The dynamics of villages, towns and cities in sub-Saharan Africa: The case of Mali*

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Abstract

We analyze the urbanization process over time in a land-locked sub-Saharan African country – Mali – using census microdata on the population distribution over a 30-year time span. More specifically, we estimate the role of changes in local access to markets on the dynamics of local population growth and of sectors of employment throughout the system of urban and rural localities. First, we find that local access to markets does indeed have a significant positive impact on local population growth. Second, isolating the contributions of population changes and transport network improvements to changes in market accessibility, we also investigate how these two dimensions affect the urbanization process. We find that most of the relationship is due to the effect of improved transport network on the development of small rural localities. We also find that changes in market access have a positive impact on sectoral employment, especially for services.

JEL codes: O18, R11, R12

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1 Introduction

Half of the world's population now lives in urban areas, and the urban population is continuing to grow at a fast pace in developing countries. Between 1950 and 2010, the world's urban population increased almost fivefold while total population increased less than threefold. Although urban growth may seem very intense in sub-Saharan Africa, where the urban population in 2010 was 16 times greater than in 1950, this region is still one of the least urbanized in the world, with only one third of its population living in cities (United Nations Population Division, 2015). Another particularity of sub-Saharan African countries is their unbalanced urban systems where the main city, usually the capital city, is disproportionately large compared to cities of smaller size. In addition, the ongoing phenomenon of urbanization in sub-Saharan African countries has not been accompanied by sustained economic growth and does not seem to be accompanied by structural economic transformation through a change in the sectoral distribution of employment. As a matter of fact, non-agricultural activities seem to be developing at a lower pace than urbanization. This experience is atypical compared to that of Europe in the 19th century, where urbanization took place alongside an increase in non-agricultural activities and sustained economic growth in the wake of the Industrial Revolution. In most other developing countries, particularly in Asia, over the course of the 20th century, urbanization was also accompanied by deep structural changes. Urbanization in sub-Saharan Africa has therefore been described as a case of urbanization without growth (Fay and Opal, 2000).

Seeking to understand the factors that explain the particular demographic and economic dynamics of the urbanization process in sub-Saharan Africa is a complex task and studies are scarce. Until now, most research on this issue has focused on macroeconomic determinants and analyzed country level data. Papers have attempted to identify elements differentiating sub-Saharan Africa from other continents, such as the impact of their revenues from agricultural exports on their process of urbanization. According to Gollin et al. (2016), revenue from agricultural exports may indeed bring about urbanization but, because it will mostly be used to purchase consumer goods and favor service and import activities, there is less likelihood of an industrialization process occurring. Rather surprisingly, Henderson et al. (2013) find that increased agricultural revenue in sub-Saharan African countries does not accelerate urbanization but actually decelerates it, possibly because such income is not reinvested in urban production activities. They also observe that positive shocks in the modern sector do not result in faster urbanization, probably because of institutional and economic constraints that hinder the expansion of manufacturing activities. Jedwab and Storeygard (2016), who investigate the effect of road construction on city population growth in sub-Saharan

Africa over the 1960-2010 period, find that investments in transportation infrastructure is an important determinant of city population growth at the regional level. They also show that road network expansion has long-term effects on urbanization.

Although those recent works shed interesting light on the process of urbanization in Africa, they have two important limitations. First, currently available cross-country data on urbanization are imperfect as they are often estimates or projections based on earlier censuses (Cohen, 2004; Bocquier, 2005).[1] In addition, these data may not properly capture urban population as they do not adequately account for the spatial expansion of existing cities and the emergence of small urban centers (Champion and Hugo, 2003). Second, cross-country analyses may lead to unwarranted generalizations regarding the urbanization process, while idiosyncratic factors may play a prominent role. Country-level studies or comparisons may therefore be particularly valuable to understand the challenges associated with urbanization in different contexts. There is unfortunately a paucity of quantitative research in this area. One exception is the work of Jedwab (2013), studying the urbanization process in Côte d'Ivoire and Ghana. He finds the same results as Gollin et al. (2016): city growth is mainly driven by the rise of agricultural activities and rural incomes but does not bring about an industrialization process.

Another important dimension to understand the process of urbanization is the role transportation networks. In spite of significant progress over the past decades, most roads in sub-Saharan African countries remain of poor quality, which, combined with the low density of roads networks, makes the transport of goods slow and costly (Foster and Briceno-Garmendia, 2010). Road improvements – which reduce transport costs between localities – can thus facilitate the movements of people and goods, possibly with significant effects on spatial economic patterns. The literature on transport (see Berg et al. (forthcoming) for a survey on roads and economic development) shows that improved market access from better road connections can affect local economic activities in both urban and rural areas in various ways.

Studies in the rural areas of Uganda, Ethiopia and Nigeria find that better roads increase participation to markets, enhance the adoption of modern techniques, and facilitate the development of commercial agriculture (Kyeyamwa et al., 2008; Minten et al., 2013; Damania et al., forthcoming). These results are confirmed by a region-wide study of sub-Saharan Africa which finds that a shorter travel time to the nearest urban market is associated with a higher agricultural production (Dorosh et al., 2012). The impact of rural roads, however, is not limited to production and employment in the agricultural sector as rural roads may also facilitate the growth of the non-agricultural

[1] The reference international dataset is the World Urbanization Prospects (United Nations Population Division, 2015).

sector, sometimes at the expense of the agricultural sector (see Mu and van de Walle (2011) on Vietnam, Gertler et al. (2014) on Indonesia, or Ali et al. (2015) on Nigeria). In this respect, (Asher and Novosad, 2016) find that, because rural roads in India enable workers to access external labor markets, they facilitate the shift away from agriculture. Whether just stimulating agricultural sector growth or leading to structural transformation (the shift from agricultural to manufacturing activities), roads in rural areas have unambiguously been found to have a positive impact on poverty reduction through higher local incomes (see Khandker et al. (2009) on Bangladesh, Jacoby (2000) on Nepal, Jacoby and Minten (2009) on Madagascar, Mu and van de Walle (2011) on Vietnam, Emran and Hou (2013) on China). In line with the above results, studies on the impact of rural roads on migration find that roads not only reduce incentives to migrate out from rural areas (see Castaing Gachassin (2013) on Tanzania), but also increase incentives to migrate in (see Fafchamps and Shilpi (2013) in the case of Nepal).

