessite des données d'enquête fiables, précises et détaillées, souvent fondées sur des questions liées à la consommation alimentaire des individus par aliment ou type de produit et leur fréquence de consommation. Au-delà des mesures directes de consommation alimentaire, d'autres indicateurs sont utiles pour évaluer la sous-nutrition et ses conséquences, comme les indicateurs d'anthropométrie. En mesurant la taille et le poids, ces indicateurs peuvent rendre compte des retards de croissance, de l'émaciation et de l'insuffisance pondérale. Bien qu'ils soient appropriés pour comprendre certaines conséquences de la dénutrition sur la santé, les indicateurs anthropométriques ne peuvent être utilisés pour identifier la source de la sous-nutrition en termes d'accès à la nourriture. Pour cette raison et pour la disponibilité des données, cette thèse s'appuie principalement sur des indicateurs d'apports en calories et leur comparaison aux besoins énergétiques de chacun pour étudier la sous-nutrition au niveau des ménages.

Surpoids et obésité

Avec l'intensification de la mondialisation, de l'urbanisation et des inégalités, et la nouvelle hégémonie de l'industrie des produits transformés, d'autres formes de malnutrition telles que le surpoids et l'obésité sont devenues une nouvelle menace pour la santé des sociétés à travers le monde entier, y compris pour les populations des pays en développement.

L'Organisation Mondiale de la Santé (OMS) définit le surpoids et l'obésité comme « une accumulation anormale ou excessive de graisse corporelle qui représente un risque pour la santé » (WHO, 2020a). La cause caractéristique de l'obésité et du surpoids se trouve dans l'apport excessif et inadapté de nourriture (souvent relié à la consommation d'aliments à forte

valeur énergétique, hautement concentrés en graisse, sucre et sel) par rapport aux besoins en énergie déterminés par le niveau d'activité physique de chacun.

La croissance de l'industrie agroalimentaire et l'accélération de la mondialisation, de l'urbanisation et des progrès technologiques à travers le monde ont favorisé ensemble l'adoption de modes de vie sédentaires et néfastes pour la santé, tel que la dépendance aux moyens de transport motorisés (qui réduisent l'activité physique). Des modes d'alimentation de plus en plus déséquilibrés se sont également installés suite à l'offre colossale de produits alimentaires transformés (et ultra-transformés) – à faible valeur nutritionnelle (e.g. faible teneur en micronutriments comme les vitamines ou les minéraux) – plus accessibles à tous puisque disponibles à des prix relativement faibles, faciles à préparer et souvent prêts à consommer (WHO, 2020a; Dury et al, 2019; OECD, 2019a; Monteiro et al., 2013; Pi-Sunyer, 2002).

Avec plus de deux milliards d'adultes en situation de surpoids ou d'obésité à travers le monde, cette nouvelle épidémie de malnutrition s'est rapidement répandue à la fois dans les pays en développement et dans les pays à revenu élevé (Dury et al., 2019; FAO et WHO, 2018). Aujourd'hui, 40% de la population mondiale souffrent de surpoids et 13% souffrent d'obésité. De même que pour la sous-nutrition, l'épidémie de surpoids et d'obésité a tendance à toucher plus durement la population jeune, et surtout dans les pays en développement. Dans le monde, plus de 38 millions d'enfants de moins de cinq ans et 340 millions d'adolescents souffrent actuellement de surpoids ou d'obésité (WHO, 2020a; FAO et WHO, 2018).

Bien que l'épidémie d'obésité et ses comorbidités se soient répandues à un rythme impressionnant à travers la planète entière depuis les trente dernières années, les habitants du continent américain – et plus particulièrement ceux vivant aux Etats-Unis et au Mexique – ont été les plus affectés. Sur le continent américain, 62% et 26% de la population étaient respectivement en surpoids et obèse en 2015 ; des taux significativement plus élevés que dans d'autres régions du monde, comme en Asie où le taux d'obésité approche les 5% (OPS-WHO, 2015; OECD, 2019a; Ramachandran et al., 2012). Au-delà des moyennes nationales, les dommages engendrés par l'obésité se répandent aussi de manière inégale à l'intérieur-même des pays et affectent de manière disproportionnée les groupes les plus vulnérables comme les ménages à faible revenu et les femmes – reflétant ainsi des inégalités sociales et d'éducation déjà existantes (OECD, 2017).

Mesurer l'obésité et le surpoids suscite moins de discussions que la mesure de la dénutrition. L'indicateur standard pour identifier le surpoids et l'obésité au niveau individuel est l'Indice de Masse Corporelle (IMC) (c'est-à-dire le ratio entre le poids en kilos et la taille en mètres au carré). Pour des populations adultes, la classification usuelle de l'IMC indique le surpoids quand le ratio est supérieur à 25 kg/m², et l'obésité lorsqu'il excède 30 kg/m². Une catégorisation plus nuancée de l'IMC peut également être adoptée afin de différencier l'obésité modérée (IMC entre 30 et 35 kg/m²) de l'obésité sévère (IMC au-delà de 35 kg/m²). Des indicateurs complémentaires peuvent être utilisés pour identifier l'origine de l'obésité, comme l'apport en calories par rapport aux besoins de chacun ou la diversité du régime alimentaire (pour rendre compte de la qualité de l'alimentation). Pour étudier le surpoids et l'obésité, cette thèse se fonde principalement sur une mesure de l'excès en calories par rapport aux besoins ainsi que sur des données d'IMC.

Pourquoi est-il important d'étudier la sécurité alimentaire et la nutrition ?

Chacune des formes d'insécurité alimentaire et de malnutrition est associée à des conséquences dévastatrices, immédiates et à long-terme, sur la santé des individus et leur bien-être. Les gouvernements, les organisations internationales et la société civile aspirent à éradiquer l'insécurité alimentaire de manière formelle depuis le milieu du 20^{ème} siècle mais la problématique persiste et même continue à se répandre, sous d'anciennes comme sous de nouvelles formes, aidée par l'émergence de nouvelles crises globales, y compris la pandémie de COVID-19.

Continuer à fournir la recherche sur la sécurité alimentaire et la nutrition est essentiel pour aider à améliorer les conditions de vie de milliards d'individus à travers le monde. En effet, afin d'informer au mieux et de concevoir des politiques publiques efficaces, il est crucial de comprendre les causes changeantes de la malnutrition et ses répercussions sur les sociétés et la santé publique. De plus, documenter les tendances de la sécurité alimentaire et de la nutrition peut aider à créer des synergies avec d'autres objectifs de développement au niveau mondial, y compris les actions pour protéger la planète.

