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Abstract

The past three decades have witnessed a dramatic expansion of artisanal and small-scale gold mining (ASgM), transforming the economic and spatial opportunities of tens of millions of people. We show how this transformation has shaped urbanization in Sub-Saharan Africa since 1975. Our empirical strategy exploits plausibly exogenous variation in ASGM activity generated by the interaction between international gold-price shocks and local geological suitability for artisanal extraction, which we combine with new continent-wide data on urban population, nighttime lights, and household welfare. Although ASgM is commonly viewed as a rural activity, we find that ASgM exposure significantly accelerates urbanization, accounting for roughly five percent of total urban population growth. This expansion takes the form of extensive, decentralized urbanization: new towns emerge in remote, infrastructure-poor areas, while the growth of pre-existing towns and cities does not accelerate. Both new and existing urban entities exposed to ASgM exhibit lower living standards and limited industrial activity. Overall, ASgM contributes to a fragmented pattern of urbanization without structural transformation.

Keywords: Urbanization; Artisanal and small-scale mining; Gold; Spatial Development
JEL codes: O13, O55, Q32, R11, R12, R14.

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1 Introduction

Classical migration theory predicts that urbanization follows rising urban–rural income gaps (Harris and Todaro 1970). In contrast, recent evidence from countries such as Tanzania, Sudan, and Guinea suggests that rural income gains driven by artisanal and small-scale mining (ASM)[1] may have initiated urban growth (Bryceson and MacKinnon 2012). ASM relied on an estimated 49 million workers in 2022, a fourfold increase since 1999 (IGF 2017; Hruschka 2022), inducing significant population movements between occupations and places for miners, workers along the mines' value chain, and their families. With gold prices at their historical highest and large share of the minerals critical to the energy transition produced in artisanal mines, the boom is not expected to stop any time soon.

The implications of this mining boom for spatial development and the nature of Africa's urban transition are theoretically ambiguous. Resource-driven income shocks may affect spatial development through three channels: beyond the income equalization channel that should reduce rural-urban migration (Harris and Todaro 1970; Bazillier and Girard 2020); a market channel may generate local (boom)towns (Sanchez de la Sierra 2020; Fafchamps et al. 2017), while a liquidity channel would ease migration to larger cities (Bryan et al. 2014).

This paper documents how artisanal and small-scale gold mining (ASgM), the predominant form of ASM, has shaped the urbanization of Sub-Saharan Africa (SSA) since 1975. Africa is a unique and urgent setting to study this question. As Africa witnessed a remarkable increase in the number of artisanal miners and workers employed in related activities in the past 30 years (Boafo and Arthur-Holmes 2025).[2], ASgM impacts will depend on what these workers and their families do. Given ASgM specificities, combining limited rents to the central government, a high labor intensity, and an extractive nature, we can hardly expect to learn from the impacts of industrial resource extraction or agriculture to know how ASM impacts spatial development.[3] Finally, since 1950, Africa has been the fastest urbanizing

1. ASM, a labor-intensive and often informal method of extracting minerals, is "[today] the predominant nonfarm rural income in many parts of the world" (Perks et al. 2024).

2. ASgM, the most prevalent ASM form (Hruschka 2022), now employs an estimated 11 million miners in Africa alone (Hruschka 2022), with at least three times more people working in supporting activities (World Bank 2020), and each of these workers having an average of five family dependents (*Minerals and Africa's Development* 2016).

3. Compared with industrial resource extraction, artisanal and small-scale gold mining (ASGM) yields limited fiscal rents for central governments, yet employs an order of magnitude more workers, reflecting its

continent in the world (United Nations 2019). However, Africa's urbanization trajectory diverges from standard urban economic models as it unfolds despite limited observable gains in agricultural productivity or industrialization (Gollin et al. 2016; Henderson and Kriticos 2018). This urbanization is also characterized by stark polarization between megacities and small towns, with populations under 50,000 (Figure A.1). Such a polarization may be a concern if small towns are too small for the emergence of large industries and scale economies (Turner and Weil 2025). We ask whether exogenous shocks linked to ASgM activities have slowed-down, accelerated, or re-allocated endogenous urbanization forces.

The analysis is based on the combination of three novel and comprehensive data sources that cover all Sub-Saharan African countries from 1975 to 2020. First, we construct a comprehensive panel of urban population and agglomerations recorded in grid cells of 0.1×0.1 degree (11 by 11km at the Equator), covering all of Sub-Saharan Africa since 1975. The latest release of the GHS data (European Commission 2021) allows us to compute and track over time, for each pixel, both the total local (urban) population and the existence and evolution of a total of 21,218 urban entities, defined as a cluster of pixels with a population of at least 5,000 inhabitants and a population density above 1,500 inhabitants per km2 of permanent land (OECD/SWAC, Africapolis (database); Bellefon et al. 2021). Second, we take urban entities as given and examine the quality of life of urban dwellers. We assess economic activity using nighttime light emissions for the universe of urban entities (Chiovelli et al. 2023), and welfare indicators recorded by the Demographic Health Survey Program for 2,584 urban entities in 40 countries of the continent (Khavari et al. 2021). Finally, we use detailed geological data, combined with annual international gold prices as a source of variation in the potential value of artisanal gold activities at each location (Girard et al. 2025).

The plausibly exogenous variation in ASgM exposure comes from the interaction between global gold prices and local geological suitability for artisanal mining. A significant concern is that as population density increases, it becomes more likely that someone will discover gold and initiate its exploitation. To alleviate this concern, our empirical design builds on

high labor and land intensity (Bazillier and Girard 2020; Hruschka 2022; Girard et al. 2025). In contrast to agriculture, ASgM is less land-intensive and thus more likely to generate dense population concentrations in gold-bearing areas ; but the nonrenewable nature of the resource raises questions about whether these mining-led settlements are primarily temporary or can evolve into permanent towns.

the approach of Girard et al. (2025), who establish that geological suitability is largely uncorrelated with observable overground characteristics such as agricultural potential, rainfall, or temperature.[4] By interacting this time-invariant suitability with global gold price shocks,[5] we isolate changes in potential ASgM intensity that are orthogonal to other local economic trends. We further distinguish artisanal from industrial mining by controlling for large-scale industrial mine activities, although they account for less than 0.3% of gold-suitable areas in our sample. Our approach includes controls for local weather fluctuations, changes in the value of local agricultural activities, high-dimensional fixed effects to account for local idiosyncrasies (including suitability for ASgM), as well as time-variant differences in urbanization patterns within countries (such as windfalls from industrial resource exploitation or a macroeconomic crisis).

We find that exposure to ASgM substantially accelerates urbanization, accounting for roughly five percent of the observed increase in Africa's urban population since 1975. This number represents an extra 11 million people living in urban areas who would otherwise have remained in rural areas. These results reflect extensive rather than intensive urban growth: new, small towns emerge in gold-suitable areas, but existing cities do not expand at a faster rate.

We further investigate how infrastructure connectivity both shapes urban areas emergence, and reacts to their expansion. The strongest urbanization effects occur in initially disconnected areas, and we do not observe any convergence in infrastructure connectivity as ASgM exposure increases. These results are consistent with ASgM exposure leading to a fragmentation of the urban network.

Acknowledging established drivers of urbanization from the litterature, we confirm that the urbanization-ASgM results are primarily driven by the potential value of ASgM activities: they are not confounded by other factors such as local weather shocks, the opening of industrial gold mines, or comovments with other international prices like those of local crops. Finally, our results are robust to alternative specifications of distance-based exposure

4. Transposing to gold the widely used notion of crop suitability (Nunn and Qian 2011). Previous research has established the validity of this measure of ASgM exposure (Girard et al. 2025). While not all gold-suitable locations will host artisanal mines, mining success is likely to be higher in areas that are gold-suitable.

5. ASgM activities depend directly on the international gold price, as artisanal miners' revenues are closely tied to fluctuations in the global gold market (Alvarez et al. 2016; Sanchez de la Sierra 2020); but still, artisanal miners are price-takers.

to gold deposits and to the use of a first-difference estimator that is less sensitive to concerns about non-stationarity.

In the second part of the paper, we document how urban entities characteristics react to ASgM exposure – taking urbanization as given. We find that places more exposed to ASgM do not exhibit any additional economic activity, as proxied by nighttime light emissions (Chiovelli et al. 2023). Focusing on the sample of urban entities that existed already in 1975, in order to abstract away from the fact that some new towns and cities emerged due to ASgM exposure after that period, we find that the towns or cities most exposed to ASgM display a slower growth of NTL per capita than the others. In other words, economic activities in ASgM-exposed urban areas are equivalent to or smaller than those that emerge in other urban areas. This conclusion is reinforced when looking at urban entities with household-level records from the Demographic and Health Surveys: residents from ASgM exposed towns and cities tend to be poorer, with worse water and sanitation amenities, and suffer from higher child mortality, than other urban dwellers (Croft et al. 2023). Furthermore, we find that exposure to ASgM influences employment patterns away from structural transformation, leading to a decrease in employment in the industrial sector.

Taken together, these results suggest that artisanal mining has been a powerful yet spatially fragmented driver of Africa's urban transition. Consistent with the market channel dominating the income or liquidity channel, the process appears to generate new agglomerations that remain economically marginal, with limited prospects for industrial diversification or productivity gains. This finding connects to the broader concept of "urbanization without structural transformation" (Gollin et al. 2016), suggesting that the recent mining-led urban wave has contributed to a dispersion of population rather than a concentration of productive activity. From a macro-development perspective, this form of decentralized urbanization may have ambiguous welfare implications. On one hand, small mining towns can provide better access to markets, services, and social interaction than both isolated rural settlements or mega-cities (Christiaensen and Todo 2014). On the other hand, the predominance of service and primary-sector employment and the absence of industrial activity imply limited potential for sustained income growth and scale economies (Turner and Weil 2025).

These findings are policy relevant. As the global transition to clean energy intensifies mineral demand (Boafo and Arthur-Holmes 2025), governments will increasingly face the challenge of physically and economically integrating these emergent mining towns into broader urban systems, transforming extractive agglomerations into productive ones.

Our results contribute to three main research strands. The first is the recent research highlighting the specificity of African urbanization patterns. Urbanization occurs at lower income levels than in other continents, with little gain in agricultural productivity and minimal industrialization (Gollin et al. 2016; Henderson and Kriticos 2018). The "urbanization without structural transformation" theory shows how the dynamism of the largest urban areas and capital cities explains part of these original urbanization patterns (Gollin et al. 2016; Henderson and Turner 2020). In parallel, recent data releases indicate that a significant proportion of the urban population resides in small towns (OECD/SWAC, Africapolis (database); European Commission 2021). As much as 25% of the total urban population increase since 1975 occurred in urban entities with less than 50,000 inhabitants (Figure A.1). Few papers have looked into these relatively smaller entities.[6] Two recent exceptions show how infrastructure trigger urban growth in smaller towns (of up to 10,000 inhabitants Jedwab and Storeygard 2022), while ethnic fractionalization shapes urbanization in multiple towns rather than concentration in the main urban entity (Eberle et al. 2020).Our results contribute to this literature by highlighting the importance of considering changes in sources of livelihood when examining the emergence of towns and cities since 1975. Furthermore, aligned with a pattern of urbanization without structural transformation, we demonstrate that urban dwellers with higher exposure to ASgM are less likely to work in the industrial sector.

Second, our work calls for giving more attention to urbanization in the literature investigating a potential resource curse and its channels (surveyed by Venables 2016). The impact of resource exploitation on development, including through the channel of urbanization, is subject to debate. Glaeser et al. (2015) or Fafchamps et al. (2017) suggest that large-scale resource exploitation, or its aftermath, may trigger urbanization and enable some structural transformation, where urban industries benefit from agglomeration externalities and economies of scale. In contrast, Gollin et al. (2016), Ebeke and Ntsama Etoundi (2017), and Huang et al. (2023) argue that one channel of the resource curse may be the emergence of

6. Up until recently, we lacked the data to study them continent-wide as administrative or census records of towns use country-specific definitions (IPUMS 2024).

"consumption cities," which capture the rents from large-scale resource exploitation without significant industrialization. The latter theory aligns well with the notion that the resource curse is essentially a political resource curse (Brollo et al. 2013). Our work suggests that yet another channel may be at play. Indeed, the mechanism of centralized resource rent is largely muted with ASgM: even in countries where ASgM can be formalized, the central state often fails to levy significant rents (Bazillier and Girard 2020).[7] We demonstrate that ASgM fragments the urban network and concentrates the urban population in places with poorer amenities, worse human development, and an employment structure less geared towards the industrial sector.

Finally, we contribute to the recent literature that sheds light on the local economic impact of artisanal mining. Directly or indirectly, 9% of the population of Sub-Saharan Africa depends on artisanal mining for their livelihood (Hilson et al. 2019). Recent papers document how artisanal mining may, in the short term, increase household health and consumption, as well as armed groups revenues and conflicts, while also contributing to deforestation (Parker et al. 2016; Bazillier and Girard 2020; Sanchez de la Sierra 2020; Rigterink 2020; Girard et al. 2025). Here, we shift the focus to a question that is likely to have medium to long-term consequences for the economic geography of mining-exposed locations. We show that ASgM has shaped the spatial distribution of the population between rural and urban areas, the location of new urban areas, and the quality of urban life. Our results suggest that central states face the emergence of new urban areas in remote zones, which do not appear to lead to an endogenous increase in infrastructure connectivity. A concern may be that, over time, the development of such remote urbanization may lead to a suboptimal distribution of resources, both spatially and across different sectors of the economy (Gollin and Kaboski 2023). This concern may be exacerbated if small towns are too small for the emergence of large industries and scale economies (Turner and Weil 2025). At the same time, recent

7. Burkina Faso allows formal ASgM in the hope of levying taxes on the sector. Yet, as reported by the World Customs Organization, "200 officially recognized artisanal mining sites and around 800 illegal gold panning sites were operating in Burkina Faso in 2017" (Somda 2018). In a period of high gold prices and concerns around the amount of artisanal gold smuggled out of the country (Somda 2018), the Ministry of Mines launched a large campaign to ensure the regularity of each mining site. The number of legal artisanal mining sites in Burkina Faso collapsed from 362 in 2015 to 61 in 2017 (Table 125 in MEME 2020). Ethiopia took the lead in attempting to formalize ASgM in order to tax it, yet even there, only a small fraction of the potential tax revenue seems to be collected (officially estimated at less than 20% of the full potential) (EEITI 2016).

work emphasizes that the average urban areas consistently outperform rural areas on a wide range of economic indicators, underscoring the improved living standards that even small and remote urban environments can provide (OECD/UN ECA/AfDB 2022). As the green transition is a mineral transition and is expected to lead to more ASM, these results call for more academic and policy attention on the role the sector may play in the development path of resource-rich localities and countries.

The paper is organized as follows. Section 2 presents qualitative evidence on the link between ASM activity and urbanization before summarizing it in three conceptual forces. Section 3 presents the data, with the construction of a novel panel of towns and the measurement of the artisanal mining activity. Section 4 presents the empirical strategy, and Section 5 presents the results.

2 Background

This background section presents how both the scale and the specificity of the recent Artisanal and Small-Scale gold Mining (ASgM) expansion make it an original driver of population movement and concentration. The first part of the section provides a brief overview of the core characteristics of the ASM sector and documents its increasing significance over recent decades. The second part synthesizes case-study evidence, which suggests that ASM and ASgM have been a leading force behind rural transformation and settlement change in many low-income countries, albeit with debated impacts on economic and human development. The final part summarizes in a succinct conceptual framework the main forces through which ASgM may shape urbanization.

Artisanal and small-scale mining (ASM) refers to "formal or informal mining operations with predominantly simplified forms of exploration, extraction, processing, and transportation. ASM is typically requires little capital and uses high labor-intensive technology, according to the commonly used definition of the OECD (2016). Organizational forms vary widely, from "men and women working on an individual basis [...] involving hundreds or even thousands of miners" (OECD 2016), reflecting the sector's flexibility and mobility. As summarized by Maclin et al. (2017), the activity is fuelled by two major pull forces: a "demand-pull: diversification driven by desire for greater economic return"; and a "rush-type: 'get rich quick' entrepreneurship."[8]

The sector's large human scale today is the result of a relatively recent expansion. Although ASM has existed for centuries, the number of people directly involved in it has increased sharply over the past two decades, from an estimated 13 million in 1999 to 49 million in 2022 (IGF 2017; Hruschka 2022). Given its extensive upstream and downstream linkages, "[a]s of 2024, those engaged directly and indirectly in the sector's labor value chain make up more than 225 million people" (Perks et al. 2024). The expansion has also reshaped global commodity supply. The sector now accounts for the majority of employment in extractives: worldwide, Pact (2023) estimates that 90% of extractive-sector workers are engaged in artisanal mining, compared to 10% in industrial mining. Although artisanal mines are less capital-intensive and less productive on a per-worker basis, the artisanal mining boom has translated into substantial output growth. In gold – the dominant ASM commodity – "in the 1990s, [ASgM] contributed 4 percent of total global supply and now represents 20 percent." (Perks et al. 2024).[9] This expansion came with significant consequences for population movements and settlement patterns. ASM sites are *de facto* spread across the continent, and the movement and settlement of miners are determined mainly by the distribution of mineral deposits. Numerous case studies suggest that the activity's movements may lead to human or trade inflows in remote villages or secondary urban centers, which will function as support hubs for thriving ASgM sites, as happened in Nsoko (The Economist 2016b).