Road investments may also have an impact through increased productivity in the manufacturing sector in or around cities, fostering trade and leading to greater income generation locally. These effects, however, may be heterogeneous as better inter and intra-city roads can in theory lead to a spatial reorganization of production. In the Anas and Xiong (2003) model, lower inter-city transport costs lead to the relocation of activities as cities specialize while cheaply importing the goods they do not produce. In India, Ghani et al. (2015) find that road improvements (highways) led to the clustering of manufacturing activities along the transport network. In an empirical study of Colombia, Duranton (2015) finds that within-city roads shift economic activities towards the production of tradable goods.

More generally, lower transport costs from road improvements should facilitate both internal and external trade and stimulate exports (Freund and Rocha, 2011). It has been estimated that an upgrade of the primary road network to connect the major cities in sub-Saharan Africa could increase trade within the region by 250 billion USD over five years (Buys et al., 2010).

In this paper, we study the demographic and economic dynamics of localities over three decades in Mali, and the specific role of market access. Focusing on a specific country allows us to analyze structural transformation as measured by sectoral employment dynamics at the local level. Mali is a typical example that illustrates the disconnect between urban growth and economic growth. While the urban population of Mali quadrupled between 1976 and 2009, its real GDP per capita increased by only 36 percent during the same period. As a result, Mali is still one of the poorest countries in the world. In addition, Mali has witnessed very little structural transformation over this period, even in the largest cities (Mesplé-Somps et al., 2015). Furthermore, urbanization in Mali has been unbalanced as its city system is characterized by a high primacy rate.[2] In line with mechanisms underpinning New Economic Geography models, the objective of our paper is to study the role played by market access to explain the dynamics of population growth and structural transformation, distinguishing between different categories of localities: villages, towns, and cities. We thus not only focus on the dynamics of the urban population but also on that of the rural population.

We make use of comprehensive microdata from four different waves of the census for the period 1976-2009, and of recently compiled GIS panel data on the Malian road network throughout the same period (Jedwab and Storeygard, 2016). Using census data at a very detailed geographic level allows us to overcome the limitations associated with ad hoc definitions of rural and urban areas as we reconstruct urban agglomerations according to contiguity and density criteria (Bernard et al., 2012).

In the next section, we discuss the characteristics of the urbanization process in Mali. In section 3, we present our empirical methodology. Section 4 is devoted to the data used in this paper. We present our results in section 5, and section 6 concludes.

2 Urbanization in Mali: descriptive evidence[3]

2.1 Urban growth and primacy

Mali is a large, sparsely populated and low income country located between the 10th and the 25th parallels. A large part of its territory is located in the Saharan part of Africa, a region threatened by drought and desertification that can hardly be used for agriculture. Most of the population lives in the Southern part of the country (89 percent). Even in the Southern region, population density remains low (on average 53 people per km2).

Most of the largest localities are in the South-East of the country, in the cotton and rice production areas, and along the Niger and Senegal rivers. This spatial distribution is consistent with towns being primarily economic centers where urban activities are linked to the needs of surrounding rural areas. As noted above, there has been a significant increase in the urban population over time, but this was also the case for the rural population. Consequently, the urbanization rate increased by only 13 percentage points between 1976 and 2009, reaching 27.5 percent in 2009. Moreover, the number of urban localities has remained quite stable, with few localities crossing the rural/urban threshold. In 2009, there were 10,916 populated places in Mali, 98 percent of which had less than 5,000 inhabitants and an average population of 882 people. There were 188

[2] Which is a frequent feature of urban systems in developing countries (Ades and Glaeser, 1994; Overman and Venables, 2005).

[3] This section draws on related works by the authors on the Malian city system (Bernard et al., 2012; Mesplé-Somps et al., 2015). Unless otherwise noted, the figures in this section refer to the 2009 population census.

localities with a population between 5,000 and 30,000 inhabitants, of which 60 can be defined as small-sized cities with a density greater than 250 people per km2. 15 localities had more than 30,000 inhabitants and can be defined as medium to large-sized cities (all with a density greater than 250 people per km2). Together, these 75 Malian cities had a population of 3.9 million people, representing only 27.5 percent of the total population of the country.

A key feature of the Malian city system is that the majority of the urban population is concentrated in the capital city, inducing a very strong primacy. In 2009, Bamako hosted more than 2.1 million people, more than half of the country's urban population. The three largest cities after Bamako are medium-sized: Ségou (166,000 people), Sikasso (143,000 people) and Kayes (127,000 people). Bamako therefore has 13 times more people than Ségou, the second-largest city. Although many factors may account for primacy in sub-Saharan Africa, in the case of Mali, it is most likely reinforced by the centralized nature of the political power as well as an inadequate transport network in the rest of the country. The predominance of Bamako dates back to the colonial period, when the choice of Bamako to host the colony's government gave rise to significant migration towards the decision-making center and heavily influenced the layout of roads during that period. In the case of Mali, the disproportion between the capital and the other large cities has kept on increasing over the years: we find that the ratio between the population of Bamako and that of the second city was "only" 4 in 1960, and reached 7 in 1976, 8.5 in 1987 and 10 in 1998. Spatial imbalances may reflect a lack of economic growth in secondary urban centers, but may also hinder it, when the share of the capital city in the economy has become too strong.

Taking a more detailed look at the long-term urbanization process, we observe that the population of Bamako grew on average at a rate of 4.9 percent annually over the period 1987-2009, with an acceleration during the period 1998-2009, when it grew at an extremely high annual average rate of 6.1 percent. By contrast, medium and small-sized cities and rural localities grew at slightly lower rates (3.6 percent and 2.3 percent respectively over 1987-2009). Figure 1 represents the unbalanced population growth of urban places throughout these periods.

The data also show that, although both natural growth and internal migration contributed to urban population growth in Mali, migration plays an especially important role in the largest cities. In Bamako for instance, more than 40 percent of residents were born in another region of Mali or in a foreign country. This contrasts greatly with rural areas where migration originates and where migrants represent less than 5 percent of the population.

2.2 Demographic characteristics

Demographic characteristics are not very different between rural and urban areas. For instance, the proportion of children in the population is almost the same across rural localities, towns and cities. It is only in the two largest cities (Ségou and Bamako) that the share of children is significantly lower. As a consequence of the high birth rate, average household size remains very high throughout Mali (8.1 at the national level). Surprisingly, however, the household size increases with city size: households in urban areas are larger by more than one household member compared to rural areas. Urban households are in fact more likely to host extended family members than rural ones: although the average proportion of extended family members in rural households is already high at 40 percent, it reaches about 50 percent in cities. This difference is partly due to the presence of students and adults looking for jobs in medium-sized cities and in Bamako.

Education levels are very low throughout the country in spite of progress over time in primary and secondary education in rural areas and small towns, and in spite of increasing levels of secondary and tertiary education in middle-sized cities and in Bamako. There are, however, large spatial variations, and the share of educated adults increases with city size. In 2009, while 86 percent of the population aged 15-64 in rural areas had no schooling, this share was much lower in Bamako (39 percent). It is only in the three major cities, Bamako, Ségou and Sikasso, that more than 20 percent of the working age population has at least a high-school education.

2.3 Employment

Employment in rural localities and small towns is predominantly in agriculture. The share of agricultural jobs decreases with locality size, from an average of 86 percent of all jobs in rural localities to only 3 percent in Bamako. However, agricultural jobs still represent a significant share of employment in middle-sized cities (close to 25 percent). The share of administrative jobs, service jobs and, above all, trade activities increases with city size. In the four largest cities, trade jobs account for about 30 percent of employment. This may reflect over-specialization in commerce and the lack of value-creating activities in Malian cities. In particular, the manufacturing sector is significantly underdeveloped and has not increased over the last decade: manufacturing and crafts represent only 4 percent at the national level, and less than 10 percent of employment in medium-sized cities and Bamako.[4] The lack of manufacturing activities in middle-sized cities as well as the high prevalence of agriculture in these places show that structural transformation is still very limited in Mali, and that cities are unlikely

[4]By contrast, in neighboring Senegal, the share of employment in the industrial sector is much higher and had reached 14.8 percent by 2006 (source: African Development Indicators 2012/13).

to exert significant positive externalities on the rest of the country. With a share of 39 percent of the Malian GDP and a whopping 87% of all firms (CAP-Primature, 2014), Bamako is the only place with significant private formal non-agricultural employment.

3 Empirical methodology

3.1 Market access and local population growth

In this paper, we endeavor to analyze the process of population growth in villages, towns and cities in Mali, as well as the dynamics of sectoral employment at the local level. To do so, we assess the role of market access in the dynamics of urban localities, controlling for geographic factors.

There is a consensus in the economic geography literature that access to markets is one of the main economic factors driving the emergence of agglomerations and their growth. If demand for goods produced in a given locality is low, this locality is unlikely to attract new economic activities, given the weak profitability prospects. In the context of increasing returns to scale in production, such demand constraints play a particularly important role as firms need to reach a sufficient production scale to cover fixed cost.[5] Several factors can exert constraints on market access, impeding the development of towns and cities. The first factor is low income, as without access to external demand, poor localities may find themselves in a poverty trap. The second factor revolves around transportation costs and the extent of transport networks. Investments in transportation infrastructure can reduce transportation costs and make the sale of local products to distant markets profitable. By improving market access, transportation investments can turn increasing returns to scale activities into profitable endeavors. In turn, labor demand will increase, inducing in-migration. Yet, the impact of lower transportation costs can be ambiguous because of heterogeneous impacts. Under increasing returns to scale, or if cities generate positive externalities (e.g. informational externalities), the biggest cities will be better able to attract new workers and new businesses. This can induce discrepancies in the economic and demographic dynamics of localities, the expansion of bigger places occurring at the expense of smaller ones.[6] A road network centered on the main city (generally the capital city) can prevent the development of secondary urban centers. On the contrary, demand from rural areas favors urban dis-

[5]This mechanism was first identified by Rosenstein-Rodan and Hirschman and formalized by Murphy et al. (1989). In the wake of Krugman (1991), theoretical models of *new economic geography* have been developed where the location of activities and their concentration in cities revolve around access to market in the presence of increasing returns to scale.

[6]Puga (1998) develops a model in which the interaction between transport costs, increasing returns to scale, and labor migration across sectors and regions creates a tendency for urban agglomeration. In developing countries, transportation costs and more elastic labor supply to the urban sector than 19th century Europe can explain why primate cities dominate.

persion, so that transportation improvements between the countryside and secondary urban centers can lead to a more balanced urban system. Consequently, the impact of transport infrastructure on the dynamics of secondary urban centers may depend on the distance to the main city. Localities that are most distant to the main city could benefit more from an improvement in market access than those which are closest.

A standard measure of market access of a locality i at time t can be approximated by the sum of the population around this locality weighted by distance:

$$MA_{i,t} = \sum_{j \neq i} P_{j,t} \tau_{ij,t}^{-\theta} \tag{1}$$

where $P_{j,t}$ is the population of locality j at time t – which proxies for the size of the local market[7] – $\tau_{ij,t}$ is the time required to travel between locality i and j along the road network, and θ is a measure of trade elasticity. In order to study the role of market access in local population growth, we compute the change in market access for a locality i between two successive censuses (which are collected approximately every ten years):

$$\Delta \ln MA_{i,t-10,t} = \ln MA_{i,t} - \ln MA_{i,t-10} = \ln \sum_{j \neq i} P_{j,t} \tau_{ij,t}^{-\theta} - \ln \sum_{j \neq i} P_{j,t-10} \tau_{ij,t-10}^{-\theta}. \tag{2}$$

Improvements in market access can stem from two different sources: increased market size, i.e. population growth in areas around locality i, or increased proximity, i.e. reduced transport costs. It is therefore useful to decompose the change in market access in two components: Δ_{pop} which corresponds to population growth in localities around locality i, holding the transport network fixed, and Δ_{road} which corresponds to the improvement in the transport network, holding the population fixed. We can thus write:

$$\begin{aligned} \Delta \ln MA_{i,t-10,t} &= \Delta_{pop} \ln MA_{i,t-10,t} + \Delta_{road} \ln MA_{i,t-10,t} \\ &= \left(\ln \sum_{j \neq i} P_{j,t} \tau_{ij,t}^{-\theta} - \ln \sum_{j \neq i} P_{j,t-10} \tau_{ij,t}^{-\theta} \right) \\ &+ \left(\ln \sum_{j \neq i} P_{j,t-10} \tau_{ij,t}^{-\theta} - \ln \sum_{j \neq i} P_{j,t-10} \tau_{ij,t-10}^{-\theta} \right) \end{aligned} \tag{3}$$

Here, the population component of the total change in market access is evaluated using the road network of the final period t, while the road component is evaluated using the population distribution in the initial period $t-10$. There is an alternative decomposition of the total change in market access, where the change in the population component is evaluated with the road network in $t-10$ and the road component is evaluated with the

[7] Of course, it is an imperfect proxy that overlooks income heterogeneity.

population distribution of period t. In our empirical analysis, we will use the former, but we check that the results are indeed exactly the same with the latter decomposition.

To investigate the role of market access in local population growth, our baseline empirical specification is the following:

$$\Delta \ln P_{i,t-10,t} = \beta \Delta \ln MA_{i,t-10,t} + \gamma X'_{i,t-10} + \epsilon_{i,t} \tag{4}$$

where X_i is a vector of control variables at the locality level, including the log of the population in $t-10$. This model can be estimated by OLS, or in a panel framework by adding time invariant locality fixed effect δ_i. Estimating the model with fixed effects is useful to reduce a potential bias due to the correlation between change in market access and time invariant characteristics of localities that may affect population growth. In this case, the fixed effects also capture the effect of time invariant dimensions of X_i. This vector includes latitude, longitude, region $\times$ year dummies, population density, rainfall and the number of public goods. With the exception of rainfall and public goods, all those variables are time invariant and their effect cannot be identified in fixed effects specifications. Geographic location and rainfall variables are aimed to control for agronomic conditions which might affect agricultural supply. Region $\times$ year dummies capture changes in macroeconomic situation, among them the expansion of cotton production, that can have an heterogeneous impact.[8] Density is a proxy for externalities that may favor urbanization and economic development, such as information externalities.[9] Finally, the number of public goods is included to take into account that people are willing to migrate to localities with better public amenities, such as schools, health centers and water connections. This variable can also capture the localization of the local or central power. In these localities, jobs related to the administration and public buildings are available and attract people looking to be close to the administrative and decision-making structures in order to obtain benefits. This type of city is described by Braudel (1979) and Bairoch (1985) to illustrate the primacy of religious or administrative capitals, common to many countries.

Using the decomposition of the change in market access provided in equation 3, we can also investigate how each component of market access contributes to local population growth:

$$\Delta \ln P_{i,t-10,t} = \beta_{pop} \Delta_{pop} \ln MA_{i,t-10,t} + \beta_{road} \Delta_{road} \ln MA_{i,t-10,t} + \gamma X'_{i,t-10} + \epsilon_{i,t} \tag{5}$$

This model can also be estimated using regular OLS, or a fixed effects specification.

[8]Geographical coordinates and regional dummies also capture the proximity to external markets.

[9]Since locality area is fixed, the coefficient of density cannot be identified separately from the coefficient of population in fixed effects models. Density is therefore not included in those specifications.

The coefficient associated with the road component of the change in market access measures the impact of the expansion of the Malian road network, with the distribution of the population being set constant. The coefficient of the population component of the change of market access captures the impact of demographic growth of Malian localities, without any change in the road network.

In the models described by equations (4) and (5), overall population change at the locality level is taken as a proxy for economic dynamism. Indeed, in the case of sub-Saharan African countries, there is a paucity of local economic data that would provide better information (such as regional GDP, wages, or local employment). This is also the approach taken by Jedwab and Storeygard (2016). Total population growth, however, results from natural increase and net migration. The latter is arguably well correlated with economic growth because migrants are more attracted to places with better economic opportunities. This is much less clear for natural increase. Although one can expect a positive impact of income growth on natural increase through lower mortality, this effect probably operates on the long run and is unlikely to be very localized because it mostly arises from better public health goods. The effect of income growth on births is positive in a Malthusian framework, but negative in a demographic transition perspective (through the quantity-quality trade-off, for example). It can therefore be expected that the relationship between improved market access and overall population growth will be a quite noisy approximation of the actual causal effect of market access on economic development.

In addition, natural increase is driven by factors that are unlikely to be locality-specific. We can therefore expect positive spatial autocorrelation in total population growth due to this. Since the market access variable puts more weight on localities that are closer, it might capture part of this spatial autocorrelation. In this case, the coefficient of the change in market access will be upwardly biased.

Using comprehensive census microdata allows us to test the impact of changes in market access on two other outcomes which are better able, in our opinion, to approximate local economic development: the change in 15-64 working population of the locality, and the change in 15-64 migrant population.[10] Over a 10-year period, changes in the working population are less influenced by differences in natural increase than changes in total population, and account for both the contribution of net migration and labor demand. From this point of view, changes in migrant population are probably an even better proxy for local economic development since they are not affected by lagged local demographic changes. When estimating the model with these two outcomes, we control for their initial level (log number of workers or migrants in $t - 10$).

As discussed above, changes in market access and its different components can have

[10]Migrants are defined as individuals who were not born in their current region of residence.

ambiguous effects, depending on the type of locality and on the distance to the main cities. We therefore investigate the heterogeneous impact of changes in market access on local economic development for different types of localities: in equations (4) and (5), we introduce interaction terms between categories of locality and the market access variables. We define three categories of locality: (i) small rural localities – "villages" – with a population of less than 2,500, (ii) larger rural localities – "towns" – with a population of more than 2,500 but a low density (less than 250 people per km2), as well as localities with less than 5,000 inhabitants and a density higher than 250 people per km2, and (iii) "cities", which we define as localities with more than 5,000 inhabitants and a high density (more than 250 people per km2). We also investigate the heterogeneity of the impact depending on the distance to the capital city, Bamako.[11]

3.2 Market access and sectoral employment growth

Local economic development should go with structural transformation: as towns and cities develop, workers should move away from agriculture and into other sectors, especially in the largest cities. As we have noted in Section 2, however, the Malian economy has diversified very little during the recent decades and industrial jobs remain rare. We analyze this process at the local level, by looking at employment growth in three main sectors: agriculture, industry, and services. We use the same empirical approach as for total population growth (or working population, or migrant population), and regress the change in employment of sector k in locality i between $t-10$ and $t, \Delta \ln E_{i,k,t-10,t}$, on the change in market access.

As for population variables, we also investigate the heterogeneity of the impact of change in market access across locality categories, and depending on the distance to Bamako.

4 Data

We use microdata for the 1987, 1998 and 2009 population censuses of Mali, as well as locality-level population data from the 1976 census. Studying urbanization requires establishing a relevant definition of cities and their boundaries. In general, urban and rural areas are distinguished according to criteria such as the population of localities or their legal status. However, these definitions do not necessarily correspond to the actual urban extent, especially for the largest cities, where several neighboring urban localities may constitute a single agglomeration. One of the methodological challenges of studying urban dynamics is therefore to identify the spatial extent of economically

[11] With respect to the distance to Bamako, localities are classified in terciles (*dist Bamako 1*: from 0 to 218 km; *dist Bamako 2*: from 218 to 344 km, *dist Bamako 3*: from 344 to 751 km).

relevant spatial units. After building a panel of localities across the four censuses – a task complicated by the multiple changes in the geographic coding scheme in Mali during this period – and thanks to the geo-referencing of each locality, we constitute agglomerations on the basis of localities or urban neighborhoods, according to a dual criterion of proximity and population density[12]: we define agglomerations as a group of contiguous localities or neighborhoods with population density exceeding or equal to 250 people per km2 (Bernard et al., 2012; Mesplé-Somps et al., 2015). This procedure is carried out independently on the four censuses. We were able to identify 49 agglomerations meeting this criterion in 2009. Due to the fact that census data does not provide the coordinates of many localities in Northern Mali, we restrict our analysis to the Southern part of Mali.[13] The panel of localities used in our empirical work includes 9,077 localities among an initial set of about 10,000.

As discussed above, for each locality and each census from 1987 to 2009, we compute the total population, the working population (15-64), the migrant population (15-64), and the number of workers in agriculture, industry and services. For the 1976 census, we are only able to compute the total population. Descriptive statistics of those variables for each category of localities are provided in Table 10 in the appendix. Over time, there are more and more rural towns and cities, and fewer small rural settlements. The average population of rural settlements and cities grew over time, but it stagnated in rural towns. The average proportion of workers aged 15-64 in the total population ranges from one quarter to one third, depending on the year and the locality category. It is typically higher in rural localities than in cities. By contrast, the share of migrants aged 15-64 in the total population is much higher in cities than in rural areas: it is around 10-12% in cities, but less than 5% in rural localities.

We also compute the share of each economic sector (agriculture, industry, services) in total employment by locality. Averages for the different categories of localities are given in Table 10. As expected, agriculture is predominant in rural localities. Although its share in urban localities has dropped over time, it remains quite large, with more than 40% in 2009. Industry is significant only in urban localities, especially in 1998 and 2009. Almost half of all jobs in urban localities are in services.

To construct the market access variable, we use data on the Malian road network, compiled by Jedwab and Storeygard (2016), and the census population data discussed above. We use the most recent road data before each census: 1973, 1986, 1996 and 2008. The topologically correct road data provide three categories over time by road segment

[12]To determine population density in the places, it is necessary to move from a representation of space through a set of points (the places and their geographic coordinates) to a breakdown of the territory into zones. In the absence of mapping of the boundaries of places, we use a breakdown of the territory into Voronoi polygons.

[13]The regions included in the analysis are Kayes, Koulikoro, Sikasso, Ségou, Mopti and Bamako. The missing regions are Tombouctou, Gao and Kidal.

in Mali: paved, improved and earthen roads. Following the same speed assumptions in Jedwab and Storeygard (2016), we convert the road distance by category and areas without roads into a transport cost (in time): paved (60 kph), improved (40 kph), earthen (12 kph) and area with no known road (6 kph). In the case where a locality is not located directly on a road, we construct a line to the nearest road segment and assign a walking speed of 5 kph. We restrict the calculations to travel times under 6 hours. We provide three scenarios depending on the value of trade elasticity, θ, in equation 1. Following Donaldson (forthcoming), we choose $\theta = 3.8$ as our baseline. We test the robustness of our results by computing market access variables with trade elasticity equal to 0 (considering the total population in a given parameter without any discount) and 8.2 (the highest trade-elasticity value in the literature).

We also match the coordinates of each locality with rainfall data from the Climate Research Unit (CRU) at the University of East Anglia. Precipitation levels are available on a monthly basis with a precision of 0.5x0.5 degree. We compute average annual rainfall for each locality over the nine year period before the date of each census. Finally, public good data is taken from the census, and include schools, health centers and fountains. The public good variable is a discrete one, it equals to zero if there is no public good, one if there is one public good and two if there are two public goods or more.

5 Results

5.1 Total population, working population, and migrants

In the baseline model (Table 1, Panel A), we find a significant positive effect of the total change in market access on local population growth. This result holds in different specifications, OLS or fixed effects, with or without controls. The fixed effects model with controls predicts a 1.5 percentage point difference in population growth over 10 years between a locality experiencing, during the same period, a change in market access of 10 percent (the first quartile) and one experiencing a change in market access of 40 percent (the third quartile). This is therefore a relatively modest effect.

In Panel B of Table 1, we decompose the total change in market access into two variables, one capturing the change attributable to population growth, and one capturing the change attributable to the reduction in travel time. The population component is larger than the road component in all specifications. In the fixed effects model with controls, the coefficient for the population component is almost twice as large than that of the road component.

Introducing the lagged effect of the change in market access (Table 2), i.e. the impact of changes in market access between $t-20$ and $t-10$ on population growth between $t-10$

and t, shows that the cumulated effect over 20 years is a bit larger than the contemporary effect alone (0.11 vs 0.076). However, this is entirely driven by the lagged population component, as the lagged road component actually has a (small) negative effect. Note that this lagged effect can only be estimated on the two most recent intercensal periods (1987-1998 and 1998-2009).

Table 3 compares the effects of market access changes on different outcomes: total population, workers, and migrants. Due to the lack of data in 1976 for the number of workers and migrants, regressions are run on the 1987-2009 sub-period. Focusing on the fixed effects specifications, we find that the overall effect of change in market access is stronger on change in total population than on change in workers' or migrants' population, which lends credit to the hypothesis that the regression on total population change is biased because of spatial autocorrelation. Decomposing the total effect of market access into the road and population components (Panel B), we find that the two variables have a similar positive coefficient in the total population model, but that the road component matters much more in the workers and migrants regressions. In the latter, the population coefficient is not significantly different from zero. Improved market access increases immigration only through reduced transportation costs.

In Table 4, we investigate the heterogeneity of these results across categories of localities. Regarding the overall effect of market access change (Panel A), we find that the positive relationship is entirely driven by what happens in the smallest rural localities (population of less than 2,500). For larger rural localities, as well as for cities, the change in market access does not seem to have any significant effect on the growth of total population, working population or number of migrants. The decomposition with the road and population dimensions shows that, whatever the outcome, better roads only matter for small rural settlements. On the other hand, we find a significant effect of the population component of market access on local population growth and working population growth, especially for large rural localities and cities. However, this effect disappears when we focus on the change in migrant population.

As shown in Table 5, distance to Bamako also affects the relationship between change in market access and local population growth. For total population and working population, the effect of total change in market access is stronger for localities that are closer to the capital, although the coefficients for other localities are significant as well. For the migrant variable, there is positive significant effect only for localities close to Bamako (Panel A). In the decomposition (Panel B), we find significant effects of both the road and population components of market access change on total population growth, with a stronger effect of roads closer to Bamako, and a stronger effect of population in localities that are far away from the capital. The same pattern holds for the working population, although the coefficients for the population component are much lower and less significant. Finally, when the outcome is the growth of the migrant population, we find a significant effect of roads only for localities at intermediate distance from Bamako. Interestingly, for this model, there is a positive effect of the population component for localities close to Bamako, but a negative effect for localities that are far away: a higher rate of population growth is a positive pull factor for migrants when it occurs near the capital, but it has the opposite effect in remote areas.

5.2 Sectoral composition of employment

Results of Tables 3 and 4 show that better market access has a positive impact on the growth of the working population, but that this impact is mainly driven by what happens in small rural localities. In Tables 6, 7 and 8, we examine how change in market access affect the the distribution of employment across three sectors: agriculture, industry and services. In Table 6, we look at the average effect across all localities: total change in market access has a positive impact on the three sectors, but the effect is modest for agriculture, intermediate for industry, and stronger for services (Panel A). In Panel B, we decompose this effect into changes due to population growth and changes due to lower transportation costs. Except for agriculture, where only roads matter, both components have similar coefficients.

In Table 7, we find that most of the effect of total change in market access is concentrated in small rural localities (Panel A). However, with the road–population decomposition (Panel B), we observe that, while small rural localities benefit only from better roads, employment in the three sectors in large rural localities and urban areas actually benefits strongly from improvements in market access driven by population growth.

Finally, the impact of market access change is generally higher for localities that are closer to the capital (Table 8), especially for employment in services, where the coefficients are almost twice higher for those localities compared to localities that are farther away.

5.3 Robustness checks

[To be completed]

- Add external market access using *Africapolis* data on cities in SSA
- dif in dif estimator of road impact on rural localities (see Tables 9)
- Tackle endogenous issue by instrumenting road segment by ”donut” MA variable

6 Conclusion

[To be completed]

- Positive impact of change in MA on local population growth
  - Attenuated for growth of working population or migrant population
  - Works mostly through road component
- Effect of total change in MA significant only for small rural localities
  - This effect is driven only by the road component of MA
  - Population component has a large effect on growth of total and working population, especially for cities but not on migrant pop.
- Distance to Bamako matters: larger effect of change in MA for localities close to the capital
  - Growth of migrant population through population component: positive effect close to Bamako, negative effect in remote areas
- Positive impact of change in MA on local sectoral employment
  - Agriculture < Industry < Services
  - Roads matter for small rural localities
  - Large coefficient of population component for cities
  - Non linear effect of distance to Bamako on industry employment

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Table 1: Estimates of the impact of the change in market access on population growth, 1976-2009

	OLS		FE	
	(1)	(2)	(3)	(4)
Panel A				
$\Delta \ln \text{MA}(t-10, t)$ - total	0.063^{a}	0.034^{a}	0.084^{a}	0.045^{a}
	(0.005)	(0.005)	(0.006)	(0.005)
Controls	No	Yes	No	Yes
Observations	27231	27231	27231	27231
Groups			9077	9077
R-sq	0.065	0.121	0.371	0.498
Panel B				
$\Delta \ln \text{MA}(t-10, t)$ - roads	0.034^{a}	0.015^{b}	0.062^{a}	0.038^{a}
	(0.006)	(0.006)	(0.007)	(0.006)
$\Delta \ln \text{MA}(t-10, t)$ - pop	0.135^{a}	0.081^{a}	0.129^{a}	0.060^{a}
	(0.012)	(0.012)	(0.012)	(0.010)
Controls	No	Yes	No	Yes
Observations	27231	27231	27231	27231
Groups			9077	9077
R-sq	0.068	0.123	0.372	0.498

Note: OLS (columns 1 and 2) and fixed effects (columns 3 and 4) regressions of $\Delta \ln \text{pop}(t-10, t)$ on the total change in log market access between $t-10$ and t (Panel A), or the road and population components of change in log market access between $t-10$ and t (Panel B). All regressions control for the log of the population in $t-10$. Additional controls included in the OLS regression (column 2): region $\times$ year dummies, latitude and longitude, log of population density in $t-10$, average rainfall between $t-10$ and t, number of public goods in $t-10$. Additional controls included in the FE regression (column 4): rainfall, number of public goods in $t-10$. Robust standard errors in parentheses. c: $p < 0.10$, b: $p < 0.05$, a: $p < 0.01$.

Table 2: Estimates of the impact of the change in contemporary and lagged market access on population growth, 1987-2009

	FE	FE-lag	
	(1)	(2)	(3)
$\Delta \ln \mathrm{MA}(t-10, t)$ - total	0.076^{a}	0.084^{a}	
	(0.007)	(0.008)	
$\Delta \ln \mathrm{MA}(t-20, t-10)$ - total		0.028^{a}	
		(0.008)	
$\Delta \ln \mathrm{MA}(t-10, t)$ - roads			0.068^{a}
			(0.008)
$\Delta \ln \mathrm{MA}(t-10, t)$ - pop			0.166^{a}
			(0.017)
$\Delta \ln \mathrm{MA}(t-20, t-10)$ - roads			-0.031^{a}
			(0.009)
$\Delta \ln \mathrm{MA}(t-20, t-10)$ - pop			0.138^{a}
			(0.016)
Controls	Yes	Yes	Yes
Observations	18154	18154	18154
Groups	9077	9077	9077
R-sq	0.547	0.547	0.552

Note: Fixed effects regressions of $\Delta \ln \mathrm{pop}(t-10, t)$ on the total change in log market access (columns 1 and 2), or the road and population components of change in log market access (column 3) between $t-10$ and t. All regressions control for the log of the population in $t-10$. The models in columns 2 and 3 include the change in market access between $t-20$ and $t-10$ as an explanatory variable. Controls included in the FE regressions: rainfall, number of public goods in $t-10$. Robust standard errors in parentheses. c: $p < 0.10$, b: $p < 0.05$, a: $p < 0.01$.

Table 3: Estimates of the impact of change in market access on growth of total population, working population and migrant population, 1987-2009

	OLS			FE		
	(1) Population	(2) Workers	(3) Migrants	(4) Population	(5) Workers	(6) Migrants
Panel A						
$\Delta \ln \text{MA}(t-10,t)$ - total	0.025^a	0.041^a	0.077^a	0.076^a	0.055^a	0.032^b
	(0.007)	(0.009)	(0.015)	(0.007)	(0.009)	(0.015)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18154	18154	18154	18154	18154	18154
Groups				9077	9077	9077
R-sq	0.131	0.518	0.266	0.547	0.797	0.746
Panel B						
$\Delta \ln \text{MA}(t-10,t)$ - roads	0.016^b	0.035^a	0.048^a	0.073^a	0.067^a	0.050^a
	(0.007)	(0.010)	(0.017)	(0.008)	(0.010)	(0.018)
$\Delta \ln \text{MA}(t-10,t)$ - pop	0.050^a	0.059^a	0.156^a	0.082^a	0.031^c	-0.006
	(0.014)	(0.020)	(0.029)	(0.014)	(0.018)	(0.026)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18154	18154	18154	18154	18154	18154
Groups				9077	9077	9077
R-sq	0.131	0.518	0.266	0.547	0.797	0.746

Note: OLS (columns 1 to 3) and fixed effects (columns 4 to 6) regressions of $\Delta \ln Y(t-10,t)$ on the total change in log market access between $t-10$ and t (Panel A), or the road and population components of change in log market access between $t-10$ and t (Panel B). Y: total population in columns 1 and 4; working population aged 15-64 in columns 2 and 5; migrant population aged 15-64 in columns 3 and 6. All regressions control for $\ln Y$ in $t-10$. Additional controls included in the OLS regressions: region $\times$ year dummies, latitude and longitude, log of population density in $t-10$, average rainfall between $t-10$ and t, number of public goods in $t-10$. Additional controls included in the FE regressions: rainfall, number of public goods in $t-10$. Robust standard errors in parentheses. c: $p < 0.10$, b: $p < 0.05$, a: $p < 0.01$.

Table 4: Estimates of the heterogeneous impact of change in market access on growth of total population, working population and migrant population, by category of locality, 1987-2009

	(1) Pop. 76-09	(2) Pop. 87-09	(3) Workers	(4) Migrants
Panel A				
$\Delta \ln \text{MA}(t-10,t)$ - total $\times$ rural 1	0.046^{a}	0.079^{a}	0.056^{a}	0.032^{b}
	(0.005)	(0.007)	(0.009)	(0.015)
$\Delta \ln \text{MA}(t-10,t)$ - total $\times$ rural 2	0.010	0.006	0.033	0.060
	(0.023)	(0.018)	(0.029)	(0.050)
$\Delta \ln \text{MA}(t-10,t)$ - total $\times$ urban	0.092	0.016	0.100	-0.050
	(0.090)	(0.047)	(0.061)	(0.063)
Controls	Yes	Yes	Yes	Yes
Observations	27231	18154	18154	18154
Groups	9077	9077	9077	9077
R-sq	0.498	0.548	0.797	0.746
Panel B				
$\Delta \ln \text{MA}(t-10,t)$ - roads $\times$ rural 1	0.041^{a}	0.079^{a}	0.071^{a}	0.050^{a}
	(0.006)	(0.008)	(0.011)	(0.019)
$\Delta \ln \text{MA}(t-10,t)$ - roads $\times$ rural 2	-0.012	-0.024	-0.009	0.075
	(0.017)	(0.021)	(0.034)	(0.056)
$\Delta \ln \text{MA}(t-10,t)$ - roads $\times$ urban	-0.056	-0.084	0.016	-0.108
	(0.088)	(0.087)	(0.102)	(0.106)
$\Delta \ln \text{MA}(t-10,t)$ - pop $\times$ rural 1	0.057^{a}	0.080^{a}	0.025	-0.006
	(0.010)	(0.014)	(0.018)	(0.027)
$\Delta \ln \text{MA}(t-10,t)$ - pop $\times$ rural 2	0.110	0.132^{a}	0.213^{a}	0.000
	(0.113)	(0.046)	(0.066)	(0.125)
$\Delta \ln \text{MA}(t-10,t)$ - pop $\times$ urban	0.412^{b}	0.205^{a}	0.289^{b}	0.088
	(0.202)	(0.076)	(0.135)	(0.149)
Controls	Yes	Yes	Yes	Yes
Observations	27231	18154	18154	18154
Groups	9077	9077	9077	9077
R-sq	0.498	0.548	0.798	0.746

Note: Fixed effects regressions of $\Delta \ln Y(t-10,t)$ on the total change in log market access between $t-10$ and t (Panel A), or the road and population components of change in log market access between $t-10$ and t (Panel B). Y: total population for the period 1976-2009 in column 1; total population for the period 1987-2009 in column 2; working population aged 15-64 in column 3; migrant population aged 15-64 in column 4. The coefficients shown are the interactions between the change in market access and the category of the locality. Each regression also contains the relevant direct effects. Localities belong to one of three categories: *rural 1* for localities with less than 2500 inhabitants, *rural 2* for localities with at least 2500 inhabitants and a density lower than 250 people per km2, as well as localities with less than 5000 inhabitants and a density higher than 250 people per km2, *urban* for localities with at least 5000 inhabitants and a density higher than 250 people per km2. All regressions control for $\ln Y$ in $t-10$, interacted with locality categories. Additional controls: rainfall, number of public goods in $t-10$. Robust standard errors in parentheses. *c*: $p < 0.10$, *b*: $p < 0.05$, *a*: $p < 0.01$.

Table 5: Estimates of the heterogeneous impact of change in market access on growth of total population, working population and migrant population, by terciles of distance to Bamako, 1987-2009

	(1) Pop. 76-09	(2) