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DEVELOPMENT DISSERTATION BRIEF

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MARKETS AND MARKETPLACES: ESSAYS ON ACCESS AND TRANSFORMATION IN REMOTE RURAL ECONOMIES

EBA

Markets and Marketplaces: Essays on Access and Transformation in Remote Rural Economies

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Tillmann von Carnap is currently a postdoctoral scholar at the Center for Food Security and the Environment at Stanford University. In the fall of 2024, he will take up a position as Assistant Professor at University of Oslo. Tillmann von Carnap is interested in Development Economics and Economic Geography, with a focus on the role of trade infrastructure for rural development in Sub-Saharan Africa. In a current project, he uses high-resolution satellite imagery to map rural marketplaces and track their activity over time as a real-time measure of economic activity in remote areas.

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Introduction

Following an extraordinary global reduction in extreme poverty over the last century, progress on eliminating poverty has slowed. The latest figures show that the number of people in extreme poverty has in fact risen in sub-Saharan Africa. The remaining pockets of poverty worldwide are increasingly concentrated in remote rural areas.

My thesis "Markets and marketplaces: Essays on access and transformation in remote rural economies" (2022) consists of four chapters asking how people in such regions can efficiently get access to income opportunities and essential services. Empirically studying remote rural areas is challenging, because – almost by definition – data is scarce. Measurement of outcomes is typically based on farm or household surveys, which provide great detail, yet often capture only specific moments in time and are, due to their costly collection, limited in scope. Therefore, another theme connecting the chapters in the thesis is the reliance on various forms of satellite data which can help overcome critical data scarcities.

This Development Dissertation Brief (DDB) focusses on chapters 2 and 3 of my thesis. The former introduces a novel methodology to detect periodic market-places and track their size over time, there-by giving us an unprecedented opportunity to describe trends in rural economic activity in real-time and in areas where formal data collection systems are lacking. Chapter 3 builds on this methodology, both empirically studying how marketplaces – a widespread, age-old institution of rural trade – have shaped the economic development of their surroundings in Kenya over the last 50 years and, through the lens of a formal model, how they interact with other infrastructure providing market access.

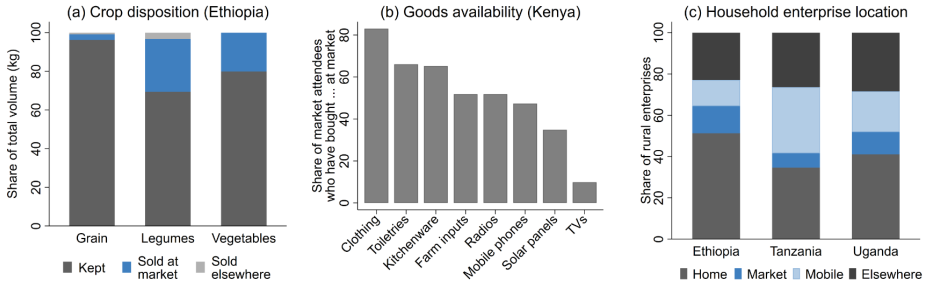
In the rest of the thesis, chapter 1 uses a readily constructed, locally tailored machine learning algorithm to show that, in the context of Northern Mozambique, market access constraints are limiting agricultural intensification in areas relatively close to existing population centres, whereas more re-mote regions appear to have limited potential to benefit from typical transport infrastructure investments. Chapter 4 builds on an existing application of satellite data – remotely measured rainfall – intersected with data from a randomized control trial to study whether community-based healthcare provision can mitigate adverse health effects of climate change.

Remotely-sensed market activity as a high-frequency economic indicator in remote rural areas

There is growing awareness among policymakers and researchers that effective spatial and temporal targeting of social policies as well as their rigorous evaluation require localized, timely and relevant data (World Bank, 2021). With the majority of the world's poor depending on agriculture and informal businesses for their livelihoods (ILO, 2018), information on these sectors across space and time is particularly valuable. However, available sources often have limited applicability to many policy and research questions as they are collected infrequently (e.g. nationally representative household surveys), do not cover the informal sector (e.g. tax records) or do not pick-up short-term fluctuations (e.g. remotely-sensed nightlights or other wealth indicators). This data scarcity is particularly salient for policies that are implemented over large areas, such as road improvements or social safety nets. Here, both local and aggregate effects may be of interest, but unless dedicated data collections are implemented at often considerable cost, the coverage of available data may be insufficiently sparse.

In this section, I present a scalable method generating a high-frequency economic activity measure for rural areas of developing countries. I focus on changes in attendance of rural periodic markets using satellite imagery. Periodic markets are a common and persistent feature of the rural economy across low- and middle-income countries. Typically, buyers and sellers meet once or twice per week in a public space, trading a wide range of goods and services such as vegetables, clothing or kitchenware (Mukwaya, 2016; Kithuka et al., 2020; Balineau et al., 2021). In Ethiopia, for example, the vast majority of crops produced for sale are sold at marketplaces, as opposed to other, more formal channels, and up to a fifth of rural household enterprises operate at marketplaces (Figure 1). By aggregating otherwise thin supply of rural products and demand for urban goods, these markets function as key locations of trade within and across regions. Beyond direct trading, marketplaces are also where small-scale businesses in sectors such as food processing or tailoring operate, taking advantage of these periodic population gatherings.

Figure 1: Marketplaces as a manifestation of the market economy



Source: LSMS-ISA data from 2018/2019.

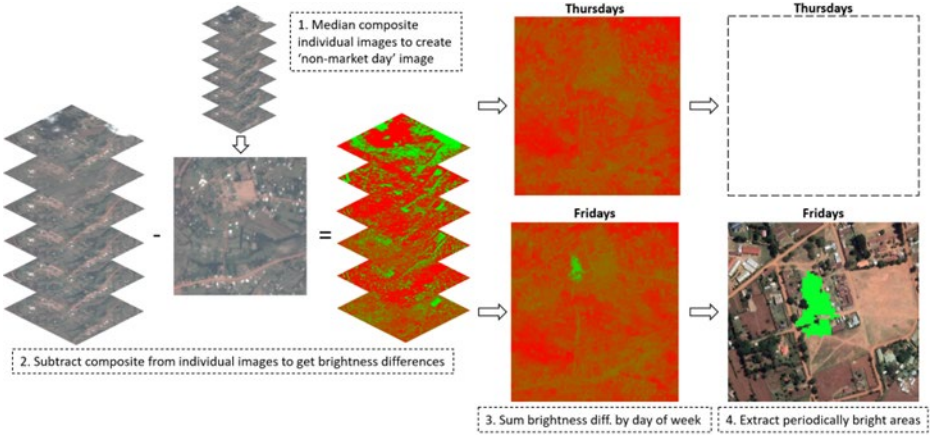
Due to these markets' close link with rural economies, trends in their activity – i.e. changes in the presence of buyers and sellers – are informative about local economic conditions: busier marketplaces reflect that attendees either have more income to spend, more goods to sell, or both.

Observing this activity at scale across large geographies thus holds potential to better understand local and aggregate impacts of social policies. Data collection using satellite imagery furthermore allows researchers and policymakers to understand on-the-ground conditions when information is otherwise hard to come by, such as during violent conflict or after extreme weather events.

Tracking rural market activity requires knowledge of marketplaces' locations. However, comprehensive and up-to-date market maps are rarely publicly available. This lack of maps does not necessarily reflect authorities' lack of interest in marketplaces, but rather stems from their nature as modes of trade in informal, non-urbanized economies where traditional, ground-based monitoring systems can be prohibitively expensive to maintain.

My method addresses this challenge by first screening imagery of locations where markets may be expected to exist for indicative reflectance patterns (Figure 2). I exploit two characteristic features of periodic markets for their detection. Firstly, stalls, vehicles and crowds are distinctly bright in images taken on market days when compared to the bare ground of the marketplace and surrounding areas on other days. Secondly, markets' regular occurrence provides a temporal signal to distinguish them from other, idiosyncratic changes in the imagery over time.

Figure 2: Detecting periodic marketplaces from high-frequency satellite imagery based on their reflectance patterns



Source: Developed by the author.

I use PlanetScope optical imagery which is available since 2016 with global, daily coverage at three meter resolution. The high frequency and deep stack of the imagery allows me to exploit these regularities: in essence, the method screens stacks of imagery for contiguous areas within candidate locations for periodic changes in brightness. I perform various exercises to show that the method indeed (i) reliably identifies marketplaces where they exist and (ii) does not pick up other periodic events such as religious gatherings. While I focus on applications in Kenya and Ethiopia, the method can in principle be applied in any relatively cloud-free context where open-air periodic markets exist.

In order to assess the accuracy of market detection, I first examine whether the method indeed identifies weekly markets and not other periodic events such as religious gatherings – a low false positive rate of market detection. I show that detected locations of periodic activity are centered on roads or village squares, as opposed to around known places of worship. Secondly, I show that the

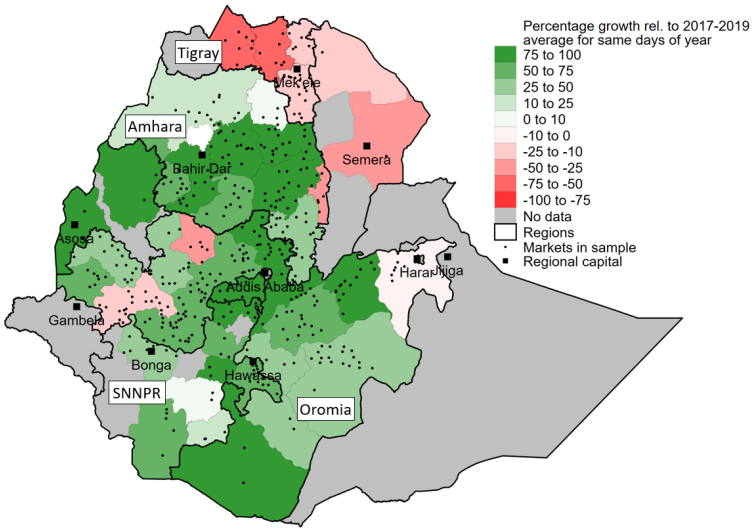
method identifies a high share of actual markets – a high true positive rate – by comparing the detected markets and market days against a validated ground sample in Western Kenya (Bergquist and Dinerstein, 2020). Currently available ground-truth data does not allow me to test, however, whether the true negative rate – not detecting a market when there is none – is also high, as maps of locations without markets are not available. It is reassuring in this respect that, conditional on detecting a market in the validation dataset, I always confirm the stated market day instead of detecting features on other days. On such non-market days, market locations should look similar to places without markets.

Equipped with a sample of marketplaces in a region of interest – in my case East Africa – I then turn to measuring market activity. For this, I measure the density of participants within the detected market area by extracting the median brightness across all pixels contained therein from each image of a given location. I interpret this measure as tracking *changes* in local economic activity or 'GDP' – places with larger markets may not necessarily have higher GDP levels than places with smaller or without markets; for a given market, however, days on which measured market activity is high compared to other days likely reflect increased goods exchange and revenue by market participants.

I focus my applications on East Africa. In Ethiopia and Kenya, I gather between two and five observations for market activity per marketplace and month, depending on seasonal cloud coverage and market frequency. To illustrate that the remotely-sensed market activity can indeed be interpreted as a measure of changes in economic activity, I present three applications using data from 954 detected marketplaces in Kenya, Ethiopia and Uganda, maps of which were not previously publicly available. First, I correlate quarterly changes in market activity with estimates for sectoral GDP in Kenya. I find that the novel indicator varies between quarters at similar magnitudes as official agricultural production statistics, though differences between the two indicators in their

respective timing of seasonal peaks suggest that remotely-sensed market activity can provide higher temporal resolution. Second, I show how in areas with rain-fed, small-scale agriculture, market activity is seasonal overall, and levels of harvest-season market activity increase with levels of rainfall during the previous growing season. Third, I illustrate the effects of external events that can be expected to impede economic conditions on market activity, focusing on government-mandated lockdowns during the COVID-19 pandemic and the ongoing war in Tigray and other regions of Ethiopia.

Figure 3: Market activity changes in Ethiopia – January 2022 relative to pre-2020 levels



Source: Developed by the author.

Measuring rural market activity expands the toolkit for data collection in developing countries in various dimensions. Existing micro-level data often capture great levels of detail, but has limited temporal and spatial coverage

(e.g. DHS, LSMS surveys), can be difficult to obtain from data proprietors (e.g. call detail records), or does not cover the informal economy (e.g. tax records, tariff data). Remotely-sensed data has some advantages over these aforementioned data sources (see Donaldson and Storeygard, 2016 for a review). Compared to nightlights – a commonly used indicator of economic wealth (Henderson et al., 2012) – market activity is available at a sub-yearly frequency, is more likely to pick up short-term changes in economic conditions including downward adjustments, and tracks even non-electrified places. Beyond nightlights, other recent work has constructed local poverty estimates from very-high resolution imagery using machine learning (Jean et al., 2016; Huang et al., 2021). Here, market activity provides a downward-elastic indicator related to short-term income flows, as opposed to more long-term wealth implicitly proxied by village structures and rooftop materials which are commonly used for wealth prediction in this literature. Finally, rural market activity provides a useful complement to the upstream measures of production provided by the agricultural yield estimation literature (Lobell et al., 2018). Overall, by providing large-scale coverage and local measures of market activity, the method can contribute to our understanding of spatial patterns of economic development, as for example in the following chapter.

Rural marketplaces and local development

Rural areas in low-income countries rarely look like centres of economic dynamism. In some places, however, this changes drastically if you visit at the right time: On market days, sleepy villages awake into bustling hubs where farmers sell their produce, local entrepreneurs offer services and itinerant traders display goods that are otherwise unavailable. As places where buyers meet sellers, such periodic gatherings are focal points of the 'market access' often argued to be a driver of improved rural welfare (FAO, 2018).

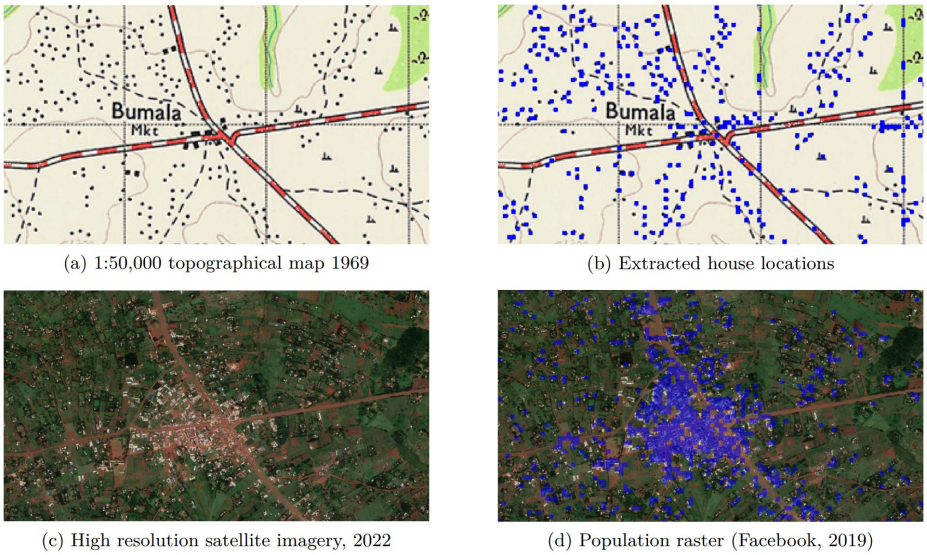
Yet, neither do we know how marketplaces shape their surroundings – because we lack data on markets' locations as well as long-term development indicators – nor how they interact with other means of market access, because canonical spatial models abstract from trade happening at dedicated locations. I make progress on both questions in this chapter, focusing on Western Kenya over the last five decades.

"Excuse me, where do I find the nearest market?" For most people in rural areas, this question would be easy. In Ethiopia, for example, marketplaces are by far the most common location for farmers to sell their produce, and many types of goods, e.g., clothing, electronics and farm tools, are frequently purchased there. Few governments, however, maintain consistent market maps, and existing ones can get outdated quickly. This lack of data does not seem to reflect lack of interest: 42 of 47 Kenyan county development plans, for example, mention marketplace-related policies. But it can be prohibitively costly to collect and maintain data on this informal mode of trade away from urban centres.

I use the method from Chapter 2 to describe markets in my study area: the typical contemporary market is quite large at 5,200m^2 and takes place biweekly on Wednesdays and Saturdays. I complement the contemporary market maps with a unique country-wide listing of periodic markets from 1970.

Having established where markets are and used to be, I turn to measuring development around them. This is challenging because we lack information about outcomes at small geographical scales, including for individual marketplaces. I adopt an approach from economic history which argues that in agricultural economies, places with higher population density are likely better off: they can either sustain more people through more productive farming or have diversified beyond agriculture (Hanlon & Heblich, 2022).

Figure 4: Historical and contemporaneous population density measures



(a) 1:50,000 topographical map 1969

(b) Extracted house locations

(c) High resolution satellite imagery, 2022

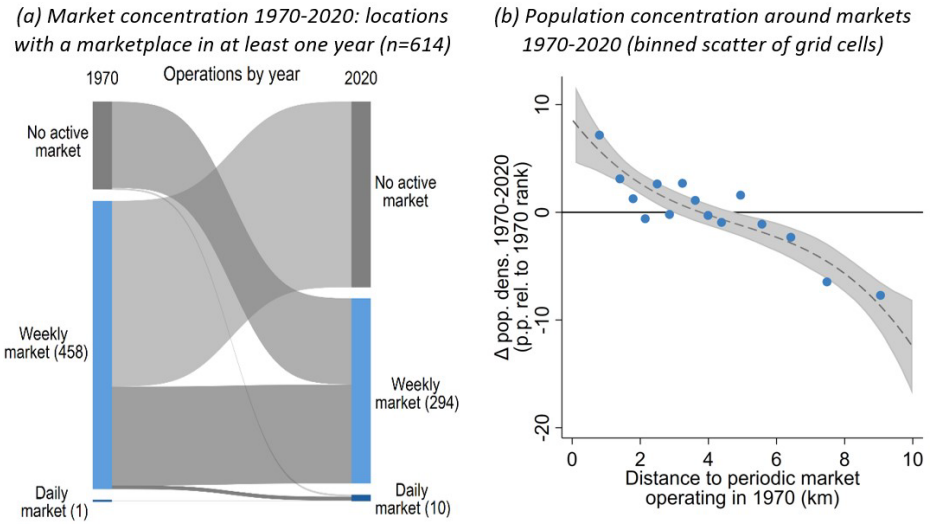
(d) Population raster (Facebook, 2019)

To measure population density, I collect and digitize topographical maps from around 1970, on which cartographers painstakingly dotted the locations of individual houses using high-resolution aerial photography. I use a pattern detection algorithm to identify each house, and match these data with their modern, computer vision-based equivalent derived from high-resolution satellite imagery (Figure 4).

To account for measurement differences across time and space, I rank each of 5,200 2.5km x 2.5km grid cells covering Western Kenya according to their house density. Then I can construct a measure that captures whether house density grew faster in a given grid cell than in others around it, moving up the ranking. I also construct for each cell and year the distance to the closest existing marketplace. With this data, I establish a set of novel facts on rural marketplaces and local development.

Despite a fourfold increase in rural population and agricultural trade liberalization, there are 30% fewer marketplaces operating today than in 1970 (Figure 5a). This average masks substantial shifts: 60% of markets that operated in 1970 no longer exist today, while half of today's markets emerged where European-origin settlers owned plantations and traditional marketplaces were largely absent. The median distance from one market to the next increased from 4.5 to 6 kilometres and only a small minority of weekly markets turned into daily ones.

Figure 5: Two stylized facts on marketplaces and local development



Source: Figures developed by the author and published in the original thesis.

In contrast to the reduction in marketplaces, population on average concentrated both close to and right at 1970 marketplaces (Figure 5b). I show that this is unlikely to be driven by location fundamentals other than the marketplaces, such as pre-existing industries or road connections. In particular,

I only compare grid cells within the same percentiles of 1970 population density and access to large towns. Here, grid cells within 1km of a 1970 market on average moved up 7.2% between the 1970 and 2020 rankings, whereas cells between 1km and 10km on average moved down 0.4%. In the modern data, a 7.2 + 0.4 = 7.6 percentage point rank difference corresponds, at median population density, to an 11% higher population density.

Furthermore, even places that were barely populated to begin with but had a market grew faster than their surroundings, especially if their market persisted. These patterns suggest that at least some marketplaces contributed to the emergence and growth of rural towns. The new data show that some, but not all marketplaces form nuclei for rural development. For this insight to be useful to policymakers, we need to understand how these patterns arise. To do this, I turn to a spatial model that also provides a sandbox for policy exercises.

In the model, agents either work in a central city producing tradable ('shoes') and non-tradable goods ('haircuts') with increasing returns to scale, or they farm food in the city's surrounding rural area with constant returns. Everyone wants to consume all three goods, so they have to be transported at a cost from where they are produced to where agents live. I depart from the canonical way of modelling trade flowing directly between locations of production and consumption, and instead integrate marketplaces as trade hubs that can emerge away from urban centres.

Based on real-world characteristics, marketplaces have two functions: first, bulking goods for transport enables scale economies in shipping goods to and from the central city. Second, market-day gatherings make it worthwhile for producers of non-tradables to visit the market: initially as itinerant vendors and, once local demand grows enough, producing in-situ. With scale economies in transportation, farmers may prefer distant, large markets over nearby, small

ones, leading to trade concentrating in fewer markets. Cheaper transport to and from marketplaces also makes farming near them attractive with lower consumer and higher producer prices.

Furthermore, concentrated demand at marketplaces can support local production ('rural towns'). While tradable goods are cheap to import and hence unlikely to be produced locally, producers of non-tradables benefit from easy access to gatherings of potential customers. This is especially relevant for locations that are relatively shielded from larger and more efficient industries in the city.

The canonical model suggests that improving transport links between cities and the hinterland only deepens regional specialization, slowing the growth of potentially beneficial rural towns instead of kickstarting local structural transformation (Ingelaere et al., 2018). Evaluations of road projects often find similar results (Asher and Novosad, 2020; Faber, 2014). But adding marketplaces to the picture suggests that complementary transport infrastructure can sometimes foster the emergence of towns, depending on the types of places it connects to.

Better connections between the marketplace and the city expose aspiring entrepreneurs at markets to import competition, reducing the incentives for local production. Better connections between the marketplace and its hinterland, however, enlarge the customer base and foster local non-agricultural production. These results suggest that policymakers who wish to promote rural structural transformation should invest in local access to trade hubs, rather than solely focussing on connections to larger cities.

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How can people in remote rural regions that live in poverty efficiently get access to income opportunities and essential services? That is one of the questions that this thesis tries to answer. “Markets and marketplaces: Essays on access and transformation in remote rural economies” uses various forms of satellite data to answer this question, which is a way of overcoming challenges with data scarcities.

Hur kan människor i glesbygd som lever i fattigdom få bättre tillgång till service och bättre inkomstmöjligheter? Det är en av frågorna som denna avhandling försöker besvara. “Marknader och marknadsplatser: Förändring och ekonomisk utveckling i glesbygd” använder olika former av satellitbilder för att besvara denna fråga, för att hantera utmaningar med bristen på tillförlitlig data.

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