Focusing on gold, the recent boom in the number of miners is mirrored in the way case studies describe the role of ASgM as an evolving driver of rural transformation and urbanization in Africa. ASgM is established and growing in many African countries. Historically, "[m]ineral production and trade have had a significant influence on Sub-Saharan African urbanization [...]. Early urban settlements were generally associated with centralised kingdoms

8. We leave aside the distress push factors, directly linked to weather shocks. We will, of course, control for weather shocks. However, while the impacts of these shocks on urbanization are the focus of a rich literature, their measurement is less consensual than that of price shocks. We do not expect this focus to significantly affect our estimate, as distress and pull shocks have been documented to be orthogonal drivers of ASgM activities (Girard et al. 2025).

9. In Africa, ASgM employs at least two-thirds of all artisanal miners. The remaining third mostly extracts various types of gemstones or diamonds (Hruschka 2022).

and/or important trading nodes for highly valued commodities including slaves, ivory and minerals, notably gold." (Bryceson and MacKinnon 2012). More recently, as the activity expanded in response to the rising gold price since the 2000s, miners' mobility and settlements also intensified, such that, in the words of Bryceson and MacKinnon 2012, "mining has given birth to urban centres as well as propelled their growth over the past two decades."

Many miners initially cluster in (semi-)temporary mining camps. For a large share of miners, ASgM is embedded in agrarian livelihoods, subsistence-oriented, and performed on a seasonal basis, generating limited permanent settlement formation (Hilson 2016). In Upper Guinea, for example, Dessertine and Noûs (2021) observes that "These activities have historically involved seasonal mobility and semi-temporary mining camps (Bolay 2014, 2016; Dessertine 2013, 2016)." In a survey of 13 mining sites in Cameroon and the Central African Republic (CAR), Ingram et al. (2011) reports that "Most mining sites are short term; almost half (53%) are under a year old [...]. Miners make one to four trips to sites per month, with a mean of two in Cameroon (SD = 0.47) and three (SD = 1.15) in the CAR. Most miners do not live on-site and are based in villages and towns, shifting sites when judged unproductive." Comparable patterns of high mobility and seasonal mining have been documented in other countries, such as Burkina Faso, the DRC, and Zimbabwe (Bazillier and Girard 2020; Sanchez de la Sierra 2020; Mkodzongi and Spiegel 2020).

However, ASgM also shapes urbanization patterns more permanently. From the three theoretical relations possible between ASgM and urbanization – namely, attaching rural households to their rural livelihoods, relaxing liquidity constraints to migrate to larger agglomerations, or triggering mining boomtowns – case studies have, by and large, focused on the emergence and evolution of mining boomtowns. Mining camps require a steady supply of basic goods—food, lodging, tools—and need channels through which to sell extracted minerals. This generates local markets and stimulates the growth of "support villages" (Sanchez de la Sierra 2020). These may be pre-existing villages that thrive because they sit at the crossroads of productive mining sites, or entirely new agglomerations that emerge adjacent to rich deposits (Hilson 2009; Bryceson and MacKinnon 2012; Bryceson et al. 2012). Put differently, ASgM can trigger urbanization both directly, when large mining camps evolve into towns, and indirectly, when pre-existing agglomerations are transformed into urban centers. Gagnol and Afane (2019) describe how the urbanization dynamic depends on a combination of pre-existing settlement patterns, the scale of the rush, and how the central state treats the prospect of the emergence of new urban areas linked to ASgM. These factors shape the possibility to observe an accentuation of pre-existing urbanization (Agadez), spontaneous urbanization (Tabelot), interrupted urbanization (Tchibarakaten), or planned urbanization (Chami). In the map of Niger produced by the authors, spontaneous urbanization appears to dominate (see Figure A.4).

Beyond debates on the extent of rural–urban migration and resettlement within the aforementioned mining-related towns, the potential externalities for nearby agglomerations are a crucial question. For Roger Tape, the chief of the nearest formal town to a mining area (Gregbeu, 25,000 inhabitants), mining and non-mining settlements may operate in parallel. He reports no negative externalities, only that his constituents benefit little from mining as "Simply the miners get what they can get" (The Economist 2016b). Yet other case studies point to broader spatial effects. Commenting on the expansion of secondary clusters in Tanzanian mining zones, Bryceson and MacKinnon 2012 note that "[t]his is likely to have contributed to Dar es Salaam's declining urban primacy". Case studies from Ghana and Tanzania consistently find that mining stimulates the growth of small towns and secondary centers Bryceson and MacKinnon 2012; Gough and Yankson 2012. Whether this only reflects beneficial decentralization, or comes with a reduction in the scale of primate cities potentially impeding agglomeration economies, remains an open question.

Finally, views differ on how mining-induced urbanization shapes development prospects in affected areas. On the one hand, for Waly Keita, 63, resident of Bantakokouta, Senegal, cited by Al Jazeera (2023), "The gold has brought wealth. In the past, we used to go to Mako."[10] In fact, the number of people attracted to ASgM suggests that the activity offers higher returns than local alternatives, and recent quantitative evidence finds significant increases in household consumption and asset wealth (Bazillier and Girard 2020; Girard et al. 2025). Furthermore, the literature review by OECD/UN ECA/AfDB (2022) insists

10. Mako is a town in Senegal, 20km (12 miles) away from Bantakokouta. Waly Keita vision's is also echoed in the declaration of an anonymous muner from Nsoko, in Ivory Coast who notes that "If you're lucky, tomorrow you might find a big rock like that one [...] you can pay for your motorcycle, you can open a small business, you can buy nice clothes." and, the documentary by The Economist (2016b) comments that "A year ago, [Nsoko] was a tiny forest village, now it's a boom town, several thousands strong [....]. The locals call it Abidjan 2, because its dense population and frenzied energy remind them of the country's biggest city."

that recent trends in African urbanization, although occurring at lower income levels than typical urbanization trends, remain positive news for city dwellers. On the other hand, "for many governments and do-good development agencies, informal mining towns are the very definition of unsustainable — dirty and disorganised, with transient populations." (The Economist 2016a) This view echoes qualitative studies in Angola, Zimbabwe, and Zambia describing a worrying pattern with the emergence of "precarious towns" in mining regions – namely, settlements that grow rapidly in response to resource booms but struggle to achieve sustained improvements in human development and institutional integration (Udelsmann Rodrigues and Tavares 2012; Kamete 2012; Mususa 2012).

Overall, which of these qualitative insights will dominate, shaping the scale and location of ASgM-induced urbanization (or non-urbanization), will depend on three key economic channels. The income equalization channel designates a case where expected urban incomes would stop exceeding rural incomes when the latter are complemented by extractive activities, thus decreasing urbanization and slowing down overall prospects of structural transformation (Harris and Todaro 1970). The liquidity channel implies instead that higher mining incomes may relax the constraint linked to the cost of migration and enable households to move to larger, more productive cities, supporting a dynamic of successful urbanization (Bryan et al. 2014). The market channel would lead to an intermediary form of urbanization. This channel will dominate if the support villages meeting rising local demand for goods and services gradually evolve into small towns (Sanchez de la Sierra 2020), or initially temporary mining camps themselves transform into boomtowns, sustained as long as resource rents persist, and potentially after (Fafchamps et al. 2017). A concern is that this channel would lead to decentralized urbanization near mineral-rich areas, which are unlikely to be the best locations in terms of pre-existing infrastructure networks (Venables 2016; Henderson et al. 2022) and employment structures, likely geared towards the primary and service sectors (Venables 2016). Understanding which channel dominates is central to assessing whether artisanal mining fosters or fragments economic development.

This background section thus raises key empirical questions to which we will dedicate the remainder of the paper. In particular, we will document whether mining-related urbanization takes place at a scale that is statistically detectable and makes economic sense; whether such urbanization takes place at the extensive or intensive margin and in smaller or larger urban entities; and, last but not least, the consequences of such changes for the living standards in ASgM-exposed towns and cities.

3 Data

We are interested in how the recent expansion of a unique alternative source of rural livelihood — artisanal and small-scale gold mining — shapes where and how people live. We consider two main sets of outcomes. First, outcomes related to the population concentration and the existence of towns and cities. Second, outcomes related to the living conditions of urban dwellers.

3.1 Urban areas shape and population

We study the evolution of towns and local population concentration in a balanced panel of 0.1×0.1 degree cells (11 by 11km at the Equator), spanning every 5 years from 1975 to 2020.

Tracking urbanization, especially in areas where maps and surveys are scarce, such as Africa, is challenging. The challenge is exacerbated when studying urban areas from different countries, given that the definition of towns or cities tends to be country-specific (OECD/SWAC, Africapolis (database)). The recent development of high-resolution satellite imagery allows us to overcome this challenge.

We exploit data from the most recent release of the Global Human Settlements (GHS) project of the European Commission (European Commission 2021). The GHS project relies on two main inputs. The first is national censuses, exhaustive administrative data typically available every 10 years. The second is the identification of fine-grained patterns of human settlements obtained through machine learning image processing algorithms applied to high-resolution satellite images from the Landsat 30-meter resolution satellite and the Sentinel-2 10-meter resolution satellite. Combining both data sources allows the downscaling of the local population data from censuses to fine-grained 1-km^2-pixels. The GHS defines urban clusters as contiguous cells with more than 5,000 inhabitants and a population density superior to 1,500 inhabitants per km^2 (OECD/SWAC, Africapolis (database); European Commission 2021). The GHS dataset has recently been utilized in studies such as that of

Henderson et al. (2022), which examines how ethnolinguistic diversity affects built-up areas across various types of settlements. We extend the exploitation of the GHS data by building a new, time-consistent panel of the shape of urban areas along with their total population.

The GHS is particularly well-suited to answer our research question as it combines a comprehensive definition of urban areas, extensive coverage, and fine-grained resolution. The GHS improves over the main global-scale population datasets, as it characterizes areas not only by their population density (Láng-Ritter et al. 2025; Henderson and Turner 2020), but also by their land use and total population. Furthermore, the GHS also covers a time more than twice as long as all these alternatives, while keeping a fine-grained resolution at the one km2 pixel, key to our tracking of urban areas boundaries over time. Finally, the GHS offers a more accurate coverage of urban areas' appearance and disappearance, and allows for a larger variety of urban entities than the only other long-panel available for Africa, the OECD's Africapolis.[11] The main drawback of the GHS is that it tends to under-report rural populations by a lot, including compared to alternative available datasets (Láng-Ritter et al. 2025). Bearing this caveat in mind, our analysis focuses virtually exclusively on urban populations.

We combine the datasets provided by the GHS, which tell us, for each 1-km^2 pixel, whether this pixel is urban (in 6 categories in the GHS-SMOD) and how many people live in this pixel (GHS-POP). From there, we can directly compute the total (urban) population of each 0.1 by 0.1 degree cell on each date.

We also want to assess the presence and evolution of towns and cities over time. We thus first isolate the boundaries of each urban area for each wave of data. To do so, we vectorize contiguous urban pixels. Put differently, we draw the urban boundaries to enclose all neighboring urban pixels, considering the 8 direct neighbors of each pixel. We then track each urban entity over time, thanks to the overlap in boundaries. Furthermore, for

11. Africapolis takes the boundaries of towns as they appeared in 2020 as starting points. Then, assuming the boundaries of these towns have been fixed, the Africapolis adds retrospective information on the population of these towns in previous years. Consequently, the Africapolis is not ideal for tracking whether towns may have merged or potentially disappeared over time. We show the coherence of both datasets for the year 2020 in subsection A.2.4.

each date, we sum the gridded population data from GHS-POP located within each urban entity's boundaries to obtain that entity's population.[12]

The final sample comprises 22,129 distinct urban entities. This count encompasses all entities that, at some point during the sample period, had a population of 5,000 or more inhabitants. From 1975 to 2020, we observe that 15,516 towns appear, while 3,326 disappear.[13] Table A.1 presents summary statistics on these urban entities over time. The continent has undergone significant urbanization, with the total number of observed towns and cities increasing from 6,613 in 1975 to 18,803 in 2020. The number of metropolitan areas with more than 1.5 million inhabitants has exploded, from 3 in 1975 to 77 in 2020. The median population per urban entity has stayed stable at around 9,200, while the mean has increased from 20,000 to 40,000.

Finally, we allocate each urban entity to the cell where its centroid lies. Our final sample comprises 205,480 0.1×0.1 degree cells. The cell-level approach allows us to agnostically consider the universe of locations where potential new towns may be created, and populations tend to agglomerate. We observe at least one town or city in 3.3% of the sample cells, with a clear increase over time. In 1975, only 1.8% of the cells hosted an urban entity, whereas in 2020, 4.8% of the cells hosted one. With the exception of a single outlier case containing six distinct towns within one cell, 90% of the cells that contain at least one urban entity host exactly one and only one.

3.2 Urban population living standards and employment patterns

Besides the existence and growth of urban areas, we are interested in assessing key aspects of economic geography. We will look into how towns relate to one another in terms of infrastructure and connectivity, and document urban life quality and its link to structural transformation as revealed by employment patterns.

We first consider cities' connectivity to the road network and travel time to the national capital, a key determinant of endogenous urbanization. We utilize data on historic

12. If some urban entities merge, we reallocate a proportion of the total population of the merged entity to each sub-entity, based on the proportions we can observe in the last year before the entities merged. We present the construction of the panel of towns in more detail in Appendix A.2.

13. Towns appear when they exceed the 5,000 inhabitants threshold, and disappear when they fall below this threshold.

roads derived from the digitalization of Michelin maps, made available by Müller-Crepon et al. (2020), as well as the derived measure of national capital access (Muller-Crepon 2023).

Turning to human development, in the absence of historical continent-wide measures of urbanization quality, we follow recent work and either resort to nighttime light emissions (Chiovelli et al. 2023), or exploit information from the Demographic and Health Surveys (Khavari et al. 2021). Nighttime light emissions are widely recognized for the insights they provide into local economic activities, reflecting changes at the household, state, and company levels (Henderson et al. 2012; Pinkovskiy and Sala-i-Martin 2016). We analyse the cell-level average of winsorized nighttime light emissions, as compiled by Chiovelli et al. (2023), by harmonizing various satellite data sources for the years between 1992 and 2020.[14]

Three key features of the DHS make it a relevant complementary measure of urban dwellers' living standards: the survey records several critical indicators of human development, GPS codes enable us to determine which household belongs to which town, and a significant amount of data has been available since 1990. We pool 147 DHS surveys from 33 countries on the continent, representing 600,000 urban households. Urban households are defined here as those whose geographical position lies within an urban polygon in the panel year following the survey year[15] spanning the period 1990 to 2020. For each variable, we aggregate all survey answers from each urban entity into one observation per urban entity and year of available data. Most data is available only for the year of the DHS survey. The exception is infant mortality, which is recorded as a function of the year of birth of each child.

14. Source: https://drive.google.com/drive/folders/1smOB47MJra-vdDXyYvz5uXEA3NFsQj44. To mirror the urbanization data, we consider all dates every five years from 1995 onwards. We know based on results in Table A.5) that the main urbanization results hold by that period, which actually leads them. Nightlights data are winsorized at the 99.96th percentile. Above this value, a clear jump is observed in 2013, at the transition from the DMSP to the VIIRS satellite.

15. 87% of these households are also defined as urban in the DHS survey, while the proportion of households classified as urban but falling outside city boundaries is 23%. We keep in the sample DHS-labeled rural households whose GPS fall within the boundaries of one of the GHS-defined urban entities because the urban definition is not homogeneous across the various DHS countries and often differs from the (homogeneous) definition of urban areas in the GHS project. The DHS program randomly displaces some clusters, from 0 to 2km. This limited and random displacement may introduce a small amount of noise, making our estimates slightly less precise. Source: https://dhsprogram.com/pubs/pdf/SAR7/SAR7.pdf. The erroneous attribution of a DHS cluster as urban rather than rural, or attributed to the wrong town, may add noise to our results. However, since all DHS cluster displacements are random, these displacements will not induce a bias in our results.

We consider several measures of living standards and employment present in the DHS. Living standard data cover both asset wealth and non-monetary indicators. The non-monetary indicators are related to health and include the quality of sanitation, water source, and the child mortality rate. For employment patterns, we group the harmonized DHS sectors of activity into four broad categories: agriculture, industry, services, and other sectors.[16] Work in "agriculture" is defined for each household as a binary variable that takes the value one if the respondent's or their partner's main sector of activity is agriculture, and similarly for the other sectors. We then consider the share of the population in each activity within each urban area.

3.3 Artisanal and small-scale gold mining

ASgM is a major activity in Sub-Saharan Africa. However, assessing its impacts is difficult as the activity is largely informal, often illegal, and partly seasonal. We thus lack reliable statistics on the location of mines and their operational status. An additional problem to answer our research question is reverse causality: as the local population increases, it becomes more likely that someone will discover gold and establish a new mine, or that more people will join existing mines.

To overcome these issues, our empirical analysis relies on the value of potential ASgM activities in the surroundings of each cell. The construction of this value involves both spatial and temporal sources of variation, as exploited in (Girard et al. 2025), which also document the reliability and consistency of this approach.[17]

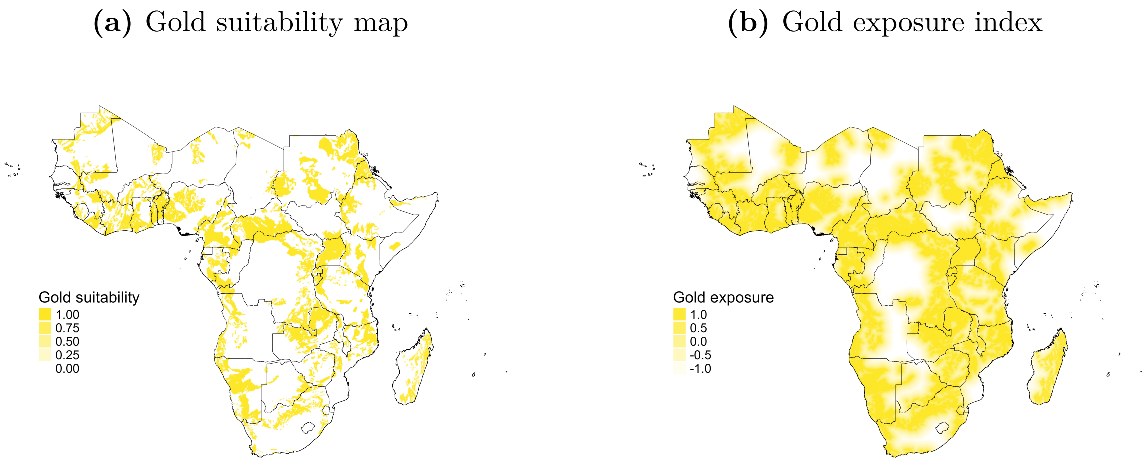
For the spatial variation, we use geology-based data compiled and made available in Girard et al. (2022) based on the geological census of Africa of Thieblemont (2016). These data tell the suitability for artisanal and small-scale gold mining at a very disaggregated geographic level.[18] This approach transposes the notion of suitability to gold mining activities

16. Appendix A.3 gives more information on this classification.

17. Girard et al. (2025) performs several validation exercises backing up the credibility of this approach. In particular, they show that the data on geological gold suitability correlates well with the few known existing records of ASgM activities, and an increase in ASgM potential revenues increases the probability that individuals work in the extractive sector, as well as deforestation, nighttime light emissions, and household wealth.

18. Thieblemont (2016) collected information on each African geological layer's contours, age, and chemical characteristics. Based on these data and recent research in geology, Girard et al. (2025) determine which geological layer has the right combination of geological age and composition to be suitable for bearing gold.

Figure 1: Gold suitability



Note: Figure (a) depicts the mean gold suitability, and Figure (b) the gold exposure index at the cell level. The index is equal to the standardized log of the inverse of the distance.

(Nunn and Qian 2011). Figure 1 shows the location of gold-suitable areas, which are spread over 18% of the total surface of the continent. Importantly, not all gold-suitable locations will host artisanal mining. However, if mining were to take place, it would be more successful in these locations.

Specifically, to measure the cell's exposure to gold, we typically consider the theoretical minimum distance to a mine, expressed as the log of the inverse of the distance to a gold-bearing layer. To provide a sense of the relevant potential scales for spatial exposure based on a few published studies, in the DRC, the average distance of a mining site to its support village is 10 hours of walking (Sanchez de la Sierra 2020), which would be 50km on a straight line at the average walking speed for adults of 5km/hour. In Burkina Faso, artisanal mines significantly increase household consumption up to 10 to 25km of the mines, and household heads living up to 30-40km from the closest official artisanal mining site are more likely to declare that they work in the extractive sector during the lean agricultural season (Bazillier and Girard 2020).

The temporal variation comes from the international gold price. This approach aligns with recent vivid literature, arguing these variations provide an exogenous source of change to the activity's revenues both for ASM (e.g. Sanchez de la Sierra 2020; Girard et al. 2025; Rigterink et al. 2025), agriculture (Berman et al. 2023; McGuirk and Burke 2020), or industrial extraction (Dube and Vargas 2013; Berman et al. 2017). Artisanal miners sell gold at a price highly correlated with the fluctuations of the international gold market, where they are price takers (Alvarez et al. 2016; Sanchez de la Sierra 2020). As a result, a high international gold price may increase ASgM both at the intensive and extensive margin: when the gold price is high, ASgM workers may put in more effort, or new workers may join. The estimated number of people directly involved in the activity increased from 13 million in 1999 to 49 million in 2022, and many more through linkages (IGF 2017; Hruschka 2022). Interestingly, the gold price varied substantially over our study period, with an initial short spike followed by a period of slight decrease until 2000, and a quasi-continuous sharp increase thereafter (see Figure A.2). In terms of magnitudes, between 1975 and 1995, the gold price remained unchanged. Between 2000 and 2020, the gold price increased by a factor of seven.

Knowing where artisanal gold mining may occur and the revenues it may generate allows us to assess the potential ASgM exposure of each cell. Our main explanatory variable will be the product of the 5-year moving average of the international gold price index (capturing mining potential revenues) and the cell's exposure to gold-suitable geologies (based on the geology present in each cell's surroundings). We consider a price index (base 1 in 1970). If ASgM activities favor the creation of mining towns, we would expect cells surrounded by more ASgM activities to experience an increase in population up to the point where new urban clusters may emerge. On the contrary, if ASgM locks households in rural areas, we would expect cells exposed to ASgM to see less urbanization.

3.4 Control variables

Industrial mines. As gold-suitable areas are also more likely to host industrial gold mines, we control for the presence of industrial mines within and around each cell. We consider both industrial gold mines and industrial mines from other minerals as recorded in the most comprehensive dataset on industrial mining, the SNL Metals and Mining database owned by *S&PGlobal* (Berman et al. 2017; Benshaul-Tolonen 2019). The data provide information on the location, the dates of opening and closure, and the mineral extracted since 1980. We control for the ever-present industrial mines recorded in the S&P data for each mineral,[19] interacted with the international price of that mineral. Given the large fixed costs required to operate an industrial gold mine, only 0.47% of gold-suitable cells have ever hosted an industrial gold mine.

Weather. Weather conditions are typically seen as a push factor towards urbanization, as they decrease agricultural productivity (Henderson et al. 2017; Peri and Sasahara 2019). We control for the average temperature and the average precipitation in the last five years in each cell's surroundings, and also consider how good these weather fluctuations are for local vegetation by controlling for the Standardized Precipitation and Evaporation Index (SPEI) Vicente-Serrano et al. (2012). We compute these variables from the CRU TS dataset (Harris et al. 2020), which provides monthly climate data at a 0.5-degree resolution.

Agricultural commodities. We also control for changes in the value of local agricultural commodities. We multiply the local suitability for each crop recorded by the GAEZ dataset by the international price for that crop from the World Bank's Commodity Market Outlook (FAO et al. 2012; Nunn and Qian 2011).[20] This approach mirrors our measure of the potential value of artisanal mining activities.

3.5 Descriptive statistics

Table 1 presents key descriptive statistics for our primary outcomes of interest: total population, total urban population, share of urban population, and the presence of any town or city in the cell. To split these statistics by exposure to gold, we divide the sample into two groups based on whether the cell is located within 50 kilometers of a gold-suitable geological layer. Table 1 shows the increasing urbanization over the study period, which also saw a marked widening of the difference in various measures of urbanization in gold-exposed and non-exposed cells. Appendix Table A.1 shows statistics disaggregated by year.

19. Minerals included are bauxite, iron, copper, lead, tin, nickel, zinc, gold, platinum, and silver. Figure A.3 shows the spatial distribution of mines by mineral. Gold industrial mines account for 53% of the total industrial mines observed.

20. Crops included are cocoa, coffee, tea, maize, rice, oil palm, and sorghum, based on long-term commodity prices data available.

Table 1: Descriptive statistics

Variable	Mean	Std. Dev.	Mean	Std. Dev.	Diff
Gold exposure	*Not exposed* (N = 89,298)		*Exposed* (N = 116,242)		
Year			**1975**		
Urban population (log)	546	7,057	742	8,760	195.94***
Urban share (%)	1.6	11	2.1	12	0.45***
Urban entity in cell (%)	2.3	15	3.1	17	0.8***
City (over 50k) in cell (%)	0.21	4.6	0.25	5	0.04*
Year			**2020**		
Urban population	2,340	33,382	3,257	36,171	917.47***
Urban share (%)	3.2	15	4.7	18	1.44***
Urban entity in cell (%)	5.1	22	7.6	27	2.5***
City (over 50k) in cell (%)	0.79	8.8	1	10	0.26***

Notes: Exposed here denotes cells lying within 50km of a gold-suitable geological layer, not exposed denotes cells further away. * significant at 10%, ** significant at 5%, *** significant at 1% of a joint F-test of difference.

4 Model

Our identification strategy exploits plausibly exogenous variation in exposure to artisanal and small-scale gold mining (ASgM) to estimate its impact on population settlement patterns and urban characteristics. Specifically, we combine spatial variation in gold endowments—measured by distance to gold-suitable areas—with temporal variation in the international price of gold, which shifts the value of potential ASgM activity over time. The unit of analysis is a grid of 0.1×0.1 degrees cells covering the 48 countries of Sub-Saharan Africa. Our panel consists of 205,540 cells observed every 5 years between 1975 and 2020. This unit of analysis enables us to ensure comparability across geographical units, allowing us to test how the presence and value of natural resources affect population distribution and the emergence of urban entities across the continent. In the baseline, we use a flexible function to assess the relation between urbanization and the distance to gold-suitable areas.

Formally, we can consider the following model in levels for the cell c in year t:

$$Y_{ct} = \sum_{d \in \mathcal{D}} \beta_d \{\text{gold dist} \in d\}_c \times \{\text{gold price}\}_{[t-5,t]} + \mu_c + \alpha_{t \times Country} + \gamma X_{ct} + \epsilon_{ct} \qquad (1)$$

Where Y_{ct} is the urban outcome of interest measured at the level of the cell c in year t. We consider the cell's total urban population, the share of the population that is urban, a dummy for the presence of an urban entity, or urban-entity-level characteristics such as the average wealth of urban dwellers or access to sanitation. As described in the previous section, when investigating the set of DHS-based urban characteristics, we rely on an unbalanced panel of towns and cities, depending on the year of the DHS surveys.

$\{\text{gold dist} \in d\}_c$ is a dummy taking value one when gold lies within the distance bin $d \in \mathcal{D}$ to cell c; where $\mathcal{D}$ is the ensemble of bins of 20 kilometers from 0 to 120 kilometers.[21] The variable $\{\text{gold price}\}_{[t-5,t]}$ is the world price index of gold (base 1 in 1970), averaged in the previous five years (see Figure A.2). The interaction of these variables tells us the cell's exposure to ASgM.

μ_c are cell fixed-effects that account for all invariant characteristics of cells and towns, such as the distance to the coast, the distance to the capital, the initial population, or gold suitability. $\alpha_{t\times Country}$ are country-year fixed-effects, accounting for country-specific characteristics, both intrinsic and time-varying over the half-century covered by the study. These characteristics include, among others, the quality of the country's institutions or the legislation regarding ASgM activities. These fixed effects will also absorb any macroeconomic shocks, such as changes in the gold price level or a global financial crisis.

The model accounts for key time-varying controls at the cell level. First, we consider typical push factors for urbanization, such as adverse weather conditions and international shocks to agricultural rents. As gold-suitable areas are also more likely to host industrial gold mines, we also control the presence of these and other industrial mines around the cell. Finally, we control for the initial population of the city multiplied by a yearly trend to account for any divergence or convergence that may occur because larger cities grow faster or slower than smaller cities, potentially due to increasing local returns or agglomeration effects (Duranton and Puga 2014).

All specifications account for both cross-sectional spatial correlation and location-specific serial correlation within a 500-kilometer buffer (Conley 2008; Hsiang 2016).

21. Obviously, some gold-suitable locations may host no ASgM activities, contaminating our treatment group with non-treated units, and conversely. Such contamination may cause an attenuation bias in our estimates of the impact of ASgM on urbanization.

Given potential concerns of non-stationarity, our favored approach for all data where a balanced panel is available is to consider a first-difference specification of this model, which becomes:

$$\Delta Y_{ct} = \sum_{d \in \mathcal{D}} \beta_d \left\{\text{gold dist}_c \in d\right\} \times \Delta\{\text{gold price}\}_{[t-5,t]} + \alpha_{t \times Country} \\ + \gamma \Delta X_{ct} + \theta \left\{\text{urban population 1975}\right\}_c + \varepsilon_{ct}. \quad (2)$$

The cell-level fixed effects are absorbed by the first differencing. We further control for the initial population level of the urban entity, urban population$_{t0,c}$, to account for differences in city growth by city size due to agglomeration effects or increasing returns to scale (Duranton and Puga 2014; Jedwab and Storeygard 2022). Results in levels are reported in the sensitivity analysis. For DHS-based outcomes, only the specification in levels is used (model 1), as the DHS surveys are conducted at irregular intervals and are not well-suited for a model in first difference.

Alternatively, we reduce to one variable the dimension of the function to gold-suitable areas, using a measure of gold exposure equal to the log of the inverse of the distance to gold-suitable layers, as described in Fernihough and O'Rourke (2021). This concise measure of spatial exposure, interacted with the gold price, enables a concise estimation of the ASgM-urbanization nexus. Still using this concise measure of spatial exposure, we can also let the link between urbanization and gold exposure be period-specific. This dynamic specification enables the investigation of potential differences between periods of increasing and decreasing gold prices, allowing for the observation of any potential lags between the increase in gold prices and the outcome of interest. Equations for these models are presented in Appendix A.5.

5 Results

5.1 ASgM exposure increases urbanization

Urbanization. We first examine how the potential value of ASgM activities affects urbanization. The three panels of Figure 2 present the results on the size of the urban population (a), the urban population share (b), and the probability of observing any urban entity (c), in a given cell and year.

Exposure to ASgM activities is associated with a significant increase in urbanization. The ASgM-induced increase in the total urban population of a cell (Figure 2a), is not mechanically driven by overall population growth, as we also find a positive effect on the share of the population living in urban areas (Figure 2b). The likelihood of observing any urban entity in a cell also increases with ASgM exposure (Figure 2c), suggesting that ASgM activities trigger the creation of new towns or cities. This urbanization effect is observed up to 20 kilometers away from the gold-suitable layers and ASgM impacts taper off for cells lying further away. This spatial decay in the impacts of ASgM exposure lends credit to the use of a single measure of ASgM exposure in the remainder of the paper (Fernihough and O'Rourke 2021).

In terms of magnitude, we estimate that a one-standard-deviation increase in the international gold price results in a 2% increase in urban population up to 20 kilometers from gold-suitable areas. A one standard deviation increase in the gold price increases the probability of a new town or city appearing in a cell by 0.0015. While the latter number may seem small in absolute terms, it corresponds to 10% of the unconditional probability of a town appearing.[22]

Alternatively, we can estimate the order of magnitude for the impact of ASgM exposure on urbanization by simulating a counterfactual scenario in which the gold price remained at its 1975 level (Appendix A.4 describes the procedure). The results suggest that the increase in gold prices explains approximately 4.4% of the predicted increase in urban population in Sub-Saharan Africa since 1975, that is 11 million new urban-dwellers. In terms of new urban entities, the creation of 415 new towns or cities linked to the increase in the gold price represents 6.5% of the predicted total number of towns and cities created during the period.

These numbers are significant in comparison to standard urbanization patterns. We note that they still represent a minority of the 165 million people estimated to directly or indirectly depend on ASgM for their livelihoods, either as miners, miners' providers, or family members of both types of workers (Hruschka 2022; World Bank 2020; *Minerals and*

22. The unconditional probability of observing an urban entity in a cell is 0.37. However, most of these urban cells were urban already in 1975. If we look at the share of non-urban cells in 1975 that host a new urban entity by 2020, the mean is 0.015.

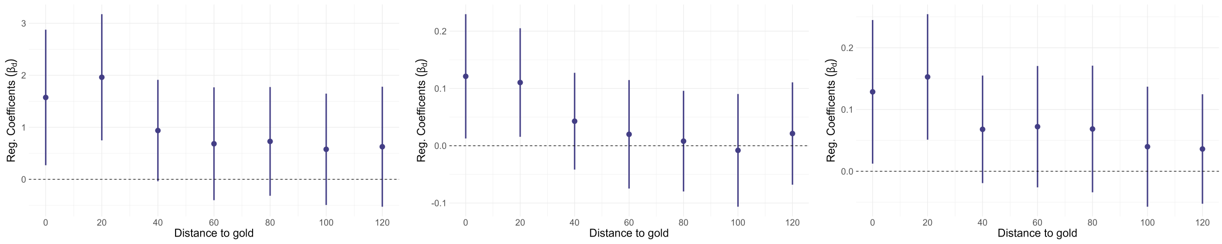
Africa's Development 2016). In other words, a large share of mine-related workers and their families appear to remain in rural villages or semi-permanent mining camps that move with the mining sites (Section 2). What we are detecting here is that, in parallel to these extreme forms of mobility, ASgM also induces urbanization, meaning the emergence of new urban areas with hard dwellings or some amenities detectable from satellite and census data (which are the inputs the GHS data builds from). Bolontou exemplifies such an entity, lying just above the threshold of 5000 inhabitants in the GHSL in 2020. It hosts several key services, including, as pinned in Google Maps, two restaurants, a primary school, a shop, and a pharmacy.

This pattern of ASgM-induced urbanization is consistent with the market channel and the liquidity channel dominating the income equalization channel. Furthermore, additional results suggest that the influx of new urban dwellers originates from gold-poor areas. The GHS class of data is not ideally suited to investigate rural population evolution as it severely under-estimates these populations (Láng-Ritter et al. 2025). Still, the data may remain informative if its biases are orthogonal to our treatment of interest. Appendix A.6 repeats our investigation for the urban population as a reference and adds the total rural population and the total of urban and rural populations for each cell as outcomes. All three population categories increase with ASgM exposure. This exercise is coherent with rural inhabitants exposed to ASgM migrating to towns and being replaced by inhabitants of gold-poor zones, or with inhabitants of gold-poor zones migrating to both rural and urban areas of gold-rich zones due to increasing gold prices. Overall, while ASgM exposure does not decrease urbanization in gold-suitable zones by keeping people stuck in rural areas, ASgM exposure still stimulates a population boom beyond urban areas, potentially in the closest villages to the mining pits or in (semi)temporary mining camps.

Intensive *versus* extensive margin. A key question to distinguish the liquidity constraint from the market channel is whether ASgM leads to mostly extensive urbanization through the creation of new towns, or rather intensive urbanization as (pre-existing) towns and cities keep growing in size. How the two forces interact will also determine whether ASgM-led extensive urbanization may handicap the growth intensity of larger entities (Bryceson and MacKinnon 2012; Gough and Yankson 2012).

Figure 2: Artisanal mining and urbanization

(a) Urban population **(b)** Urban share **(c)** Any urban



Note: The figure displays regression coefficient estimates β_d of the interaction between the discretized distance d to gold suitable areas and the gold price on (a) the total urban population of the cell, (b) the share of urban population in the cell, and (c) the probability of having a urban entity in the cell (see Equation 2). Error bar represents 90% confidence intervals. Urban population is taken in logarithm transformation. The estimation includes country×year fixed effects, as well as controls for temperature, precipitation, SPEI, the initial log population, the interaction between the ever-present industrial mines at the ring distance and the corresponding mineral prices, and the interaction between crop suitability and the corresponding crop prices. Standard errors are estimated allowing for infinite serial correlation and spatial correlation within a 500km radius (Conley 2008; Hsiang 2016).

To answer these questions, in Table 2, we examine the dynamics of urbanization in reaction to ASgM exposure in three different samples. We first show the results for the full sample of cells (top panel), simply repeating the results of Figure 2 for the concise variable rendering ASgM exposure. We then restrict the sample to the subset of urban cells, meaning all cells that have ever hosted a town or city. This sample is selected, in the sense that it includes both old urban entities (that already existed in 1975), and new entities (that were created because of their exposure to ASgM, as appears in Figure 2c). In both the top and the middle panels, the study mixes the intensive and extensive urbanization margins. In the final panel, we focus exclusively on the intensive margin. To do so, we restrict the sample to cells where towns and cities already existed in 1975, excluding all urban areas created after 1975.

Table 2 suggests that ASgM-induced urbanization is largely led by new urban entities. While ASgM exposure increases urbanization in the overall sample, or in the sample of urban cells (Columns 1 to 3 of Panels A and B), ASgM exposure never increases urbanization in the sample zooming on pre-existing cities (Panel C).[23] Still, we see a marked decrease of the mean value of the dependent variable for all variables in Columns 1 to 3, suggesting

23. Importantly, we always attribute the population of an urban entity to the cell hosting the centroid of this entity, thus, even if the entity were to explode spatially over multiple cells (as maybe the case for example for a capital), in our sample, this entity would consistently be attributed to a single one cell.

that pre-existing urban entities, on average, grow slower than new entitites.[24] As old urban entities are on average twice larger than those that emerged over the period, this pattern is coherent with (Henderson et al. 2022)'s findings that smaller entities grow faster than larger cities in Africa, contrary to Gibrat's law.

This conclusion remains true when looking at the probability that the cell starts hosting a larger urban entity, that is, a city of at least 50,000 inhabitants in Column 4. The unconditional probability of observing such a city is small, but it increases as we focus on the sample of ever-urbanized cells. Independent of ASgM, old urban entities are more than twice as likely to become a larger city over the study period than when considering all urban entities together (as indicated by the mean of the dependent variable in Column 4 of Panels B and C). Interestingly, while new towns may be more likely to become larger cities as they get more exposed to ASgM (with a large, although imprecise coefficient in Panel B column 4), ASgM exposure appears to be again largely unrelated to the probability that one of the old towns turns into a larger city (Panel C column 4). The fact that the probability of passing beyond the 50,000 inhabitants threshold remains unaffected in the panel of old towns is also important, as it indicates that ASgM does not hinder the development of larger urban entities in its surroundings. Put differently, while ASgM may empty the countryside to drag people into new towns (some of which might become larger cities), the endogenous growth dynamic from old towns to larger urban entities does not suffer from ASgM activities.

Sensitivity. Various sensitivity tests confirm these findings, including variation in the measurement of exposure to ASgM activities, the relevant confounding factors, or the estimation sample.

Most importantly, we obtain coherent results when using alternative specifications of the gold exposure measure. We consider two approaches to how ASgM exposure varied over time. Firstly, instead of imposing the functional form of the gold price, we allow the relationship between urbanization and gold exposure to be period-specific (see Appendix A.5). Figure A.9 shows that from 1975 to 2000, when the gold price was relatively low and slightly decreasing, the difference in town creation between gold-suitable and non-gold-suitable areas

24. The share of urban population in Panel C virtually stays perfectly stable over the study period and, if anything, it would decrease, consistent with an increase in the density of rural or suburban populations within the cell of old urban centers (meaning in the vicinity of the urban centers).

was insignificant. From 2000 onwards, the period when the price of gold increased significantly and almost constantly, so did the probability of a town appearing in gold-suitable areas. Secondly, if we split the sample between the pre- and post-2000 periods,[25] we find that the ASgM-urbanization link is strongest in the post-2000 period. Estimates from the pre-2000 period tend to be of much smaller magnitude, but with similar standard errors they turn imprecise, suggesting a limited relation between ASgM and urbanization in these earlier decades (Table A.5).

Alternatively, we also consider different specifications of the spatial exposure to ASgM. Figure A.10 shows the results when we replace the logarithm of the inverse of the distance to gold by (i) the share of gold suitable areas in a buffer of 100 kilometers around the cell considered, or by (ii) the weighted sum of gold suitability by the inverse of the distance to the cell.[26]

Given the obvious overlap between industrial gold mines and gold-suitable layers, we consider alternative ways to control for exposure to industrial mining in general, and industrial gold mining more specifically. Our basline approach considers as exposed to industrial gold mining any cell in the proximity of an industrial gold mine active over the study period, and similarly for other minerals like silver, copper, etc., with distance and price adjusted to always be coded in the same maner as for the ASgM exposure. We confirm that the results remain unchanged when considering a more specific control, restricted to industrial gold mines alone. More importantly, we can also remove all cells that lie within 100 kilometers of any industrial mine. This demanding approach reduces the sample by 13%. Yet the estimated relationship between ASgM and urbanization remains remarkably stable in this reduced sample (Figure A.8). Findings are also similar if we remove the 8% of cells that are within 100km of an industrial mine dedicated to gold extraction alone (Figure A.10). This stability consolidated the interpretation that previous results are rooted in artisanal rather than industrial gold exploitation.

25. While the evolution of the gold price over the study period does not allow us to assess the effects of a collapse, it does suggest two distinct phases: from 1975 to 1995, gold prices generally declined across most five-year intervals; from 2000 to 2020, they increased–often sharply–over similar intervals (see Figure A.2).

26. Transposing to ASgM expusre the market potential measure of Jedwab and Storeygard (2022), we compute for cell i, Gold $\text{exp}_i = \sum_{j \in \mathcal{L}} \text{Gold suit}_j \exp(-(d_{ij}/d_{typ}))$, with d_{ij} the distance between cell i and j, and d_{typ}, a typical distance that we take equal to 100 kilometers.

Beyond the question of controlling for industrial (gold) mining, the specification curves show the stability of estimated coefficients to alternative combinations of the set of controls (Figure A.8). In particular, we consider two alternative ways to control for exposure to agricultural activities, either through all crops or through cash crops only, as the international price of each crop might be most relevant for the latter. We also vary the inclusion of controls for weather conditions and initial population.

We document the stability of results when varying the sample. In addition to omitting cells that contain industrial mines, we show that results are virtually identical when omitting capital cities from the sample.

Finally, although the empirical test is limited by the fact that the gold price has mostly increased over the study period, the data show that ASgM-related towns' probability of disappearance is inversely related to the gold price (Table A.4), suggesting that ASgM has a symmetric effect on urban areas' appearance and disappearance.

Taken together, the results in this section suggest that ASgM contributes to accelerating urbanization more than it locks households into rural areas. At the same time, the evidence indicates that much of this urbanization seems to occur in small, newly formed towns, emerging near gold-suitable areas, and especially during the post-2000 gold price boom (Figure A.9b). In contrast, the urban growth of cells with pre-existing cities is unaffected by exposure to ASgM, and so is the probability of observing the emergence of a large city (a city of more than 50,000 inhabitants, Table 2). These results align with the market channel, where support villages meeting rising local demand for goods and services gradually evolve into small towns (Sanchez de la Sierra 2020), or initially temporary mining camps may themselves transform into boomtowns, sustained as long as resource rents persist, and potentially after (Fafchamps et al. 2017). However, this first set of resutls does not yet tell us whether the type of urbanization we are facing fully align with this channel, in the sense of a decentralized urbanization near mineral-righ places (Venables 2016; Henderson et al. 2022), and an urbanization without structural transformation, with employment structures likely geared towards the primary and service sectors (Venables 2016; Gollin et al. 2016).

Table 2: Urbanization increase with the value of potential artisanal mines

Model:	(1)	(2)	(3)	(4)
Dependent variables:	Urban population	Urban share	Any urban	50k city
Panel A: Full sample				
Gold exp. × Gold price	1.31**	0.110**	0.102*	0.019
	(0.601)	(0.052)	(0.053)	(0.022)
Observations	1,849,860	1,849,860	1,849,860	1,849,860
Mean dep. var.	0.045	0.002	0.003	0.0008
Panel B: Only urban				
Gold exp. × Gold price	6.57*	0.657*	—	0.295
	(3.82)	(0.398)	—	(0.284)
Observations	105,039	105,039	—	105,039
Mean dep. var.	0.614	0.034	—	0.014
Panel C: Only old urban				
Gold exp. × Gold price	0.484	0.082	—	0.044
	(1.68)	(0.234)	—	(0.437)
Observations	40,860	40,860	—	40,860
Mean dep. var.	0.058	-0.002	—	0.027

Notes: OLS estimations based on Equation A.3. * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors, in parentheses, are estimated allowing for infinite serial correlation and spatial correlation within a 500km radius (Conley 2008; Hsiang 2016). Gold exposure is measured as the log of the inverse distance to gold-suitable zones. Urban population is taken in logarithm transformation. The estimation includes country×year fixed effects, as well as controls for temperature, precipitation, SPEI, the interaction between the exposure to industrial mines and the corresponding mineral prices, and the interaction between crop suitability and the corresponding crop prices. All specifications control for the possibility of differential trends depending on the initial level of population (in 1975). In columns with the heading "Any urban", we restrict the sample to cells that have ever hosted an urban entity (at any point between 1975 and 2020). In columns with the heading "Old urban", we restrict the sample to cells that were hosting an urban area already in 1975.

5.2 Decentralized urbanization

The typical urbanization process is directly dependent on and at the same time a key driver of the distribution of infrastructures and population in space (Jedwab and Storeygard 2022). We found above that the value of artisanal mining activity increases the probability of small towns appearing. In the remainder of the paper, we ask how does ASgM reshape the spatial organization of economic activity, and why does this matter for productivity and development? In this section, we focus on the spatial integration and market access of these new ASgM towns.

Historical infrastructure. We first examine how historically well-connected the locations of new ASgM towns are. We exploit data compiled and made available by Muller-Crepon (2023) to examine the connectedness of each cell to national capitals or distance to main roads, using the road networks as they existed in 1975, the first year of our sample. As a preliminary step, we confirm that the density of the population and the probability of having an urban area in the cell are approximately twice as large in connected cells as in remote cells. However, Table 3 shows that the ASgM-induced urbanization happens overwhelmingly in locations with low connectedness to national capitals (Columns 1 and 2). Acknowledging that other cities and markets may be determinants besides the national capital, we confirm that results for access to improved roads corroborate those for capitals (columns 3 and 4). Overall, ASgM urbanization appears to take place in more remote areas.

Taking together this first set of results, together with those in Section 5.1, document an ASgM-induced "decentralized urbanization." The boom in gold prices from 2000 onwards has led to a significant increase in the likelihood of small towns emerging in areas with poor connectivity. These observations suggest that resource-based urbanization appears to play at both ends of the spectrum of town sizes, triggering both population hyper-concentration in the largest (consumption) cities due to rents from industrial resources' exploitation as established in the recent literature (Gollin et al. 2016), but also, in parallel, a population concentration in a multitude of decentralized small towns as a result of ASgM dispersion. In both cases, urbanization follows the location of exogenous resource rents rather than endogenous agglomeration advantages. ASgM-led urbanization, however, differs in that it

Table 3: Artisanal mining and urbanization in remote areas

	(1)	(2)	(3)	(4)
Dependent variables:	Urban population	Any urban	Urban population	Any urban
Remote definition:	Dist to nat capital (1975)		Dist to improved road (1975)	
Gold exp. × Gold price	-0.580	-0.073	-0.425	-0.041
	(0.961)	(0.083)	(0.845)	(0.073)
Gold exp. × Gold price × Remote	3.04**	0.283**	2.44**	0.206**
	(1.31)	(0.112)	(1.02)	(0.088)
Observations	1,781,262	1,781,262	1,847,547	1,847,547
Mean dep. var.	0.045	0.003	0.045	0.003

Notes: LPM estimations based on Equation A.3. * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors, in parentheses, are estimated allowing for infinite serial correlation and spatial correlation (Conley 2008) with a distance cut-off of 500 kilometers. Gold exposure is measured as the log of the inverse distance to gold-suitable zones. Urban population is taken in logarithm transformation. The estimation includes country×year fixed effects, as well as controls for temperature, precipitation, SPEI, the interaction between the ever-present industrial mines at the ring distance and the corresponding mineral prices, and the interaction between crop suitability and the corresponding crop prices. All specifications control for the possibility of differential trends depending on the initial level of population (in 1975). Remoteness in terms of travel time to the nearest national capital using the roads of 1975 (see Müller-Crepon et al. (2020)) takes the value one if the travel time is superior to 16 hours. Remoteness in terms of distance to the nearest high-quality road present in 1975 takes the value one if this distance exceeds 35 kilometers. These values corresponds to the first tercile of each of the variables considered.

is least to the creation of isolated nodes. Concretely, this pattern of town creation without infrastructure creation will result in a fragmented and poorly integrated urban network.

Non-converging infrastructure. Urbanization in poorly connected areas is not doomed to be poor. Countries are now recognizing the benefits of decentralized urbanization, encouraging the distribution of urban populations across multiple locations rather than concentrating them in overcrowded megacities (Turner and Weil 2025). Such urbanization may be particularly successful if accompanied by the development of infrastructures that allow for agglomeration externalities (Jedwab and Storeygard 2022). To investigate whether ASgM may contribute to such a positive dynamic, we turn to time-varying measures of road networks (Müller-Crepon et al. 2020).

Table 4 presents the results of the impact of ASgM on urban entities connectivity and on the development of road networks classified in unimproved (earth roads or partially improved roads) or improved (improved, paved roads and highways). Being exposed to ASgM activity does not appear to lead to any improvement in road connectivity or state access (Columns

1 and 2). Looking at the roads' presence in the cell, we see no effect overall (Column 3). Splitting by the type of roads, we do see an imprecise increase in the connection to unimproved roads (at the opposite of the general trend for these roads to disappear and being replaced by improved roads, Column 4). However, the effect of improved roads, if any, would be negative (Column 5). This set of results questions the ability of ASgM-exposed localities to attract large public investment and strikingly echoes the idea that ASgM-exposed localities may often be absent from infrastructure development plans.[27] In other words, ASgM-induced urbanization tends to take place in particularly remote areas, without any convergence taking place in terms of connectivity between these and other areas with comparable urban settlement and population.

27. "Governments have responded to the growth of informal mining settlements in two ways. One is to evict the diggers. [...] More common, however, is for governments and aid agencies to pretend these new mining towns do not exist. The UN agency and NGO signs that line so many roads in rural Africa are conspicuously absent when the scenery turns from verdant fields to mines." (The Economist 2016a).

Table 4: Artisanal mining and market access

Model:	(1)	(2)	(3)	(4)	(5)
Dependent variables:	Improved road distance	Capital distance	— Road connection — All	Unimproved	Improved
Panel A: Only urban					
Gold exp. × Gold price	0.147	0.062	-0.020	0.185	-0.213
	(1.07)	(0.757)	(0.159)	(0.308)	(0.291)
Observations	104,877	90,732	104,877	104,877	104,877
Mean dep. var.	-0.038	0.026	0.003	-0.004	0.008
Panel B: Only old urban					
Gold exp. × Gold price	-0.091	-0.508	0.032	0.374	-0.283
	(1.63)	(0.604)	(0.256)	(0.585)	(0.505)
Observations	40,815	35,705	40,815	40,815	40,815
Mean dep. var.	-0.031	0.024	0.003	-0.005	0.007

Notes: OLS estimations based on Equation A.3. * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors, in parentheses, are estimated allowing for infinite serial correlation and spatial correlation within a 500km radius (Conley 2008; Hsiang 2016). Gold exposure is measured as the log of the inverse distance to gold-suitable zones. The estimation includes country×year fixed effects, as well as controls for temperature, precipitation, SPEI, the interaction between the ever-present industrial mines at the ring distance and the corresponding mineral prices, and the interaction between crop suitability and the corresponding crop prices. All specifications control for the possibility of differential trends depending on the initial level of population (in 1975) as well as for the size of the urban population. In Panel A, the sample comprises all cells that have ever hosted an urban entity (at any point between 1975 and 2020). In Panel B, we restrict the sample to cells that were hosting an urban area already in 1975. Capital distance is the time to the nearest capital city in hours using contemporaneous roads (in log). Improved road distance refers to the distance to the nearest high-quality road, measured in kilometers (in log). Road connection refers to a dummy for having a specific road in the cell. Impoprved roads are those classified by Michelin as highways, hard surfaces, and improved, while unimproved roads are those classified as partially improved, earth roads, and other types (Müller-Crepon et al. 2020).

5.3 ASgM exposure, urban wealth, and structural transformation

Having established that urbanization increases with ASgM, albeit in a fragmented and disconnected urban network, we turn to the internal characteristics of urban areas. Despite the poor connectivity of ASgM towns to the rest of the network, a dynamic form of urbanization may still emerge if ASgM creates smaller but richer towns with urban amenities and structural transformation.

To explore these aspects, we employ a combination of satellite data and household surveys, which provide insight into what happens within the sample of urban areas (Panels B and C of Table 2). Importantly, all results in this section are controlled for the total population, both in terms of differential trends given its level in 1975, and accounting for the time-varying population of each urban entity. The goal is to examine how each entity is performing net of population influx, including potentially recent influx. In the appendix, we document that results are similar when leaving aside the time-varying control for population (Appendix Table A.7, A.8, and A.9).

Nighttime light emissions. As a first comprehensive proxy of the intensity of human economic activity and development, we turn to nighttime light emissions (Henderson et al. 2012).[28] Table 5 displays the resutls. We consider two alternative methods for utilizing nighttime lights to measure local economic wealth. First, as is standard in the literature, we use the mean value of nightlights in each cell (Column 1). The mean would increase if, for example, more economic activity gets concentrated in a cell. Second, we use nightlights per capita, following Smith and Wills (2018) (Column 2). This per-capita measure enables us to move beyond the question of activity agglomeration, exploring how this agglomeration may be linked to people's living standards.

Results suggest that while both population and activities may concentrate in ASgM-exposed towns and cities, the population growth is not accompanied by as much economic growth as it would be in entities that are not exposed to ASgM. ASgM exposure leads to an insignificant increase in nightlight emissions if we consider cells with both old and new urbanization (Table 5, Column 1 Panel A), and this insignificant effect becomes negative if we focus on cells with urban areas already existing in 1975 (Column 1, Panel B), and become precisely negative when looking at nighttime lights per capita (Column 2). In other words, taking the age of the urban entity and level of population as a given,[29] ASgM-exposed cities and towns tend to be either equally or less bright than non-exposed cities and towns, suggesting that they are less economically dynamic.

Household wealth, living conditions, and infant mortality. We turn to household-level data to test whether these differences in NTL emissions translate in differential living

28. We exploit data recently made available from 1992 to 2020 (Chiovelli et al. 2023). We replicate the analysis of urbanization, restricting the sample to one observation every 5 years between 1995 and 2020. Based on results in Appendix Table A.5, we know that the ASgM-urbanization relationship identified in the previous section is strongest during this sample of years.

29. As all estimates account for both differential trends by initial level of population, and control for time-varying population.

Table 5: Artisanal mining and human development

Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variables:	Nightlights		Wealth index		Improved		Child mortality	
	mean	per cap.	mean	median	sanit.	water	12months	24months
Panel A: Only urban								
Gold exp. × Gold price	0.311	-0.006	-3.53	-5.20**	-1.94*	-2.10	648.9***	629.3**
	(2.76)	(0.011)	(2.32)	(2.34)	(1.12)	(1.31)	(250.2)	(263.2)
Observations	58,355	58,355	4,202	4,203	5,017	5,017	34,653	34,653
Mean dep. var.	0.181	0.0002	0.869	0.860	0.749	0.807	60.6	76.0
Panel B: Only old urban								
Gold exp. × Gold price	-0.670	-0.021*	-1.13	-3.37	-1.98	-1.93	740.7***	732.2**
	(3.55)	(0.012)	(2.47)	(3.06)	(1.53)	(1.46)	(257.9)	(286.4)
Observations	36,620	36,620	2,950	2,951	3,668	3,668	24,280	24,280
Mean dep. var.	0.236	0.0003	0.829	0.820	0.750	0.800	62.2	78.3

Notes: OLS estimations based on Equation A.3 for columns 1 and 2, and the level version of that equation for the remainder of the columns. * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors, in parentheses, are estimated allowing for infinite serial correlation and spatial correlation within a 500km radius (Conley 2008; Hsiang 2016). Gold exposure is measured as the log of the inverse distance to gold-suitable zones. The estimation includes country×year fixed effects, as well as controls for temperature, precipitation, SPEI, the interaction between the ever-present industrial mines exposure and the corresponding mineral prices, and the interaction between crop suitability and the corresponding crop prices. All specifications control for the possibility of differential trends depending on the initial level of population (in 1975) as well as for the time-varying urban population size. In Panel A "Only urban", we restrict the sample to cells that have ever hosted an urban entity (at any point between 1975 and 2020). In Panel B with the heading "Only old urban", we restrict the sample to cells that were already hosting an urban area in 1975.

conditions of urban households in ASgM exposed town and cities. Following Khavari et al. (2021), we leverage the information recorded in the DHS, which is the most comprehensive harmonized historical microdata available for the countries studied. Based on GPS coordinates, we match 888,772 DHS urban-dwellers to 2,584 towns and cities present in our sample, with a median number of households interviewed by urban entity and by year equal to 43. 2,455 of these 2,584 urban entities are covered by two (or more) DHS surveys, and are thus kept in the final sample. We investigate how urban-dwellers' wealth reacts to ASgM, controlling for the population size of their town or city. The idea is to compare the characteristics of two entities of the same size, one exposed to artisanal mining and the other not. We are interested in both the level and the distribution of wealth.[30]

DHS-based results align with NTL-based results. Table 5 suggests that urban dwellers who are exposed to ASgM have, if anything, lower living standards. Towns and cities with increased artisanal mining activity tend to experience lower living standards in terms of asset wealth, sanitation, and water access, ultimately resulting in higher infant mortality rates. The results are qualitatively similar when focusing on all urban areas or only on pre-existing urban areas (already urban at the beginning of our sample in 1975), thereby avoiding sample selection and the higher prevalence of young towns in areas more exposed to artisanal mining (Panel B).

City-level coefficients assessed using a few years of DHS surveys often lack statistical power, except when examining child mortality, which is measured retrospectively and allows for longer time coverage.

Structural transformation. Finally, ASgM exposure also appears to limit the chances of structural transformation. We lack extensive data to document all the dimensions of the phenomenon. However, we can gain insights into the structure of employment in towns and cities by looking at the share of people working in each sector of activity.

Table 6 reveals that urban areas most exposed to ASgM have a lower share of industrial workers (Column 2), defined as the non-agricultural manual workers (Kotsadam and Tolonen 2016).[31] This decrease in activities in the industrial sector is, in a large part, compensated by an imprecise increase in activity in the service sector (column 3), consistent with the interpretation of mining boom towns as hubs providing shops and services to miners. This set of results aligns with the findings of (Kotsadam and Tolonen 2016), suggesting that women are more likely to be employed, in particular in the service sector, in the vicinity of large-scale industrial mines. This set of results also presents an interesting contrast with those in Girard et al. (2025). Considering all DHS respondents, both rural and urban, Girard et al. (2025) find that ASgM exposure does increase activities in the manual, non-agricultural

30. All indicators are built following the Guide to DHS Statistics https://dhsprogram.com/Data/Guide-to-DHS-Statistics/index.cfm. More details are given in the appendix A.3.

31. Appendix A.3 presents the activity classification by sector. Industrial workers are categorized into three main groups: skilled manual, unskilled manual, and professional/technical/managerial (see Table A.3).

sector (which should be the sector where artisanal miners themselves are most likely to be registered). This pattern of results reinforces our interpretation that the entities where we see urbanization taking place are not so much where the miners live, as miners are likely to live in semi-temporary mining camps. Rather, the entities we observe are the large markets, akin to the boom town of Tabelot described in Gagnol and Afane (2019), where miners go to purchase their supplies and may trade their gold, and where some families may reside.

These findings do not imply that ASgM-driven urbanization is entirely detrimental. Relative to rural baselines, the emergence of small towns can generate welfare gains by improving access to markets, services, and basic infrastructure (Christiaensen and Todo 2014). We also find that migration into mining towns largely originates from rural areas rather than from larger cities, suggesting that ASgM expands the urban system "from below" without crowding out established metropolitan centers (Tables 2 and A.6). In this sense, artisanal mining adds new layers to Africa's urban hierarchy. The evidence in this section indicates that these gains remain localized and limited, as they do not translate into broader structural transformation.

Table 6: Artisanal mining and the sectoral repartition of urban dwellers

Model:	(1)	(2)	(3)
Dependent variables:	Sectoral activity		
	Agriculture	Industry	Services
Panel A: Only urban			
Gold exp. × Gold price	0.029	-1.28***	0.511
	(0.429)	(0.440)	(0.453)
Observations	5,027	5,027	5,027
Mean dep. var.	0.058	0.170	0.190
Panel B: Only old urban			
Gold exp. × Gold price	-0.050	-1.26***	0.720
	(0.579)	(0.479)	(0.528)
Observations	3,675	3,675	3,675
Mean dep. var.	0.062	0.173	0.201

Notes: OLS estimations based on the level version of Equation A.3. * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors, in parentheses, are estimated allowing for infinite serial correlation and spatial correlation within a 500km radius (Conley 2008; Hsiang 2016). All columns include cell and country × year fixed effects. Controls for pull and push factors in the cells' surroundings include the presence of an industrial mine at any time interacted with the price of the corresponding mineral, the suitability for major crops interacting with their corresponding prices, the mean temperature, the mean precipitation, and the mean SPEI in the last five years. All specifications control for the possibility of differential trends depending on the initial level of population (in 1975) as well as for the urban population size, the mean age of city-dweller heads, the mean household size, and the proportion of female-headed households. In Panel A, the sample comprises all urban entities (all entities that had more than 5k inhabitants at any point between 1975 and 2020). In Panel B, we restrict the sample to urban areas that existed already in 1975.

6 Conclusion

This paper documents a major but previously overlooked overlooked channel of decentralized urbanization in Sub-Saharan Africa: artisanal and small-scale gold mining (ASgM). We exploit exogenous variation in the value of potential ASgM activities using a 45-year panel of geocoded population cells across the continent, combined with information on the presence of urban entities and microdata from 147 DHS surveys covering 33 countries.

We show that ASgM exposure fosters urban population growth. Quantitatively, ASgM accounts for 4.4% of the total increase in urban population in SSA between 1975 and 2020. This increase corresponds to the transition of 11 million people from rural to urban areas.

Importantly, this ASgM-led urbanization does not occur through the expansion of existing cities, but rather through the emergence of new and typically small towns. We disentangle the effects of ASgM from confounding factors such as local weather shocks or the development of industrial mines, the distinctiveness of ASgM-driven urbanization patterns remains clear.

However, the spatial geography of ASgM-driven urbanization might handicap its developmental impact. Mining towns tend to emerge in initially remote, infrastructure-poor areas and despite substantial expansion in African transport networks in the last decades (Jedwab and Storeygard 2022), ASgM-induced urban growth remained weakly integrated into the road network. These towns also exhibit a lower prevalence of industries. Instead of reinforcing urban concentration, extractive-driven urban growth appears to disperse population across space, contributing to the fragmentation of the urban system into small and disconnected entities. This pattern contrasts with classical urban models, which emphasize agglomeration economies and market access as drivers of productivity. These towns remain small, economically narrow, and weakly integrated into regional markets, limiting opportunities for cumulative growth. With such characteristics, the long-run prospects of ASgM-induced towns remain uncertain.

These findings underscore the need to move beyond a one-size-fits-all view of urbanization as a pathway to development. Policy actors typically emphasize the role of urban areas as major contributors to development outcomes, with internal dynamism and positive spillovers to their surroundings (OECD/UN ECA/AfDB 2022). In contrast, our results provide large-scale empirical evidence aligned with the emergence of "precarious towns" prone to "urbanization without structural transformation" (Udelsmann Rodrigues and Tavares 2012; Kamete 2012; Mususa 2012; Gollin et al. 2016).

Looking forward, the stakes are likely to rise. High gold prices and the artisanal extraction of minerals critical to the green energy transition suggest that mining-led urbanization will continue to expand (Boafo and Arthur-Holmes 2025). Whether this urbanization will become a stepping stone or a development trap will depend crucially on policy responses. If mining booms persist, population growth in remote regions will continue; without targeted investment in infrastructure, education, and connectivity, mining towns risk becoming permanent enclaves of low productivity. If booms reverse, many settlements may face abrupt decline, threatening economic livelihoods and the social fabric (Aragón et al. 2018). In both scenarios, a central challenge is to integrate *de facto* mining towns, transforming these extractive agglomerations into productive nodes within national urban systems.

Taken together, our findings highlight a fundamental tension at the heart of Africa's contemporary urban transition: rapid urban population growth can coexist with weak structural transformation. Artisanal mining highlights this tension at scale. Understanding how to transform consumption-driven, extractive towns into sustainable production cities remains a significant academic and policy challenge.

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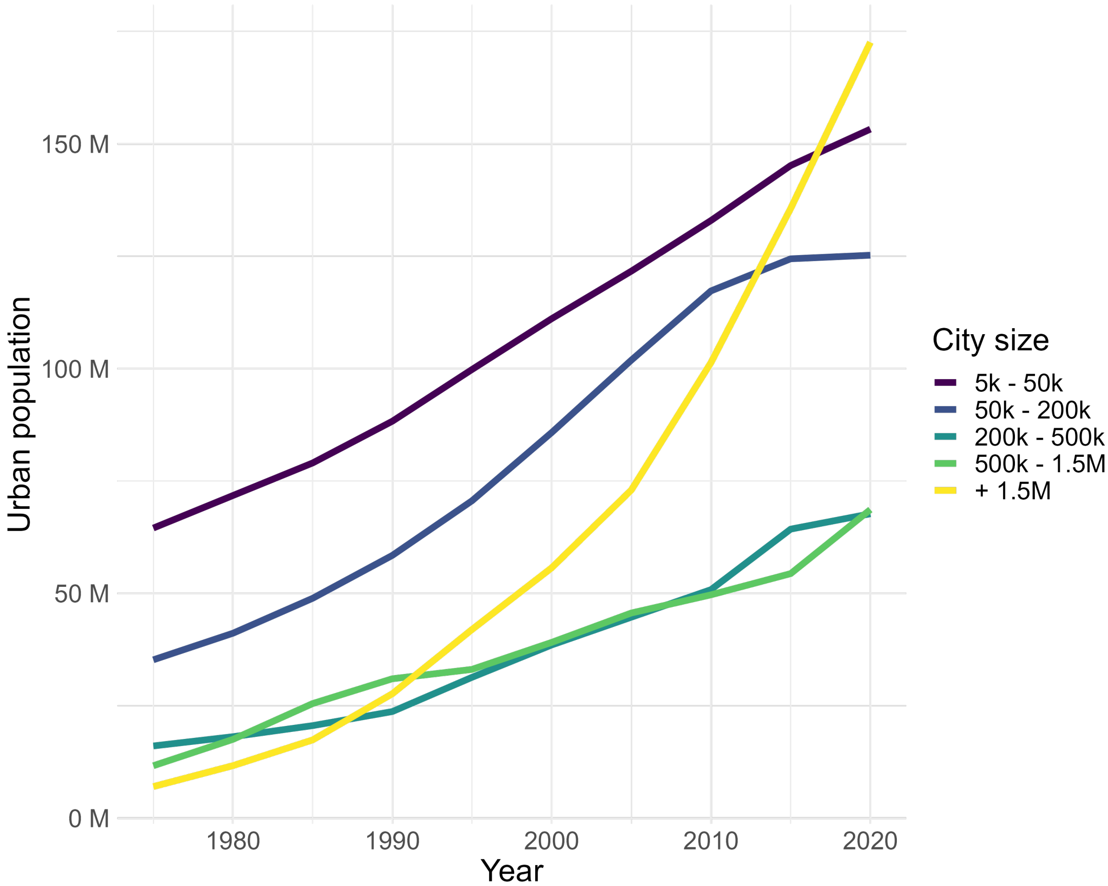
Appendix

A Appendix

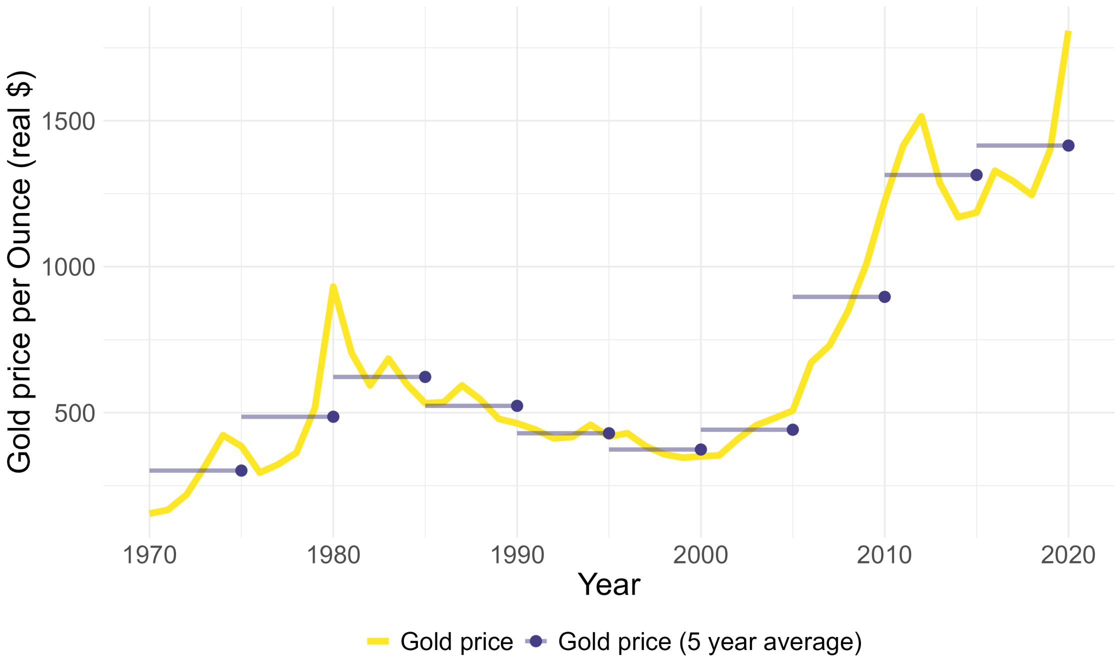
A.1 Descriptive figures

Figure A.1: Evolution of urban population by town size



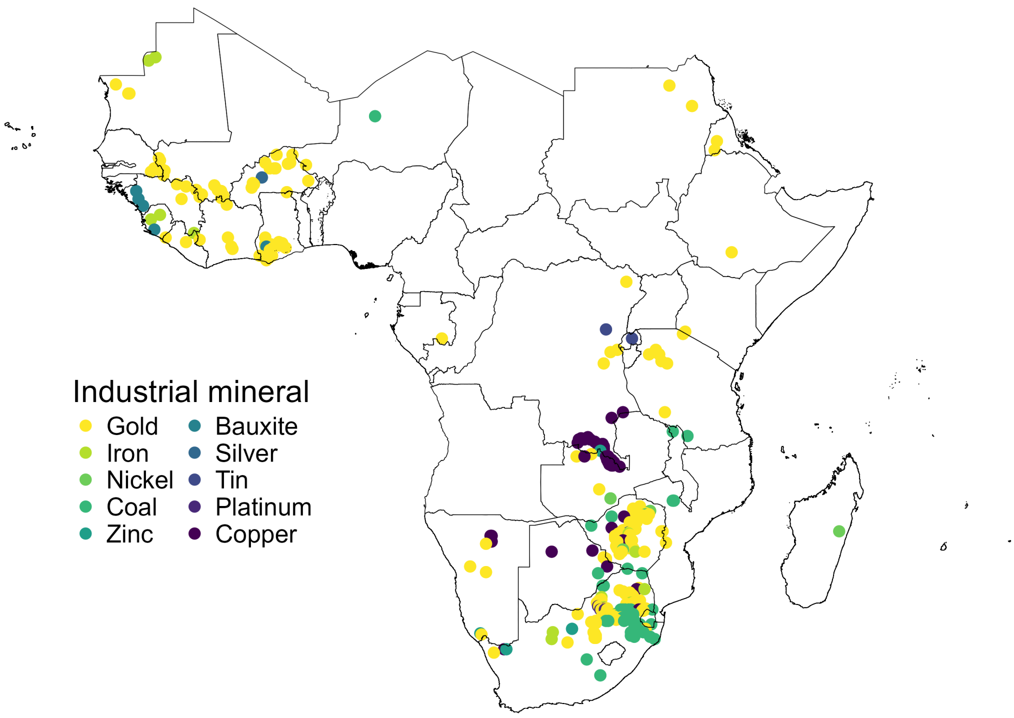
Note: Population thresholds are from the OECD (2012). Urban areas with a population of 5,000 to 50,000 are defined as towns, those with a population of 50,000 to 200,000 as small urban areas, those with a population of 200,000 to 500,000 as medium-sized urban areas, those with a population of 500,000 to 1.5 million as metropolitan areas, and those with a population exceeding 1.5 million as large metropolitan areas.

Figure A.2: Evolution of gold price



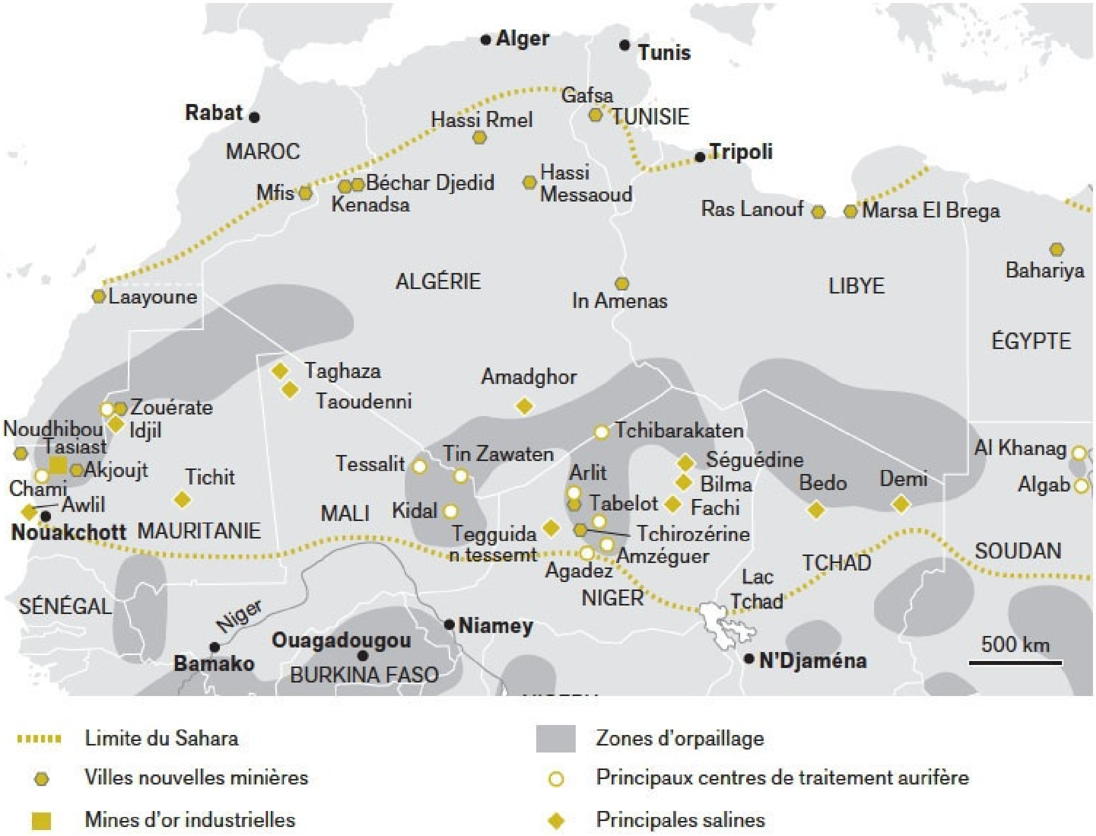
Note: Gold price data comes from the World Bank Commodity Markets database (World Bank 2024).

Figure A.3: Industrial mines location



Note: Location of ever-recoded industrial mines. Data are from the SNL Metals and Mining database owned by the S&P Global database.

Figure A.4: Mining urbanization in Sahara



Note: source: Gagnol and Afane (2019); we are thankful to the authors for allowing us to reproduce here.

A.2 Urbanization data

A.2.1 Urban areas in the GHSL data

The GHS provides a raster dataset for each 1 km^2 pixel, indicating the type of settlement present in that pixel every 5 years since 1975. We isolate the two main classes of urban cells from the GHSL SMOD, namely SMOD = 23 "Dense Urban Cluster grid cell", and SMOD = 30 "Urban Centre grid cell". Put differently, we focus on pixels with a population density above 1,500 inhabitants per km^2 of permanent land, which belong to a cluster with a total population of at least 5,000. By doing so, we exclude clusters with a total population of 5,000 if their population density is below 1,500 inhabitants per km^2.

The GHSL SMOD classification works in two steps. The GHS first classifies the 1 km^2 grid cells into three large and exclusive spatial entities: "Urban Centre" or "Urban Cluster", and the remainder as "Rural Grid Cells".

According to the GHS documentation, "the criteria for the definition of the spatial entities at the first hierarchical level are:

- "Urban Centre" (also "High-Density Cluster" - HDC) — An urban center consists of contiguous grid cells (4-connectivity cluster) with a density of at least 1,500 inhabitants per km^2 of permanent land and has at least 50,000 inhabitants in the cluster with smoothed boundaries (3-by-3 conditional majority filtering29) and <15 km^2 holes filled;

- "Urban Cluster" (also "Moderate Density Cluster" - MDC) — An urban cluster (or moderate density cluster) consists of contiguous grid cells (8-connectivity cluster) with a density of at least 300 inhabitants per km^2 of permanent land and has a population of at least 5,000 in the cluster (the urban centers are subsets of the corresponding urban clusters).

- The "Rural grid cells" (also "Mostly Low-Density Cells" - LDC) are all the other cells that do not belong to an Urban Cluster. Most of these will have a density below 300 inhabitants per km^2 (grid cell); some may have a higher density, but they are not part of a cluster with sufficient population to be classified as an Urban Cluster."

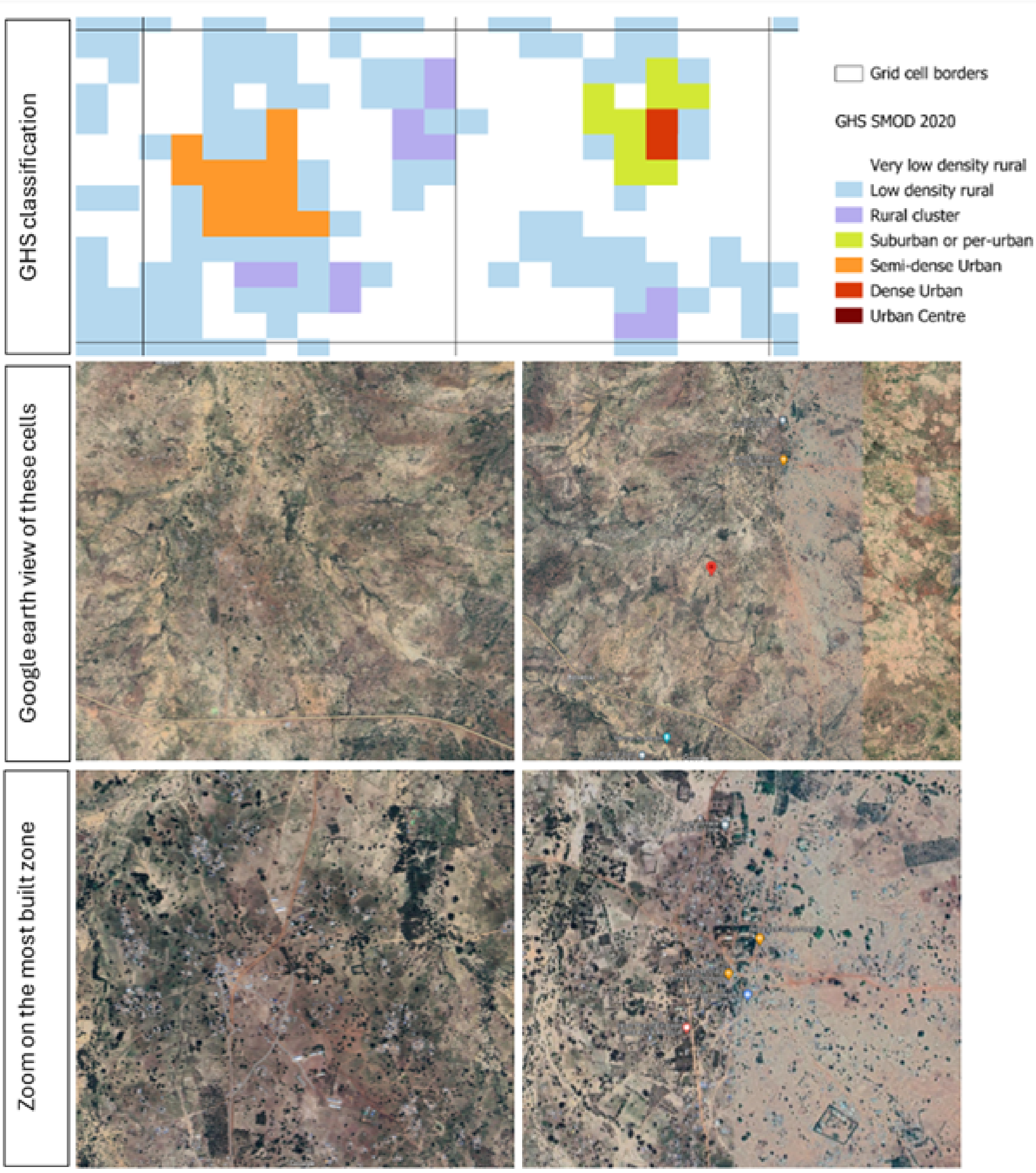
Nested within this first classification, the GHSL SMOD considers

- “Urban Centre” (also “Dense, Large Settlement”) — An urban center consists of contiguous grid cells (4-connectivity cluster) with a density of at least 1,500 inhabitants per km^2 of permanent land, and has at least 50,000 inhabitants in the cluster with smoothed boundaries (3-by-3 conditional majority filtering) and <15 km^2 holes filled;
- “Dense Urban Cluster” (also “Dense, Medium Cluster”) — A Dense Urban Cluster consists of contiguous cells (4-connectivity cluster) with a density of at least 1,500 inhabitants per km^2 of permanent land and has at least 5,000 and less than 50,000 inhabitants in the cluster;
- “Semi-dense Urban Cluster” (also “Semi-dense, Medium Cluster”) — A Semi-dense Urban Cluster consists of contiguous grid cells (8-connectivity cluster) with a density of at least 300 inhabitants per km^2 of permanent land, has at least 5,000 inhabitants in the cluster, and is at least 3 km away from other Urban Clusters32;
- “Rural cluster” (also “Semi-dense, Small Cluster”) — A Rural Cluster consists of contiguous cells (8-connectivity cluster) with a density of at least 300 inhabitants per km^2 of permanent land and has at least 500 and less than 5,000 inhabitants in the cluster.”

We focus on the first two classes to define the boundaries of towns (GHS codes 30 and 23). Considering the 3rd category to define town boundaries led to a single town covering large shares of countries, if not the entire countries, in the case of densely populated countries like Botswana. Furthermore, examining examples like the one appearing in the left panel of Figure A.5, the population density may be extremely limited (GHS code 22). These boundaries are also those that maximize the overlap between GHS-derived urban areas boundaries and those of the Africapolis (see discussion in Section A.2.4).

Figure A.5 shows the example of two neighboring cells with their classification in the GHSL, how each cell looks from Google Maps, and a zoom on the most dense part of each cell. The cell to the right hosts the dense urban cluster of Bolontou, which slightly exceeds the 5,000 population threshold based on the GHSL. The cell to the left hosts some semi-dense dwellings. We can see the difference in population density between both clusters, as well as the presence of various institutions (a market and a school) in the dense urban cluster.

Figure A.5: Two neighboring cells, GHS classes, satellite view, and zoom on built zones.



Note: The left panel of the Figure shows clusters that are not urban clusters. The right panel of the Figure shows the cluster corresponding to the small town of Bolontou, which just exceeds the 5,000 threshold for classification as urban in the GHSL in 2020 (with a record of 2,600 inhabitants in 2006, as noted in Wikipedia). The top panel displays the GHSL data classification of each pixel, the middle panel shows the cells in Google Maps, and the bottom panel zooms in on the densest part of each cell. In the bottom righ panel, Bolontou appears to have Google Map pins for two restaurants, a primary school, a shop and a pharmacy. Source of screenshots: GoogleMap

A.2.2 Construction of the panel of urban areas' contours and population

From each year of GHS data, we build a shapefile of towns. Towns are defined as clusters of contiguous urban cells, where a contiguous cell is defined as any cell that shares at least one neighbor with each of its 8 neighbors (including the direct diagonal neighbors). This definition is directly inspired by the GHSL data methodology, with the addition of considering 8 neighboring cells (as opposed to 4) to avoid excessive merging of towns.

The borders of towns are defined based on the GHS change in time, mostly because towns grow or appear. This is a challenge if we want to track towns over time in a balanced panel. To build the panel of towns from 1975 to 2020, we proceed as follows:

- We first link each layer of towns to the previous one based on the intersection of shapefiles. If the shape of a town as defined by borders in time t overlaps with that of a town as defined by borders in time $t+1$, we consider these to be the same town.
- We then build the panel of towns from the oldest year to the most recent year. If a town is split into two, we keep only the biggest of the two towns. Only 0.1% of towns experienced a split, so 84 towns dropped.

This procedure generates a balanced panel of towns for those that existed in 1975, revealing how their borders and populations have evolved over time.

Over the 45 years covered by our sample, a town may also appear or disappear, or two or more towns may merge together. We treat these cases as follows:

- New towns. We set the population of towns that do not exist yet based on the pre-existing population within the town's borders, the first time we observe the town. For example, if a town first appears in 1985, we extract the polygon of that town's borders as of 1985. Then, we use that polygon to obtain the total population present in earlier years within the borders of the (future) town. We observe 9606 towns appearing between 1975 and 2020.
- Disappearing towns. We proceed similarly for towns that disappear. Namely, we set the borders of the town's polygon in the last year of observation of the town. We consider the number of people living within these borders in each of the following years. We observe 1300 towns disappearing between 1975 and 2020.

- Merging towns. The case of neighboring towns, which were once distinct but eventually merged into the same larger urban areas as they grew, is delicate. One option would be to consider the polygon of the largest entity. This already merged town emerged in time t, and during the previous years ($t-1$, etc.), the population of all the small previous towns that eventually got absorbed was allocated to the merged town polygon. However, such an approach raises concerns regarding selection. Creating a merged town out of a combination of smaller towns is unlikely to be random.[32] The alternative approach is to stick to tracking things chronologically. We follow the latter approach. We thus observe each town develop independently. If some towns merge, we reallocate a proportion of the total population of the merged entity to each town based on the proportions observed in the last year before the towns merged. For example, if town A had a population of 6,000 and town B had a population of 12,000 in 1990. In 1995, the two towns merged, resulting in a total population of approximately 30,000. We will attribute 10,000 inhabitants to town A and 20,000 to town B. In total, 13,208 towns never merge, 819 merge only once, and 400 towns merge more than once.

Finally, we link this panel of towns to cells. We consider the total number of towns and the population of each town within each cell and year. In our baseline approach, we attribute towns to cells based on the location of the town's centroid in 1975. Alternatively, we combine all the towns and their populations within each cell and year. Table A.1 presents some descriptive statistics of African towns from 1975 to 2020 built with our methodology.

A.2.3 Background on GHS data construction

The Global Human Settlement Project provides a detailed depiction of built-up surfaces using satellite imagery from Landsat (MSS, TM, ETM sensor) for the years 1975, 1990, 2000, and 2014, at a resolution of 100 meters, and Sentinel-2 for 2018 at a resolution of 10 meters.

The construction of built-up areas is done in four steps. First, Sentinel-2 data are used to estimate the sub-pixel built-up fraction at 10-meter resolution, utilizing a machine learning algorithm and data from other sources as a learning set (GHS-BUILT-S2 R2020A, Facebook settlement delineation, Microsoft, and OpenStreetMap building delineation). In the next

32. Two neighboring towns will merge when urban growth in the region explodes, and we are precisely interested in sorting out cases when urban growth did or did not occur.

Table A.1: Descriptive statistics — urbanization over time

	1975	1980	1985	1990	1995
Median population	11473	11764	11778	11982	12217
Mean population	27100	28905	30360	32059	33812
New urban entity	0	666	838	909	1154
Urban entity disappeared	0	87	79	69	117
Number of urban entitites	4979	5558	6317	7157	8194
Urban entity pop. 5k and 50k	4495	4996	5611	6290	7095
Urban entity pop. 50k and 200k	412	474	572	701	903
Urban entity pop. 200k and 1.5M	69	82	121	149	179
Urban entity pop. above 1.5M	3	5	5	5	4
	2000	2005	2010	2015	2020
Median population	12340	12471	12679	12791	12676
Mean population	35729	37601	40064	42119	44228
New Urban entity	1132	1177	1144	1308	1278
City disappeared	78	128	152	154	436
Number of Urban entities	9248	10294	11289	12443	13285
Urban entity pop. 5k and 50k	7908	8708	9415	10340	11069
Urban entity pop. 50k and 200k	1114	1302	1489	1651	1663
Urban entity pop. 200k and 1.5M	203	251	332	406	494
Urban entity pop. above 1.5M	9	10	12	16	25

Notes: Descriptive statistics of our panel of African towns from 1975 to 2020 based on GHS data and our methodology. Urban population numbers correspond to the corrected urban population for merging towns. As a result, the number of towns is overestimated, and the population of towns is underestimated.

step, built-up surfaces are separated between residential and non-residential buildings using imagery analysis methods. Then, a multi-temporal process is run stepwise from recent to past epochs, removing built-up information using Landsat satellite imagery from the specific epoch. Finally, spatial-temporal interpolation is used to predict built-up surfaces in areas or epochs not covered by the satellite imagery, resulting in a database of built-up surfaces every five-year interval from 1975 to 2020.

From this data on built-up surfaces, population data from harmonized censuses are allocated to residential buildings in the corresponding administrative unit, resulting in a high-resolution population dataset every five-year interval from 1975 to 2020.

Finally, urban classifications are established, as defined in Section A.2, based on built-up surface continuity, population density, and total population obtained in the previous steps.

In terms of error assessment, preliminary evaluations of the built-up surfaces dataset show a high level of accuracy. The results from human visual inspections indicate an overall accuracy of about 90% in Africa. Moreover, improvements over previous releases have significantly enhanced the temporal precision, especially in detecting changes in built-up areas over time (European Commission 2021).

A.2.4 Convergence of urban areas boundaries based on the GHS and the Africapolis

The GHS (which we use), and the Africapolis (OECD/SWAC, Africapolis (database)), are the two main data used in the economics of urbanization litterature (Eberle et al. 2020; Jedwab and Storeygard 2022; Fafchamps and Shilpi 2021; Henderson et al. 2022; Akbar et al. 2023; Huang et al. 2023). The Africapolis methodology shares some similarities with the GHS; however, the researchers behind Africapolis have focused their efforts on precisely delimiting the boundaries of each city in 2020. Based on cities identified as existing in 2020, Africapolis collects data retrospectively for previous years.[33] We favor the GHS as it allows us to construct the panel of towns from the first year of observation of the city.

Table A.2 shows the large overlap of the GHS and the Africapolis for the year 2020. We also confirm that the overlap is strongest for our definition of cities' boundaries, which integrates the GHS classes of dense urban center and dense urban, and leaves aside the other definitions. The importance of choosing the right GHS classes is most evident when we exclude the sample cells, which are undoubtedly rural pixels, meaning pixels that never appear as urban pixels in either Africapolis or any of the alternative GHS classes.

Figure A.6 visually illustrates how the Africapolis overlaps with these different GHS classes for three different zones, for the capital city of Burkina Faso (a sparsely populated country, panel a), the capital city and its surroundings, and one more remote area.

33. The Africapolis defines towns as continuous built-up areas with more than 10,000 inhabitants.

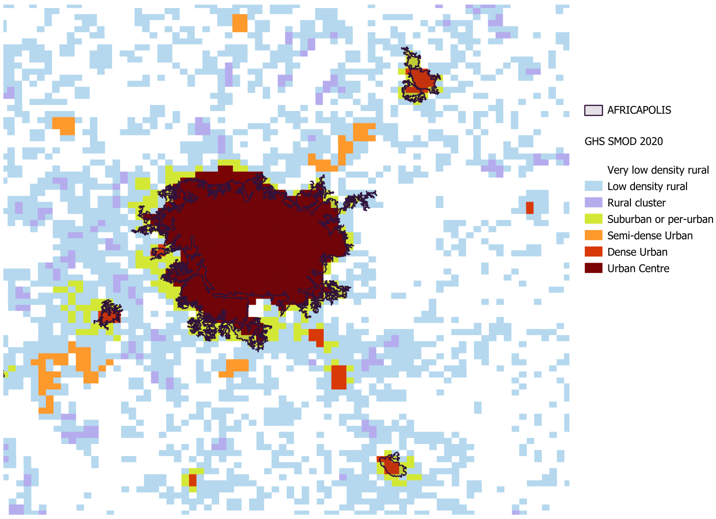
Table A.2: The overlap of GHS 2020 pixels categorization and Africapolis

	Overlap with Africapolis (%)	
	Full sample	Drop rural pixels
GHS center and dense urban	99.61	76.03
— adding semi-dense	99.39	62.69
— adding peri-urban	99.02	40.34
All	98.80	27.00

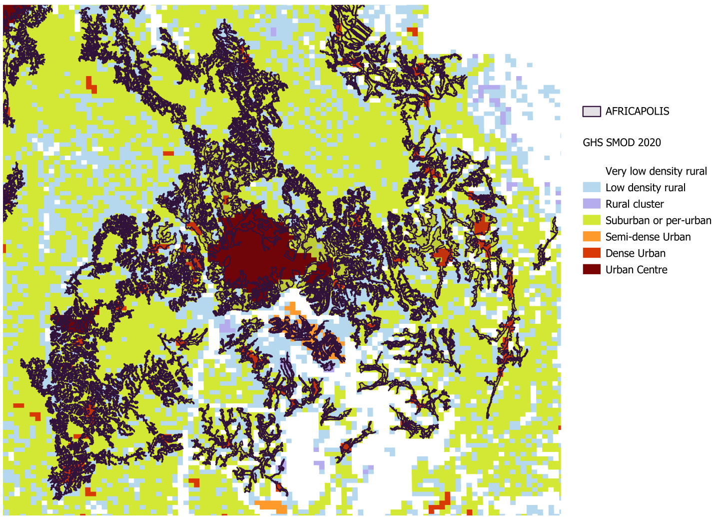
Notes: Descriptive statistics based on the Africapolis and 2020 cross-section of the GHS, taking as unit of analysis the GHS pixels. Number of observations: 24,061,362. A pixel is classified as urban according to Africapolis if the pixel centroid falls within the boundary of the Africapolis polygon; this is the case for 117,661 pixels. The GHS classifies a total of 100,378 pixels as urban when considering the categories center and dense urban, 158,647 pixels when adding semi-dense urban, and 382,579 pixels when adding suburban. Most pixels are not urban. The first cell indicates that 99.61% of the pixels have a similar classification as either urban or non-urban in Africapolis and the GHS, where urban is defined for the GHS as encompassing the urban center and dense urban clusters. The last column drops always rural pixels, meaning pixels that never appear as urban in either the Africapolis or in any of the alternative GHS potential urban areas; this restricted sample comprises 393,894 pixels.

Figure A.6: GHS 2020 pixel classes and Africapolis cities boundaries

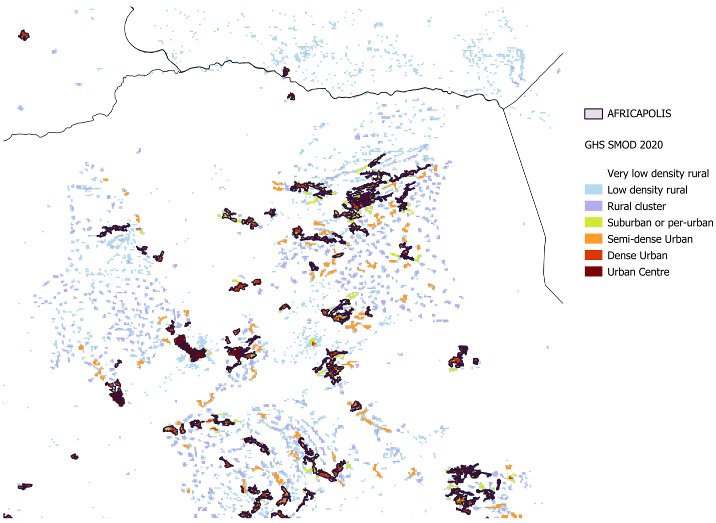
(a) Ouagadougou, Burkina Faso



(b) Kigali, Rwanda



(c) North-east of South Africa



A.3 DHS data

To build indicators of household living standards in cities based on DHS data, we follow the Guide to DHS Statistics (Croft et al. 2023).

Wealth indicators We use the following indicators for household wealth and inequality: the mean and median of the wealth index, the Gini coefficient, and the distribution of the population by wealth quintiles (based on the wealth index). The Gini coefficient is calculated using the Brown formula (Croft et al. 2023). The population distribution by wealth quintiles is computed by considering only the urban dwellers in the sample. Otherwise, the number of households in the first quintile is low, as most of this category comprises rural households.

Water, sanitation, and hygiene We also consider other indicators of living standards relative to health and the provision of public goods, such as the use of improved and unimproved sources of drinking water, the use of improved and unimproved sanitation, the time to get water, and the child mortality rate at 12 and 24 months.

Improved drinking water sources include piped into dwellings, piped to yards/plots, public tap/standpipe, piped to a neighbor, tube well or borehole, protected well, protected spring, rainwater, tanker trucks, carts with small tanks, and bottled water. Unimproved drinking water sources are unprotected wells, unprotected springs, and others.

Improved sanitation facilities include flush-to-piped sewer systems, flush-to-septic tanks, flush-to-pit latrines, flush-do-not-know-where, pit latrines, ventilated improved pits (VIP), pit latrines with slab, and composting toilets. Unimproved sanitation facilities include flushing to somewhere else, pit latrines without slabs / open pits, bucket toilets, hanging toilets/latrines, and others. The time to get water is the time it takes to fetch water from the source to the dwelling, measured in minutes. The threshold of 30 minutes is the one used by DHS.

Child mortality The child mortality rate is expressed in the number of deaths for 1,000 births. To compute the child mortality rate, we consider only children born in the 10 years preceding the survey, thereby avoiding recall bias and ensuring sufficient observations. We use birth recode files and compute for each child's year of birth the probability of dying before 12 and 24 months. We then average these probabilities to get the child mortality rate at 12 and 24 months for this specific year. This method enables us to go back ten years prior to the survey.

Sectoral activity The agricultural sector is composed of individuals who are agricultural employees, agricultural self-employed, agricultural unskilled, or in the category agriculture, breeding, fishing, and forestry. The service sector is composed of individuals labeled by services, sales, or both. The industrial sector is composed of skilled manual, unskilled manual, production, and professional/technical/managerial categories. The army, clerical, household/domestic, not working, and other categories are set in their own categories. Table A.3 presents the number and the share of urban dwellers in each sectoral activity category.

Table A.3: Sectoral activity of urban dwellers

Sector	N	Share (%)
Agriculture		
Agricultural employee	190,135	3.58
Agricultural self-employed	785,079	14.77
Agricultural unskilled	274	0.01
Agriculture	33,950	0.64
Agriculture, breeding, fishing, forest	11,727	0.22
Total	**1,021,165**	**19.21**
Industry		
Production	405	0.01
Professional/technical/managerial	246,271	4.63
Skilled manual	335,080	6.30
Unskilled manual	192,440	3.62
Total	**774,196**	**14.56**
Services		
Sales	557,093	10.48
Sales and services	6,546	0.12
Services	206,161	3.88
Total	**769,800**	**14.48**
Other		
Army	4,134	0.08
Clerical	59,211	1.11
Household and domestic	58,888	1.11
Not classified	2,024	0.04
Not working	862,714	16.23
Student	136	0.00
Other	20,136	0.38
Total	**1,007,243**	**18.95**

Notes: Number and share of urban dwellers by sectoral activity, female and spouse combined.

A.4 Aggregate effect of ASgM on urbanization

We quantify the impact of ASgM on urbanization on (1) the total urban population increase and (2) the number of towns in Sub-Saharan Africa. To do so, we estimate the following equation (equation A.3 from the baseline) in two scenarios: one with the actual increase in gold prices experienced from 1975 to 2020 and one assuming that the gold price would have remained at its 1975 level.

$$\Delta\widehat{Y_{ct}} = \sum_{d \in \mathcal{D}} \widehat{\beta_d} \{\text{gold dist} \in d\}_c \times \Delta\{\text{gold price}\}_{[t-5,t]} + \alpha_{t \times Country} + \widehat{\beta'} \Delta X_{ct} + \epsilon_{ct} \qquad (A.1)$$

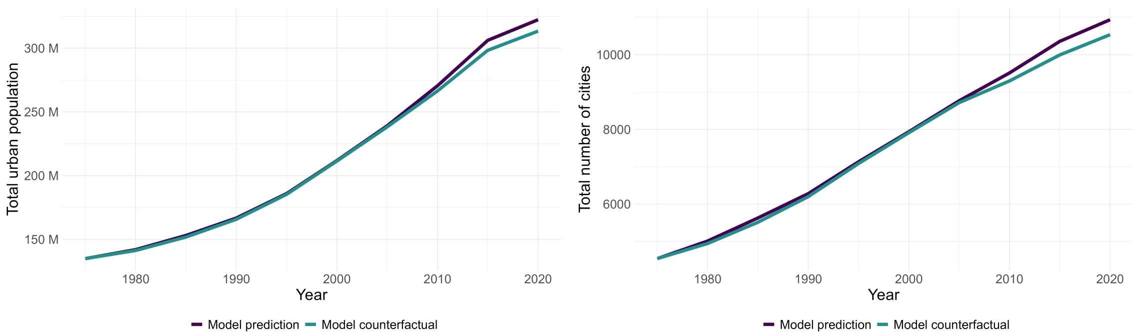
We run the following exercise for the baseline model (equation 2). To limit measurement errors, we only apply the counterfactual gold price to statistically significant coefficients from the figures 2. We retrieve the total urban population as follows:

$$Pop_t = \sum_c \sum_{t=1975}^{t} exp(\Delta \widehat{ln(Pop_{ct}}) + ln(Pop_{1975})) \qquad (A.2)$$

Figure A.7 provides the result of this quantification for all years of the sample. Overall, 4.5% of the total increase in urban population from 1975 to 2020 can be attributed to the increase in the price of gold. It represents 11 million new urban residents. 415 new cities can be linked to the increase in the price of gold, accounting for 6.5% of the total number of new cities developed in Sub-Saharan Africa between 1975 and 2020.

Figure A.7: Quantification of ASgM impact on overall urbanization

(a) Urban population **(b)** Urban population — first-diff



Note: The figure displays the total urban population (Panel A) and the total number of cities (Panel B) computed from the estimation of the model 2 in two scenarios: one with the actual international gold price (Model prediction) and one with the gold price staying at its level of 1975 (Model counterfactual).

A.5 Alternative empirical models

Exposure to gold. In this specification, we reduce the dimension of the relation between the distance to gold and the outcome of interest. Following (Fernihough and O'Rourke 2021), we use the log of the inverse of the distance to gold as a measure of gold proximity, $\{\text{gold exp}\}_c$. The model can be written as follows:

$$\begin{aligned}\Delta Y_{ct} =& \beta\{\text{gold exp}\}_c \times \Delta\{\text{gold price}\}_{[t-5,t]} + \alpha_{t\times Country} + \gamma\Delta X_{ct} \\ &+ \theta\{\text{urban population 1975}\} + \epsilon_{ct} \end{aligned} \tag{A.3}$$

The rest of the model is similar to Equation 2.

Flexible time specification Then, we allow a flexible relationship between the price of gold and ASgM-induced urbanization. We let this relation be period-specific, as in the following specification:

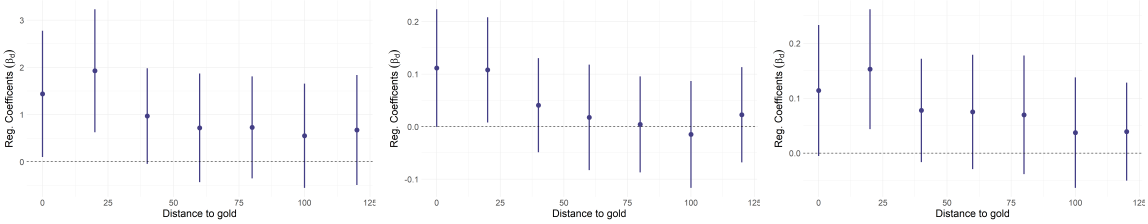
$$\begin{aligned}\Delta Y_{ct} =& \beta_t\{\text{gold exposure}\}_c \times \{\text{year}\}_t + \alpha_{t\times Country} + \gamma\Delta X_{ct} \times \{\text{year}\}_t \\ &+ \theta\{\text{urban population 1975}\} + \epsilon_{ct} \end{aligned} \tag{A.4}$$

with $\{\text{year}\}_t$ a dummy for the year t and $\{\text{gold exposure}\}_c$ the log of the inverse of the distance to gold. This model allows us to remove restrictions on the functional form of the relationship between urbanization and the international gold price. This is of interest to assess the potential asymmetrical effects during periods of increasing and decreasing gold prices. The rest of the model is similar to Equation A.3.

A.6 Further results on ASgM led urbanization

Figure A.8: Artisanal mining and urbanization — No industrial mines sample

(a) Urban population **(b)** Urban share **(c)** Any urban



Note: The figure reproduces the baseline results when removing all cells at a distance of less than 100 kilometers from any industrial mines of the following minerals: bauxite, iron, copper, lead, tin, nickel, zinc, gold, platinum, and silver. It presents regression coefficient estimates β_d of the interaction between the discretized distance d to gold suitable areas and the gold price on (a) the total urban population of the cell, (b) the share of urban population in the cell, and (c) the probability of having a city in the cell (see Equation 2). Error bar represents 90% confidence intervals in green confidence intervals in purple. Urban population is taken in logarithm transformation. The estimation includes country×year fixed effects, as well as controls for temperature, precipitation, SPEI, the initial log population, the interaction between the ever-present industrial mines at the ring distance and the corresponding mineral prices, and the interaction between crop suitability and the corresponding crop prices. Standard errors are estimated allowing for infinite serial correlation and spatial correlation within a 500km radius (Conley 2008; Hsiang 2016).

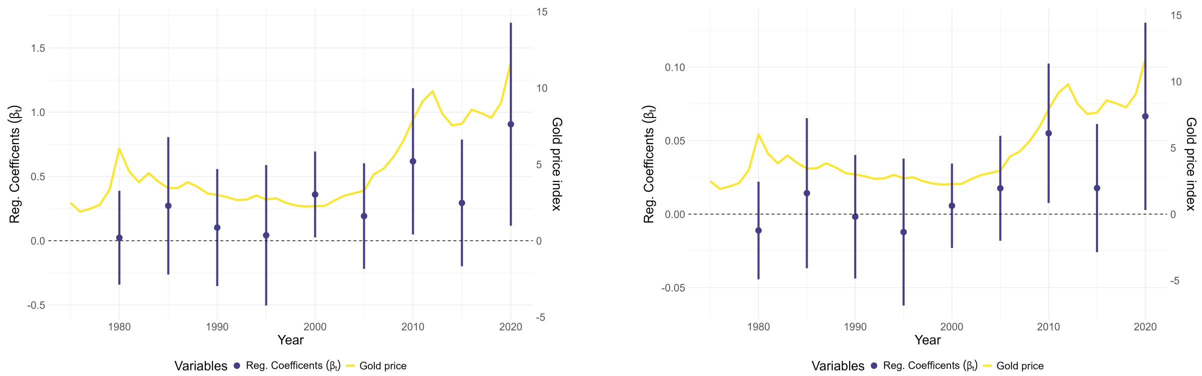
Table A.4: ASgM exposure and the probability that an urban area disappears (ceases to be urban)

Model:	(1)
Dependent variables:	City disapear
Panel A: Full sample	
Gold exp. × Gold price	-0.013
	(0.011)
Observations	1,849,860
Mean dep. var.	0.0002
Panel B: Only urban	
Gold exp. × Gold price	-0.298*
	(0.166)
Observations	105,039
Mean dep. var.	0.004
Panel C: Only old urban	
Gold exp. × Gold price	-0.345
	(0.262)
Observations	40,860
Mean dep. var.	0.002

Notes: OLS estimations based on Equation A.3. * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors, in parentheses, are estimated allowing for infinite serial correlation and spatial correlation within a 500km radius (Conley 2008; Hsiang 2016). The estimation includes country×year fixed effects and controls for temperature, precipitation, SPEI, the initial log population, the exposure to ever-present industrial mines interacting with the corresponding mineral price, and crop suitability interacting with the corresponding crop price.

Figure A.9: Artisanal mining and urbanization — Dynamic

(a) Urban population **(b)** Any urban



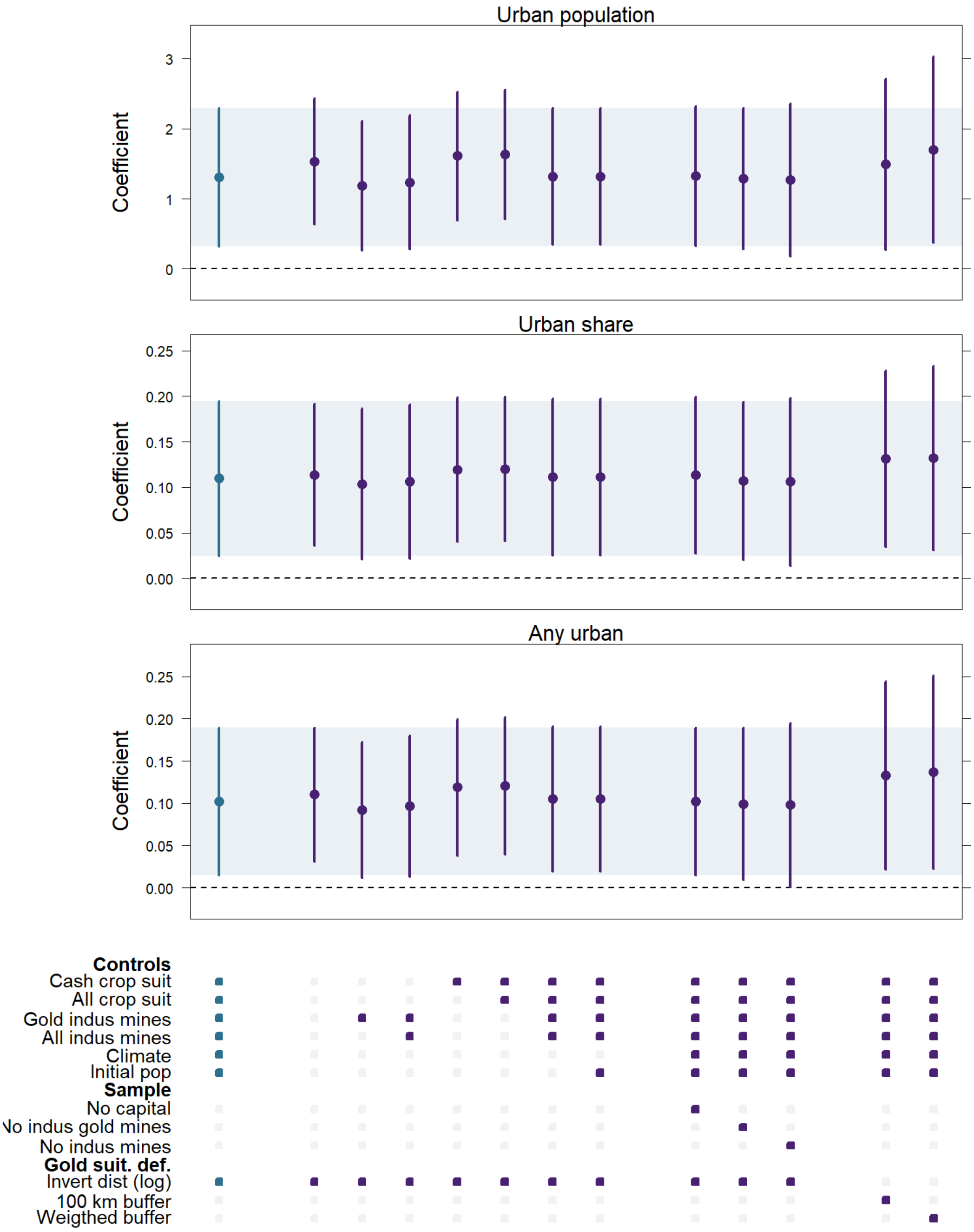
Note: The figure displays regression coefficient estimates β_t of the interaction between the gold exposure and the year on (a) the total urban population of the cell, and (b) the probability of having a town or city in the cell (see Equation A.4). Error bars represent 90% confidence intervals. Urban population is taken in logarithm transformation. The estimation includes country×year fixed effects and controls for temperature, precipitation, SPEI, the initial log population, the ever-presence of industrial mines at the ring distance interacting with the corresponding mineral price, and crop suitability interacting with the corresponding crop price. Standard errors are estimated allowing for infinite serial correlation and spatial correlation within a 500km radius (Conley 2008; Hsiang 2016).

Table A.5: Urbanization increase with the value of potential artisanal mines – period split

Model:	(1)	(2)	(3)	(4)
Dependent variables:	Urban population	Urban share	Any urban	50k city
Panel A: 1975-1995 period, gold price stagnating-down				
Gold exp. × Gold price	0.374	-0.005	0.030	0.014
	(0.706)	(0.046)	(0.076)	(0.024)
Observations	822,160	822,160	822,160	822,160
Mean dep. var.	0.041	0.002	0.003	0.0007
Panel B: 2000-2020 period, gold price booming				
Gold exp. × Gold price	1.34**	0.125**	0.107*	0.018
	(0.660)	(0.060)	(0.057)	(0.025)
Observations	1,027,700	1,027,700	1,027,700	1,027,700
Mean dep. var.	0.048	0.003	0.004	0.0009

Notes: OLS estimations based on Equation A.3. * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors, in parentheses, are estimated allowing for infinite serial correlation and spatial correlation within a 500km radius (Conley 2008; Hsiang 2016). Urban population is taken in logarithm transformation. The estimation includes country×year fixed effects and controls for temperature, precipitation, SPEI, the initial log population, the exposure to ever-present industrial mines interacting with the corresponding mineral price, and crop suitability interacting with the corresponding crop price.

Figure A.10: Specification curve — Artisanal mining and urbanization



Note: OLS estimations based on Equation A.3. Error bars represent 90% confidence intervals. Urban population is taken in logarithm transformation. All columns include country × year fixed effects. Coefficient features in from left to right, the baseline, varying control estimation, varying Conley distance, removing capital cities, and testing for other definitions of gold exposure.

Table A.6: ASgM exposure and ural and urban population, by sample period

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables:	Urban population		Rural population		Total population	
Sample period:	1975-1995	2000-2020	1975-1995	2000-2020	1975-1995	2000-2020
Gold exp. × Gold price	0.374	1.34**	1.11	2.11**	1.08	1.84**
	(0.706)	(0.660)	(0.688)	(0.921)	(0.671)	(0.903)
Observations	822,160	1,027,700	822,160	1,027,700	822,160	1,027,700
Mean dep. var.	0.041	0.048	0.105	0.079	0.100	0.073

Notes: OLS estimations based on Equation A.3. * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors, in parentheses, are estimated allowing for infinite serial correlation and spatial correlation within a 500km radius (Conley 2008; Hsiang 2016). Urban population is taken in logarithm transformation. The estimation includes country×year fixed effects and controls for temperature, precipitation, SPEI, the initial log population, the exposure to ever-present industrial mines interacting with the corresponding mineral price, and crop suitability interacting with the corresponding crop price.

Table A.7: Artisanal mining and human development — No control for time-varying urban population

Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variables:	Nightlights		Wealth index		Improved		Child mortality	
	mean	per cap.	mean	median	sanitation	water	12-months	24-months
Panel A: Only urban								
Gold exp. × Gold price	0.383	-0.006	-3.45	-5.13**	-1.93*	-2.03	645.4***	626.2**
	(2.75)	(0.011)	(2.31)	(2.35)	(1.11)	(1.36)	(248.1)	(262.0)
Observations	58,355	58,355	4,202	4,203	5,017	5,017	34,653	34,653
Mean dep. var.	0.181	0.0002	0.869	0.860	0.749	0.807	60.6	76.0
Panel B: Only old urban								
Gold exp. × Gold price	-0.741	-0.021*	-1.02	-3.29	-1.99	-1.88	736.6***	731.9**
	(3.58)	(0.012)	(2.50)	(3.07)	(1.52)	(1.48)	(257.9)	(286.4)
Observations	36,620	36,620	2,950	2,951	3,668	3,668	24,280	24,280
Mean dep. var.	0.236	0.0003	0.829	0.820	0.750	0.800	62.2	78.3

Notes: OLS estimations based on Equation A.3 for columns 1 and 2, and the level version of that equation for the remainder of the columns. * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors, in parentheses, are estimated allowing for infinite serial correlation and spatial correlation within a 500km radius (Conley 2008; Hsiang 2016). Gold exposure is measured as the log of the inverse distance to gold-suitable zones. The estimation includes country×year fixed effects, as well as controls for temperature, precipitation, SPEI, the interaction between the ever-present industrial mines exposure and the corresponding mineral prices, and the interaction between crop suitability and the corresponding crop prices. All specifications control for the possibility of differential trends depending on the initial level of population (in 1975) as well as for the time-varying urban population size. In Panel A, the sample comprises all urban entities (all entities that had more than 5k inhabitants at any point between 1975 and 2020). In Panel B, we restrict the sample to urban areas that existed already in 1975.

Table A.8: Artisanal mining and the sectoral repartition of urban dwellers — No control for time-varying urban population

Model:	(1)	(2)	(3)
Dependent variables:	Sectoral activity		
	Agriculture	Industry	Services
Panel A: Only urban			
Gold exp. × Gold price	-0.012	-1.27***	0.535
	(0.432)	(0.450)	(0.448)
Observations	5,027	5,027	5,027
Mean dep. var.	0.058	0.170	0.190
Panel B: Only old urban			
Gold exp. × Gold price	-0.112	-1.24***	0.759
	(0.574)	(0.481)	(0.540)
Observations	3,675	3,675	3,675
Mean dep. var.	0.062	0.173	0.201

Notes: OLS estimations based on the level version of Equation A.3. * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors, in parentheses, are estimated allowing for infinite serial correlation and spatial correlation within a 500km radius (Conley 2008; Hsiang 2016). All columns include cell and country × year fixed effects. Controls for pull and push factors in the cells' surroundings include the presence of an industrial mine at any time interacted with the price of the corresponding mineral, the suitability for major crops interacting with their corresponding prices, the mean temperature, the mean precipitation, and the mean SPEI in the last five years. All specifications control for the possibility of differential trends depending on the initial level of population (in 1975) as well as for the urban population size, the mean age of city-dweller heads, the mean household size, and the proportion of female-headed households. In Panel A, the sample comprises all urban entities (all entities that had more than 5k inhabitants at any point between 1975 and 2020). In Panel B, we restrict the sample to urban areas that existed already in 1975.

Table A.9: Artisanal mining and market access — No control for time-varying urban population

Model:	(1)	(2)	(3)	(4)	(5)
Dependent variables:	Improved road distance	Capital distance	— Road connection —		
	(log)	(log)	All	Unimproved	Improved
Panel A: Only urban					
Gold exp. × Gold price	0.152	0.062	-0.020	0.182	-0.214
	(1.07)	(0.758)	(0.159)	(0.308)	(0.291)
Observations	104,877	90,732	104,877	104,877	104,877
Mean dep. var.	-0.038	0.026	0.003	-0.004	0.008
Panel B: Only old urban					
Gold exp. × Gold price	-0.099	-0.515	0.031	0.369	-0.282
	(1.63)	(0.606)	(0.256)	(0.586)	(0.505)
Observations	40,815	35,705	40,815	40,815	40,815
Mean dep. var.	-0.031	0.024	0.003	-0.005	0.007

Notes: OLS estimations based on Equation A.3. * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors, in parentheses, are estimated allowing for infinite serial correlation and spatial correlation within a 500km radius (Conley 2008; Hsiang 2016). Gold exposure is measured as the log of the inverse distance to gold-suitable zones. The estimation includes country×year fixed effects, as well as controls for temperature, precipitation, SPEI, the interaction between the ever-present industrial mines at the ring distance and the corresponding mineral prices, and the interaction between crop suitability and the corresponding crop prices. All specifications control for the possibility of differential trends depending on the initial level of population (in 1975). In Panel A, the sample comprises all cells that have ever hosted an urban entity (at any point between 1975 and 2020). In Panel B, we restrict the sample to cells that were hosting an urban area already in 1975. Capital distance is the time to the nearest capital city in hours using contemporaneous roads. Improved road distance refers to the distance to the nearest imporved road, measured in kilometers. Road connection refers to the presence of a specific road in the cell. Improved roads are those classified by Michelin as highways, hard surfaces, and improved, while low-quality roads are those classified as partially improved, earth roads, and other types (Müller-Crepon et al. 2020).