Les conséquences dévastatrices de l'insécurité alimentaire sur la santé et sur le développement socio-économique

La sous-nutrition et l'obésité génèrent des conséquences dévastatrices à court- et à long-terme pour la santé, le bien-être et le développement personnel. L'insécurité alimentaire intensifie la vulnérabilité des individus aux maladies – y compris à la COVID-19 – ainsi que le risque de décès prématuré, compromet leurs conditions socio-économiques et leur qualité de vie.

La dénutrition et le déficit en nutriments sont tout particulièrement nuisibles lorsqu'ils sont vécus pendant l'enfance ou même *in utero* (Neelsen et Stratmann, 2011). Dans les pays en développement et à revenu intermédiaire, la sous-nutrition (sévère ou non) est responsable de 45% des décès chez les enfants de moins de 5 ans (WHO, 2020b). Expérimentées au stade de fœtus ou très tôt dans la vie, la sous-nutrition et la malnutrition peuvent générer un mécanisme appelé « empreinte métabolique » selon lequel les conditions d'alimentation à l'aube de la vie prédéterminent le risque de développer des maladies plus tard à l'âge adulte (FAO et al., 2018). Cette période de la vie (et ce jusqu'à l'âge de deux ans) est déterminante pour le développement personnel futur puisque c'est à ce moment qu'a lieu la croissance la plus importante du corps et du cerveau (Dewey et Begum, 2011).

Lorsque certains micronutriments (par exemples vitamines et minéraux) font défaut à l'organisme, celui-ci réduit la production d'éléments chimiques, tels que les hormones ou les enzymes, essentiels à un développement sain du corps et du cerveau. C'est l'une des raisons pour lesquelles la malnutrition altère de manière substantielle le développement physique et cognitif, affecte la capacité des enfants à apprendre et à étudier, et diminue leur capacité à travailler une fois entrés dans l'âge adulte. Des recherches montrent que les individus dénutris *in utero* ou tôt dans leur vie tendent à atteindre des niveaux d'éducation inférieurs, à gagner des revenus plus faibles et à obtenir des emplois de moins bonne qualité (McGovern et al., 2017, Dewey et Begum, 2011; Prendergast et Humphrey, 2014; Maccini et Yang, 2009; Jürges, 2013). De la même manière, les retards de croissance et l'émaciation peuvent générer des effets à long-terme au cours de la vie. Plus précisément, ils endommagent le développement cognitif des individus ainsi que leurs capacités motrices et leur mémoire, affectant ainsi leurs conditions de vie socio-économiques et leur bien-être futurs.

A l'autre extrême du spectre de l'insécurité alimentaire, l'obésité provoque elle aussi de nombreuses conséquences néfastes. Tout d'abord, elle accroît la vulnérabilité des individus à d'autres maladies. Le risque de souffrir d'une maladie non transmissible (MNT) (e.g. diabète, maladies cardiovasculaires, hypertension artérielle) augmente avec l'IMC. L'obésité est donc un facteur de risque pour le développement de MNT, qui sont elles-mêmes devenues aujourd'hui la première cause de mortalité à travers le monde puisqu'elles sont responsables de 71% des décès chez les adultes (WHO, 2020c; FAO et WHO, 2018; GLOPAN, 2016). En plus d'accroître le risque de souffrir d'une MNT, l'obésité altère également le système immunitaire et la capacité de l'organisme à vaincre les infections et les virus. En particulier, l'obésité réduit de manière significative la capacité respiratoire et représente donc une vulnérabilité considérable face aux maladies respiratoires. Alors qu'il avait déjà été montré que l'obésité aggravait l'impact d'épidémies comme celle du H1N1 (van Kerkhove et al., 2011), de nouvelles recherches – y compris cette thèse – démontrent le rôle considérable que joue l'obésité dans l'aggravation de la sévérité de la COVID-19 et la mortalité associée à cette maladie (voir par exemple Sattar et al., 2020; Simonnet et al., 2020).

En plus d'engendrer de sévères conséquences sur la santé physique et mentale, l'obésité est également un facteur d'exclusion et d'inégalités sociales et économiques. Le surpoids et l'obésité donnent lieu à une discrimination conséquente sur le marché du travail. En général, l'obésité est associée à de plus faibles niveaux de revenu, à une moindre probabilité d'embauche, à un chômage de long-terme accru et à des chances réduites d'occuper un poste de direction (Böckerman et al., 2018; Finkelstein et al., 2005; Lindeboom et al., 2010; Norton et Han, 2008). Lorsqu'elle est vécue pendant l'enfance, l'obésité affecte généralement la formation du capital humain par le biais de facteurs sociaux d'inclusion, ce qui altère directement les capacités des individus à intégrer, plus tard, le marché du travail et impacte donc leur revenu et leur bien-être tout au long de leur vie (OECD, 2019a).

Le monde n'est pas en bonne voie pour atteindre une meilleure sécurité alimentaire et une nutrition saine pour tous d'ici 2030

Assurer la sécurité alimentaire et une bonne nutrition pour tous figure au premier plan des agendas mondiaux pour le développement depuis des décennies, avec un accent particulier donné au combat contre la faim dans les pays et régions en développement. L'objectif

d'atteindre la sécurité alimentaire à travers le monde est apparu lors de la Conférence Mondiale pour l'Alimentation de 1974, avec la déclaration selon laquelle « *d'ici dix ans, aucun enfant ne devrait aller dormir en ayant faim, aucune famille ne devrait craindre de ne pas avoir suffisamment à manger le lendemain, aucun être humain ne devrait voir son avenir et ses capacités limités par la malnutrition* » (traduit de l'anglais, United Nations, 1975). Quarante ans plus tard, réduire l'insécurité alimentaire et la malnutrition reste l'un des défis les plus importants de notre temps comme le soulignent les Objectifs de Développement Durable (ODD) dessinés par les Nations Unies – par lesquels les Etats membres s'engagent à « *éliminer la faim, à assurer la sécurité alimentaire à titre prioritaire, et à mettre fin à toutes les formes de malnutrition* » d'ici 2030 (United Nations, 2015).

Malgré des efforts remarquables tant au niveau international qu'au niveau local – certains d'entre eux dignes du Prix Nobel de la Paix comme ceux du Programme Alimentaire Mondial (The Nobel Prize, 2020) –, les données et projections actuelles suggèrent que le monde n'est pas en bonne voie pour atteindre la sécurité alimentaire et une nutrition saine pour tous d'ici 2030 (FAO et al., 2020). Alors que les tendances globales en termes de dénutrition avaient commencé à décroître vers la fin du 20^{ème} siècle, depuis 2015 l'insécurité alimentaire s'accroît de nouveau. Les Nations Unies indiquent qu'entre 2014 et 2018, le nombre de personnes en situation d'insécurité alimentaire dans le monde a augmenté de 23%, amenant aujourd'hui près de trois milliards de personnes à vivre dans la dénutrition, la malnutrition, le surpoids ou l'obésité.

Il reste seulement neuf années au monde pour atteindre son objectif d'assurer une meilleure sécurité alimentaire et une nutrition saine pour tous (ODD 2) avant 2030. Dans l'ensemble, les cibles définies pour la réduction de la faim et de la malnutrition sont encore loin d'être atteintes – par exemple, les Etats membres des Nations Unies se sont engagés à réduire à 82 millions le nombre d'enfants souffrant d'un retard de croissance et à 3% la proportion d'enfants souffrant d'émaciation d'ici 2030. Pourtant en 2019, 144 millions d'enfants de moins de 5 ans avaient encore un retard de croissance et 47 millions étaient en état d'émaciation (soit 7% des enfants dans le monde), tandis que 38 millions étaient affectés de surpoids ou d'obésité. Globalement, près de 30% de la population mondiale souffre encore d'au moins une forme d'insécurité alimentaire (United Nations, 2020a).

Les gouvernements tant nationaux que locaux, les organisations internationales, les acteurs du secteur privé ainsi que la société civile devraient plus que jamais redoubler leurs efforts pour inverser la courbe de la dénutrition et de l'obésité, d'autant que la pandémie actuelle de COVID-19 est une menace supplémentaire pour la sécurité alimentaire et la nutrition des populations, pour leur santé et pour leurs vies. Une attention particulière doit être portée aux plans de récupération massifs qui utiliseront des billions de dollars en ressources publiques. Ces plans devraient intégrer la sécurité alimentaire et la nutrition comme un élément clé pour une reconstruction des sociétés résiliente et durable.

La pandémie de COVID-19 place le monde face au risque d'une crise alimentaire globale

La pandémie de COVID-19 a frappé le monde à une époque déjà grandement incertaine par rapport à l'avenir de la sécurité alimentaire globale. La sous-nutrition et l'obésité étaient déjà en hausse à cause des nouveaux conflits, des catastrophes naturelles dues au changement climatique et de l'expansion de l'industrie agroalimentaire via le commerce mondial. En s'ajoutant à ces problématiques, la pandémie de COVID-19 aggrave aujourd'hui la faim et la malnutrition dans de nombreux pays, plaçant le monde face au risque d'une nouvelle crise alimentaire globale (United Nations, 2020b). Le Programme Alimentaire Mondial estime qu'entre avril 2020 et avril 2021 (soit un an après la déclaration de la pandémie), 110 millions de personnes sont tombées dans la sous-nutrition à cause de la crise de COVID-19 (World Bank, 2021).

La pandémie actuelle exacerbe les inégalités de sécurité alimentaire entre pays, régions et villes, mais également au sein-même de ces territoires, principalement en perturbant les chaînes logistiques alimentaires mondiales et locales, en précipitant nombre d'individus dans la pauvreté, et en contraignant la mobilité et l'accès physique à la nourriture. Les mesures de protection telles que les confinements, les fermetures des magasins et restaurants, ainsi que les contrôles aux frontières renforcés ont considérablement freiné l'économie mondiale et le commerce international. En contribuant à la décélération de la production agroalimentaire mondiale, ces mesures prises à l'aube de 2020 ont directement affecté les revenus et la vie des agriculteurs, et ont restreint la disponibilité et l'accès à des produits frais et de qualité dans de nombreux territoires, notamment dans les villes des pays en développement (United Nations, 2020b).

Depuis le début de l'année 2020, 50 millions de personnes sont tombées dans la pauvreté suite aux conséquences de la crise de COVID-19, et de nouvelles projections suggèrent que ce chiffre pourrait bientôt grimper, pour atteindre entre 150 et 580 millions de personnes (Pereira et Oliveira, 2020; Sumner et al., 2020; United Nations, 2020b; Laborde et al., 2021). Pendant la pandémie, des millions d'individus à travers le monde se sont vus obligés de réduire leur consommation alimentaire pour raisons financières. La diminution des revenus et la hausse des taux de chômage, couplées aux perturbations dans les chaînes logistiques agroalimentaires et aux dépréciations de certaines monnaies (principalement en Amérique Latine et en Afrique) ont contribué ensemble à l'augmentation relative des prix alimentaires, forçant de nombreux ménages à réduire à la fois la quantité et la qualité des aliments qu'ils consomment (United Nations, 2020c).

Au-delà de l'impact direct de la pandémie de COVID-19 sur la consommation alimentaire et la nutrition au niveau individuel, la crise sanitaire affecte également la sécurité alimentaire par des mécanismes plus indirects, par exemple en épuisant une grande part des budgets publics qui en d'autres circonstances auraient pu être alloués au financement de politiques sociales. Si les gouvernements n'intègrent pas les coûts de la malnutrition sur la santé à court- et long-terme, y compris face à la COVID-19 et au risque de pandémies et catastrophes futures, ils pourraient cesser de financer certains programmes et politiques qui interviennent aujourd'hui dans la réduction de la sous-nutrition et de l'obésité. A titre d'exemple, un an après le début de la pandémie, ce sont près de 370 millions d'enfants qui bénéficiaient auparavant de repas gratuits dans leur école qui se voient aujourd'hui exposés à un risque de malnutrition à cause des fermetures des écoles, décidées sans proposition de remplacement concernant l'aide alimentaire qui était apportée aux enfants (United Nations, 2020b).

Tandis que d'un côté, la crise de COVID-19 met sérieusement en danger la sécurité alimentaire à l'échelle mondiale, d'un autre côté, la malnutrition – particulièrement sous la forme de l'obésité – accroît à son tour l'impact négatif de la COVID-19 sur la santé et les pertes humaines. Dans un tel contexte, il est essentiel d'évaluer l'efficacité des programmes d'aide alimentaire existants et de comprendre le rôle de la nutrition dans la résilience des sociétés afin d'informer les décisions et concevoir de meilleures politiques pour permettre une récupération durable à long-terme.

Les principaux sujets abordés dans la thèse

Dans un contexte où la malnutrition ne cesse de progresser et où de nouvelles menaces émergent pour la sécurité alimentaire des individus, il est essentiel d'enrichir nos connaissances sur les facteurs de la sécurité alimentaire et de mieux appréhender l'étendue des avantages à l'assurer pour l'ensemble de la population. Cette thèse étudie la sécurité alimentaire et la nutrition dans les contextes spécifiques du Pérou et du Mexique. Tandis que les cas concernant le Pérou (Chapitres 1 et 2) fournissent un témoignage sur l'efficacité de certains types de politiques (programmes d'aide alimentaire), de gouvernance (décentralisation) et de mobilité (véhicules privés) à améliorer la sécurité alimentaire des ménages, le cas du Mexique (Chapitre 3) démontre le rôle de la bonne nutrition comme source de résilience des sociétés pendant la pandémie de COVID-19.

Par quels moyens améliorer la sécurité alimentaire et la nutrition ?

Les deux premiers chapitres de cette thèse aident à comprendre comment certaines politiques et interventions publiques spécifiques pourraient fonctionner au mieux pour améliorer la sécurité alimentaire et la nutrition des individus. Tandis que le premier chapitre se concentre sur l'impact de la décentralisation de programmes d'aide alimentaire, le second explore le rôle de la mobilité urbaine, par le biais de la possession de véhicules, comme facilitateur d'accès à la nourriture.

Décentralisation et efficacité des programmes publics d'aide alimentaire

Par le biais de son premier chapitre, cette thèse s'intéresse au sujet de l'efficacité des programmes publics d'aide alimentaire lorsqu'ils sont pilotés par les autorités locales plutôt que par les gouvernements nationaux. Plus spécifiquement, le Chapitre 1 évalue l'impact de la décentralisation du programme péruvien de Compléments Alimentaires sur son efficacité à augmenter la consommation en calories des ménages. En plus de documenter l'évolution des apports en calories au Pérou avant et après la décentralisation, le chapitre explore également les canaux par lesquels ce changement dans la gouvernance du programme (passant des mains du gouvernement national à celles des autorités locales) a permis d'améliorer la sécurité alimentaire à travers le pays.

L'analyse suggère qu'en général, selon les caractéristiques des autorités locales, les processus de décentralisation peuvent avoir des impacts soit positifs soit négatifs sur les indicateurs bien-être. Dans le cas du Pérou, cette étude révèle qu'à cause d'un effet « proximité » et d'un effet « capacité » opposés, la politique de décentralisation a généré des résultats hétérogènes à travers le territoire, qui ont finalement abouti à une convergence régionale dans la consommation en calories. Alors que la consommation en calories a augmenté dans la plupart des provinces grâce à une meilleure connaissance des communautés locales par les gouvernements régionaux (effet « proximité » positif), elle a diminué à Lima à cause d'une plus faible capacité des autorités locales par rapport à celle du gouvernement central (effet « capacité » négatif).

Ce chapitre corrobore les conclusions principales de la littérature quant à l'impact des processus de décentralisation sur les indicateurs économiques et sociaux. Un pan de la recherche promeut la décentralisation puisque, sous certaines conditions, celle-ci a le pouvoir de renforcer la démocratie, d'encourager la croissance économique, et de réduire les inégalités territoriales grâce à une plus grande efficacité du secteur public à assurer une meilleure qualité des services publics. L'un des principaux avantages de la décentralisation est qu'elle permet une approche ascendante dans l'élaboration et la conduite des politiques et qu'elle fournit des incitations fortes pour les gouvernements locaux à respecter leurs engagements. Parce qu'ils sont plus conscients des enjeux au niveau local, les gouvernements régionaux ont une plus grande faculté à concevoir et mettre en place des politiques adaptées aux besoins des populations locales, et sont, en ce sens, plus efficaces (OECD, 2019b; Wallis et Oates, 1988; Bardhan, 2002; Leer, 2016). Malgré ces mécanismes avantageux, la littérature identifie plusieurs effets potentiellement préjudiciables issus de la décentralisation. Les principales sources d'inefficacité de la décentralisation concernent le manque de ressources financières et les capacités généralement plus faibles des gouvernements locaux en termes administratifs, politiques et techniques. Au-delà des contraintes financières, les autorités locales peuvent arriver à manquer des compétences appropriées pour mener à bien leurs nouvelles responsabilités (OECD, 2019b; Willis et al., 1999; Falleti, 2005).

Les conclusions de ce chapitre soutiennent que les gouvernements devraient promouvoir une approche plus locale à la sécurité alimentaire et à la nutrition, tout en s'assurant en parallèle

(y compris en fournissant une capacitation adéquate et les ressources nécessaires) que les entités locales aient les moyens financiers et techniques suffisants pour piloter efficacement les programmes décentralisés.

Mobilité urbaine et amélioration de l'accès à la nourriture

Le deuxième chapitre de cette thèse se concentre sur la problématique de l'accès aux aliments – l'une des dimensions fondamentales de la sécurité alimentaire telles que définies par la FAO – et considère la mobilité urbaine et la possession de véhicules comme l'un de ses déterminants potentiels. Plus précisément, l'analyse se demande si les ménages qui bénéficient de plus hauts degrés de mobilité au sein de l'espace urbain ont accès à une alimentation plus abondante et plus variée, et discute la manière dont les autorités péruviennes pourraient utiliser la mobilité urbaine – et en particulier certains types de véhicules – comme levier d'amélioration de la sécurité alimentaire et de la nutrition.

Un faible accès – tant économique que physique – aux aliments fait partie des principaux obstacles à la sécurité alimentaire et à la nutrition dans les villes. La recherche dans le champ de l'accès à la nourriture suggère qu'en plus de la pauvreté et des bas revenus, le manque de mobilité individuelle – et particulièrement l'absence de moyens de transport fiables – peut également menacer la sécurité alimentaire et la nutrition (Coveney et O'Dwyer, 2009). En réduisant le temps et les efforts nécessaires pour atteindre les marchés locaux, les véhicules privés contribuent à diminuer les coûts d'accès aux aliments et constituent un canal substantiel pour permettre une alimentation variée et nutritive.

L'analyse conduite dans le Chapitre 2 révèle une association significative et positive entre la mobilité et les indicateurs de sécurité alimentaire. En outre, l'analyse soutient que des moyens de transport propres et abordables tels que les vélos sont une meilleure option que les voitures pour améliorer la sécurité alimentaire et la nutrition puisqu'il s'agit de véhicules à la fois moins chers et moins polluants. A travers ces résultats, le chapitre rejoint certains des sujets au cœur des agendas mondiaux pour le développement qui promeuvent une urbanisation durable. La question des véhicules et de la mobilité urbaine est en effet étroitement liée aux problématiques du changement climatique, des risques environnementaux sur la santé, des inégalités ainsi que de nombreux autres objectifs qui ont pour but d'améliorer la vie des individus et leur bien-être. Bien que la littérature démontre que posséder un moyen de transport

fiable est essentiel pour assurer un accès continu à une nourriture suffisante et variée (Coveney and O'Dwyer, 2009), tous les types de véhicules ne devraient pas être promus comme un moyen de garantir la sécurité alimentaire. Aujourd'hui, la plupart de villes à travers le monde sont bâties sur un schéma entièrement dépendant de l'utilisation des voitures, générant de graves problèmes sociaux et environnementaux, y compris de pollution de l'air et d'émissions de gaz à effet de serre qui menacent la vie des individus aujourd'hui et celle des générations futures (Giles-Corti et al., 2016).

La mobilité urbaine et l'accessibilité aux aménagements de base sont fortement inégales entre groupes de population et à travers l'espace urbain. Ce sont en particulier les ménages à bas revenu qui manquent généralement d'options efficaces de mobilité et d'accessibilité. Alors que les voitures sont un mode de mobilité onéreux, les vélos (qui sont pourtant plus abordables) ne sont pas utilisables pour se rendre aux magasins alimentaires aussi facilement à travers l'ensemble de l'espace urbain, leurs avantages étant souvent réservés à une partie de la population au sommet de la distribution des revenus qui a tendance à vivre proche des centres urbains où la plupart des investissements en termes d'aménagement urbain sont réalisés. Le chapitre se penche sur cette problématique et trouve que seuls les ménages à plus haut revenu sont capables de tirer avantage de ces modes de transport propres et peu onéreux pour améliorer leur sécurité alimentaire et leur nutrition.

Une nutrition saine est une source de résilience des sociétés

Tandis que les deux premiers chapitres de la thèse se concentrent sur la manière dont des systèmes et politiques spécifiques peuvent améliorer la sécurité alimentaire, le troisième et dernier chapitre explore certains des conséquences et des risques associés à la malnutrition, et plus particulièrement à l'obésité.

Au niveau individuel, les personnes souffrant d'obésité sont plus enclines à développer des comorbidités et certaines maladies contribuant à accroître le risque de décès. Au-delà de la dimension sanitaire, les personnes obèses sont également plus sujettes aux discriminations sur le marché du travail, ce qui réduit leurs chances d'atteindre de meilleurs niveau et qualité de vie. A une échelle plus large, les sociétés ayant une forte prévalence d'obésité, comme le Mexique, sont généralement plus inégalitaires et enregistrent des niveaux d'espérance de vie

plus faibles. À l'inverse, des sociétés où la nutrition est globalement plus saine bénéficient d'une charge de maladies réduite, ce qui les rend plus résilientes face à la plupart des chocs, et notamment face à la pandémie de COVID-19.

Tandis que d'un côté la crise de COVID-19 met grandement en danger la sécurité alimentaire au niveau mondial, de l'autre côté la malnutrition accroît, elle, l'impact de la pandémie de COVID-19 sur la santé de manière substantielle. Le troisième chapitre de la thèse met en lumière le rôle essentiel de la bonne nutrition comme source de résilience des sociétés, particulièrement dans le contexte de la pandémie de COVID-19 au Mexique. Les résultats de cette étude coïncident avec la littérature récente – appartenant surtout au champ médical – qui introduit l'obésité comme un facteur significatif et direct de la sévérité de la maladie COVID-19 et de la mortalité qui lui est associée. Au-delà du fait que l'obésité augmente le risque de comorbidités qui sont elles aussi reliées à des complications de la COVID-19, l'obésité en elle-même est un facteur d'apparition de cas sévères de la COVID-19 étant donné qu'elle compromet la réponse immunitaire et la capacité respiratoires des individus (WHO, 2020c; Sattar et al., 2020).

Le chapitre montre également qu'au niveau des pays, l'obésité accentue de manière conséquente l'impact de la pandémie en termes de pertes humaines et de dépenses de santé. Les sociétés avec de forts taux d'obésité tendent à enregistrer un plus grand nombre de cas sévères de la COVID-19, et à faire face, par conséquent, à des répercussions de la pandémie plus importantes sur leur économie et la santé publique. De manière générale, le chapitre souligne le besoin urgent de politiques plus efficaces pour faire reculer l'obésité et pour améliorer la nutrition, puisque cela permettrait de réduire la charge de morbidité, d'augmenter l'espérance de vie en bonne santé, et de significativement améliorer la vie et le bien-être des individus.

Chapitre 1 : Décentraliser améliore-t-il l'efficacité des politiques publiques ? Le cas du Programme de Compléments Alimentaires au Pérou

Ce chapitre évalue l'impact qu'a eu la décentralisation du programme péruvien de Compléments Alimentaires (PCA) sur son efficacité, et explore les canaux par lesquels ce changement de gouvernance a amélioré la sécurité alimentaire dans les différentes régions du pays.

Depuis les années 1980, de nombreux pays à travers le monde ont initié des processus de décentralisation qui ont remodelé la manière dont les gouvernements répondent aux défis économiques et sociaux. Beaucoup d'auteurs ont dès lors étudié l'impact de la décentralisation sur une large gamme de sujets, comme par exemple sur les institutions, la croissance économique, la pauvreté et l'éducation (voir Basurto et al., 2018; Leer, 2016; Galasso and Ravallion, 2005); cependant, peu de recherches se sont penchées sur l'impact de la décentralisation sur la sécurité alimentaire. Ce chapitre cherche à combler ce manque dans la littérature en apportant des preuves empiriques des effets de la décentralisation sur la sécurité alimentaire.

Garantir la sécurité alimentaire ainsi qu'une bonne nutrition est, aujourd'hui encore, une problématique majeure et en constante évolution de manière globale. Dans le monde, une personne sur dix souffre de la faim et, contrairement à la croyance commune, l'insécurité alimentaire s'est remise à croître dernièrement principalement en Afrique et en Amérique du Sud, à cause des conflits, sécheresses et autres catastrophes engendrées par le changement climatique – le nombre de personnes en état de sous-nutrition s'est accru de 37 millions entre 2014 et 2017 (FAO et al., 2018).

Malgré des progrès remarquables ces dernières années, la sécurité alimentaire et la nutrition restent des sujets importants au Pérou. En 2000, environ un cinquième de la population péruvienne était sous-alimentée, conduisant le gouvernement à créer plusieurs programmes tel que le Programme de Compléments Alimentaires (PCA). Le PCA est l'un des plus anciens et plus importants programmes sociaux dédiés à l'aide alimentaire au Pérou. Son principal objectif est d'améliorer la consommation alimentaire des populations les plus pauvres et les plus vulnérables, en leur fournissant directement des compléments d'alimentation, distribués dans

des centres sociaux administrés par des bénévoles des communautés locales. Depuis sa création en 1992, le PCA était entièrement géré par le gouvernement central. Mais, dans l'objectif d'en améliorer l'efficacité et de s'attaquer aux inégalités régionales en termes de sécurité alimentaire, le gouvernement a décidé de décentraliser le PCA. Entre 2003 et 2014, la gestion du programme a donc été progressivement transférée aux autorités locales du pays.

Afin d'évaluer l'impact causal de la décentralisation du PCA sur la sécurité alimentaire des ménages, nous utilisons un modèle de doubles différences qui s'adapte à la mise en place graduelle de la décentralisation à travers les gouvernements locaux. Nous combinons des données très riches sur la consommation alimentaire des ménages (produits et quantités consommés) avec des données officielles sur les besoins en calories par groupes genre-âge, afin de construire un indicateur de sécurité alimentaire, nommé « l'écart en calories », qui mesure la différence entre la consommation calorique des ménages et leurs besoins en calories. La variable de l'écart en calories peut prendre soit une valeur négative (dans ce cas le ménage souffre d'un déficit alimentaire et est à risque de sous-nutrition), soit une valeur positive (le ménage consomme son minimum requis de calories, ou plus).

Nos résultats indiquent un impact général négatif de la décentralisation sur le surplus de consommation de calories des ménages par rapport au minimum requis. Cependant, l'impact de la décentralisation n'est pas homogène à travers le territoire ; nos estimations montrent que la consommation de calories diminue dans la Province de Lima alors qu'elle s'accroît dans les autres provinces du pays, menant donc à une convergence régionale dans les niveaux de sécurité alimentaire au Pérou. Nos résultats montrent que la décentralisation du PCA a généré en moyenne une diminution de la consommation en calories de 219 kcal par jour par rapport à l'apport minimum requis pour les habitants de la Province de Lima, alors qu'elle a fait augmenter la consommation en calories de 318 kcal par jour au-delà des besoins minimums requis pour les ménages résidant dans les autres provinces (hors Lima).

Nous expliquons ces résultats par l'existence de deux effets opposés provenant de la décentralisation – un « effet proximité » positif et un « effet capacité » négatif. Ces effets sont respectivement provoqués par le fait que d'un côté, les gouvernements locaux ont une meilleure compréhension des communautés locales et des spécificités régionales, relativement au

gouvernement central ; tandis que de l'autre côté, ils tendent à bénéficier de ressources financières, techniques et humaines plus faibles.

Dans les provinces hors Lima, décentraliser le PCA est bénéfique pour la sécurité alimentaire de la population car l'ampleur de « l'effet proximité » positif surpasse celui de « l'effet capacité » négatif. Les avantages associés au transfert du programme aux autorités provinciales – qui sont par essence plus proches des populations locales que ne l'est le gouvernement national – sont plus importants que les potentiels inconvénients liés à une capacité institutionnelle et financière plus faible. De l'autre côté, la décentralisation a un effet négatif sur la consommation en calories à Lima car l'ampleur de l'effet négatif de « capacité » dépasse celui de l'effet positif de « proximité ». La Province de Lima concentre sur son territoire à la fois l'administration centrale et les autorités locales de ses districts. Basés au même endroit, les fonctionnaires des autorités locales bénéficient de la même connaissance de la situation concernant Lima que les agents officiels du gouvernement central ; entraînant un gain proche de zéro dans l'effet de « proximité » à la suite de la décentralisation. En revanche, les autorités locales des districts de Lima ont une capacité technique et financière plus faible que le gouvernement central, ce qui génère un effet de « capacité » négatif après la décentralisation.

Finalement, en incorporant des indicateurs complémentaires de sécurité alimentaire, nous montrons que la convergence régionale dans la consommation de calories au Pérou améliore le bien-être général. Tandis que la décentralisation du PCA a renforcé la consommation de calories dans les provinces hors Lima qui enregistraient initialement de forts taux de sous-nutrition, la chute de la consommation en calories dans les districts de Lima est principalement tirée par les ménages montrant initialement de très hauts niveaux de consommation calorique (les « suralimentés ») et qui passent à des niveaux de consommation plus standards.

Chapitre 2 : La mobilité urbaine permet-elle d'améliorer la sécurité alimentaire et la diversité du régime alimentaire ? Le rôle de la possession de véhicules dans les villes Péruviennes

Ce chapitre explore les liens existants entre mobilité, sécurité alimentaire et diversité du régime alimentaire au sein des villes péruviennes. Il évalue le rôle respectif des véhicules motorisés et non-motorisés dans les schémas de consommation alimentaire des ménages. L'analyse se concentre uniquement sur les zones urbaines du Pérou, particulièrement touchées par des problématiques croissantes en termes de mobilité urbaine et de malnutrition.

Sur les deux dernières décennies, le Pérou a réussi à réduire considérablement ses taux de sous-nutrition. Malgré ces progrès remarquables dans la lutte contre la faim, aujourd'hui plus de deux millions de péruviens n'ont toujours pas accès à une nourriture suffisante, et pâtissent d'un apport déficient en calories (World Bank, 2018). Simultanément, la population urbaine est de plus en plus exposée à des produits agroalimentaires néfastes pour la santé – souvent industriels, à forte concentration en graisse et en sucre – qui contribuent à renforcer le risque de surpoids et d'obésité (Pia Chaparro and Estrada, 2012; McCloskey et al., 2017; Smith Torres-Roman et al., 2018). Tandis que la pauvreté et les inégalités sont connus pour être les facteurs principaux de l'insécurité alimentaire, les difficultés d'accès physique à une alimentation nutritive (via des moyens de mobilité) peuvent également figurer parmi les causes des nouvelles formes d'insécurité alimentaire dans les villes péruviennes.

La mobilité urbaine au Pérou connaît d'importantes limitations. Les transports publics sont généralement déficients et surchargés, et suivent des chemins inadaptés et inefficaces (OECD, 2016). Pourtant, de nombreux ménages n'ayant pas les moyens de s'acheter une voiture, une grande partie de la population urbaine est dépendante des transports publics ou doit se tourner vers des options de mobilité alternative (comme les scooters ou les vélos). Dans cette situation, l'accès aux aménagements et aux infrastructures de base, notamment aux magasins alimentaires et aux marchés, est difficile et irrégulier. De plus, les véhicules des transports publics sont vieillissants et la possession de véhicules privés ne cesse de croître (parmi les ménages à haut et moyen revenus), ce qui soumet les villes – et particulièrement Lima – à une pression croissante en termes de congestion et d'environnement. Les ménages urbains au Pérou

sont menacés par de forts niveaux de pollution, avec une exposition aux particules fines PM_{2.5} qui avoisine les 37 µg/m³, bien au-dessus de la recommandation de l'Organisation Mondiale de la Santé (OMS) à 10 µg/m³ (OECD-European Commission, 2020; WHO, 2016). Dans ce contexte préoccupant, ce chapitre fournit certaines idées de politiques pour améliorer, dans les villes, la mobilité et l'accès aux aliments tout en réduisant les émissions et la pollution de l'air.

Tandis que la littérature comprend de nombreuses études sur les barrières économiques et sociales à l'accès à la nourriture (e.g. Sen, 1981), l'accès physique à l'alimentation a été peu documenté – et on en sait particulièrement peu sur le rôle des moyens de transport et de la mobilité. Le rôle indépendant de la mobilité (via la possession d'un véhicule) sur la sécurité alimentaire et la nutrition n'a été que très peu exploré dans la littérature. Dans certains cas, l'effet de la mobilité sur la capacité des individus à accéder à la nourriture a en effet été confondu avec les effets du revenu et de la richesse, eux-mêmes fortement reliés à la possession de véhicules. En s'efforçant de démêler l'effet mobilité des effets revenu et richesse associés à la possession de véhicules privés, ce chapitre contribue à combler cette brèche dans la littérature.

Le chapitre utilise les riches données fournies par l'enquête ménages ENAHO pour construire des indicateurs de sécurité alimentaire et de diversité du régime alimentaire. Il explore ensuite les liens entre ces indicateurs et la possession de véhicules au niveau des ménages (c'est-à-dire si le ménage possède une voiture, un vélo ou un scooter). Nous commençons par vérifier ces associations au travers de simples régressions linéaires et modèles Tobit, tout en contrôlant pour le revenu et la richesse des ménages. Cependant, notre spécification préférentielle consiste à exploiter la dimension panel de notre base de données en incluant des effets fixes ménages qui permettent de prendre en compte les caractéristiques inobservées des ménages qui sont invariables dans le temps.

Les résultats révèlent une association significative et positive entre mobilité et sécurité alimentaire. En désagrégeant la possession de véhicules par type, l'analyse soutient que des modes de transport propres et abordables représentent une meilleure option pour améliorer la sécurité alimentaire et la nutrition. En effet, nos résultats montrent qu'avoir une voiture n'est pas essentiel en soi pour accroître l'accès à la nourriture dans les zones urbaines au Pérou, alors que les vélos et les scooters sont pour leur part deux modes de transport qui semblent aider les

familles à atteindre des paniers alimentaires plus copieux et plus équilibrés, bien que dans une mesure modérée (ce qui suggère que la mobilité est un facteur pertinent mais néanmoins secondaire de la sécurité alimentaire). Les effets des vélos et des scooters, bien que significatifs, sont d'une ampleur modérée et sont principalement tirés par les familles à moyen et haut revenus qui tendent à vivre plus proche du centre de la ville par rapport aux ménages à faible revenu, et donc à bénéficier d'espaces urbains plus adaptés à l'utilisation de véhicules non-motorisés et plus petits. Nous vérifions qu'avoir un vélo améliore l'accès à la nourriture seulement lorsque la distance des ménages au centre de la ville est relativement faible (dans les 30 km). Cette conclusion est cohérente avec la littérature montrant que les modes de transport non-motorisés ont tendance à être moins efficaces pour les individus au bas de la distribution des revenus à cause de la forte concentration des revenus dans l'espace urbain (Ortegon-Sanchez and Oviedo Hernandez, 2016).

Les politiques publiques visant à améliorer la sécurité alimentaire et la nutrition via un accroissement de la mobilité des ménages devraient prioriser et favoriser l'utilisation de modes de transport propres, tels que le vélo, par rapport aux voitures. Tandis que les autorités publiques péruviennes pourraient optimiser la mobilité urbaine en investissant dans le système de transports publics, planifier et redessiner la périphérie des villes apparaît également comme une stratégie essentielle pour permettre une meilleure accessibilité aux services et infrastructures, et notamment aux magasins alimentaires proposant des produits diversifiés et de qualité. Ceci permettrait d'améliorer la praticabilité du vélo à travers l'ensemble de l'espace urbain et d'étendre son utilisation à d'autres groupes de la population, pour ainsi faciliter l'accès à la nourriture chez les ménages plus pauvres résidant aux abords des villes.

Chapitre 3 : Quel poids du coût de l'obésité pendant la pandémie ? Obésité et sévérité de la COVID-19 au Mexique

L'objectif de ce chapitre est double ; premièrement, il s'agit de mettre en lumière le rôle de l'obésité dans l'aggravation de la COVID-19 au niveau individuel, et deuxièmement de quantifier les pertes humaines et les dépenses de santé supplémentaires que l'obésité, combinée à la COVID-19, a engendré durant la première vague de la pandémie au Mexique.

Avec plus de 13% d'adultes dans le monde souffrant d'obésité (WHO, 2020), l'épidémie d'obésité est devenue l'un des enjeux majeurs de notre temps en termes de sécurité alimentaire, de nutrition et de santé publique. L'ascension de l'industrie agroalimentaire des produits transformés couplée à la progression de la mondialisation, de l'urbanisation et des inégalités, a considérablement transformé la façon dont les individus vivent, travaillent et consomment. Plus particulièrement, ces tendances globales ont imposé des modes de vie sédentaires et néfastes pour la santé qui ont conduit à l'accroissement du risque d'obésité. Bien que l'obésité soit devenue un problème de santé à travers le monde entier, certains territoires sont plus impactés que d'autres. Le Mexique par exemple, avec plus de 36% de sa population adulte souffrant d'obésité, est l'un des pays les plus touchés par l'obésité au monde (le deuxième pays le plus touché, après les Etats-Unis) (INEGI, 2018; OECD, 2019a).

L'obésité est associée à de multiples conséquences négatives qui compromettent gravement la santé des individus, leur développement socio-économique et leur bien-être en général. Dans le contexte actuel de la pandémie de COVID-19, ces conséquences sont devenues encore plus évidentes. La littérature médicale récente – par le biais d'expériences caractérisées par des tailles d'échantillons relativement petites – montre que les patients obèses ont plus de risque de développer une forme grave de la COVID-19 après avoir été infectés par le SARS-CoV-2 (voir par exemple Cai et al., 2020; Sattar et al., 2020; Simonnet et al., 2020). Cependant, peu de recherches ont été menées sur des populations plus larges et avec une perspective spécifique de santé publique. Ce chapitre vise à combler ce manque dans la littérature en étayant le rôle de l'obésité dans la sévérité de la COVID-19 et en estimant le supplément de dépenses de santé associé à l'obésité pendant la première vague de la pandémie au Mexique (ici définie du 1^{er} janvier 2020 au 9 août 2020).

Le chapitre utilise les données publiées dans le registre des cas et décès de COVID-19 mis à jour quotidiennement par le Ministère de la Santé mexicain et qui contient des données individuelles détaillées sur les résultats de tests pour la COVID-19 ainsi que des informations médicales complémentaires – concernant notamment la présence de comorbidités chez les patients, comme l’obésité, le diabète ou l’hypertension. Nous procédons à une série de régressions logistiques contrôlant pour plusieurs caractéristiques pertinentes au niveau individuel et au niveau local, comme par exemple la capacité des systèmes de santé locaux. Par ces estimations et des tests de robustesse qui nous permettent d’atténuer certains biais d’endogénéité, nous démontrons que l’obésité est un facteur significatif de la sévérité de la COVID-19 au niveau individuel, même après avoir tenu compte d’autres comorbidités également déterminantes de la sévérité de la maladie. Les patients en situation d’obésité ont 50% plus de risque de développer une forme grave de la COVID-19 par rapport aux patients non-obèses, en moyenne.

Nous observons également un coût très lourd de l’obésité sur la mortalité liée à la COVID-19 au Mexique. Notre modèle prédit qu’entre 4 200 et 5 900 décès dus à la COVID-19 auraient pu être évités entre janvier et août 2020 s’il n’y avait eu aucun cas d’obésité au Mexique. Cela suggère que l’obésité est responsable de 8 à 12% de l’ensemble des décès liés à la COVID-19 pendant la période d’observation. La forte prévalence de l’obésité dans la population mexicaine contribue à rendre le SARS-CoV-2 plus meurtrier au Mexique que dans d’autres territoires à travers le monde et explique en partie la forte mortalité liée à la COVID-19 observée dans le pays.

Les résultats suggèrent également que l’obésité et ses implications sur la sévérité de la COVID-19 ont accru les dépenses de santé de 220 à 240 millions de dollars (USD), mettant de nombreuses familles face à des dépenses catastrophiques et générant une forte pression sur le budget de santé publique, puisque les coûts additionnels représenteraient autour de 2% du budget annuel dédié au financement de l’assurance santé universelle au Mexique (Gobierno de México, 2020).

Ce chapitre démontre que les individus souffrant d’obésité font partie des populations les plus vulnérables face à la COVID-19. Les autorités publiques en charge des réponses institutionnelles face à la pandémie devraient donc considérer les personnes obèses comme

l'une des cibles prioritaires de la campagne de vaccination. Dans l'ensemble, nos résultats apportent un éclairage sur le besoin urgent d'actions et de politiques publiques plus efficaces pour faire reculer l'obésité au Mexique. En faisant la lumière sur les coûts de l'obésité qui pèsent sur la population mexicaine, nous espérons que ce travail pourra contribuer à encourager la mise en place des politiques nécessaires à permettre une meilleure nutrition au Mexique.

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RÉSUMÉ

Garantir la sécurité alimentaire et la bonne nutrition des populations est un défi majeur de notre temps. La sous-nutrition et l'obésité se sont accrues et la pandémie de COVID-19 expose aujourd'hui le monde à une nouvelle crise alimentaire. Cette thèse étudie la sécurité alimentaire et la nutrition dans les contextes du Pérou (Chapitres 1 et 2) et du Mexique (Chapitre 3), afin d'informer au mieux les choix de politiques publiques et de démontrer le rôle crucial de la nutrition dans la résilience des sociétés.

Le premier chapitre évalue l'impact de la décentralisation du programme péruvien de Compléments Alimentaires sur son efficacité à augmenter la consommation en calories des ménages. Utilisant une approche en doubles différences, l'analyse montre que par des effets proximité et capacité opposés, la politique de décentralisation a généré des résultats hétérogènes à travers le territoire qui, globalement, ont permis d'aboutir à une convergence régionale positive dans la consommation en calories.

Le deuxième chapitre étudie l'effet de la mobilité urbaine, via la possession de véhicules, sur la sécurité alimentaire et la diversité du régime alimentaire dans les villes péruviennes. En s'appuyant sur des modèles de données panel pour contrôler des caractéristiques inobservées des ménages, les résultats révèlent une association positive entre mobilité et sécurité alimentaire. Plus précisément, l'analyse soutient que des modes de transports propres et bon marché, tels que les vélos, sont une meilleure option pour améliorer la sécurité alimentaire et la nutrition.

Enfin, le troisième chapitre met en lumière le rôle de la nutrition comme source de santé et de résilience, plus précisément dans le contexte de la pandémie de COVID-19. Par une série de régressions logistiques appliquées aux données des registres officiels des cas de COVID-19 au Mexique, l'étude démontre que l'obésité a été un facteur aggravant de la COVID-19 et qu'elle a largement contribué à alourdir les pertes humaines et les dépenses de santé liées à la pandémie. Le chapitre souligne le besoin urgent de politiques efficaces pour lutter contre l'obésité et améliorer la nutrition.

MOTS CLÉS

sécurité alimentaire et nutrition, sous-nutrition, obésité, décentralisation, mobilité urbaine, COVID-19

ABSTRACT

Ensuring food security and nutrition for all is a major challenge of our time. For the last decade, undernourishment and obesity have been on the rise worldwide, while the ongoing COVID-19 pandemic has put the world at risk of a new global food emergency. This thesis studies food security and nutrition in the contexts of Peru (Chapters 1 and 2) and Mexico (Chapter 3) to help design better policies against hunger and to demonstrate the crucial role of good nutrition as a source of health resilience.

The first chapter estimates the impact of decentralizing the Peruvian Complementary Food Program on its efficacy to increase calorie consumption at the household level. Using a difference in difference approach, the analysis shows that due to opposing proximity and capacity effects, the decentralization policy generated heterogeneous outcomes across the territory that, overall, led to a positive regional convergence in calorie consumption.

The second chapter assesses the effect of urban mobility, through vehicle ownership, on food security and diet diversity in Peruvian cities. Using panel data models to control for unobserved household characteristics, the results reveal a significant positive association between mobility and food security outcomes. More precisely, the analysis supports that clean and affordable modes of transport, such as bicycles, are a better option to enhance food security and nutrition.

Finally, the third chapter sheds light on the essential role of good nutrition as a source of health resilience, particularly in the context of the COVID-19 pandemic. Through a series of logistic regressions applied to detailed official registers of COVID-19 cases in Mexico, this study demonstrates that obesity has been a significant and direct driver of COVID-19 severity. The results also show that obesity substantially worsened the impact of the pandemic in terms of human losses and healthcare expenditure. The chapter highlights the urgent need for more effective policies to tackle obesity and improve nutrition.

KEYWORDS

food security and nutrition, undernourishment, obesity, decentralization, urban mobility, COVID-19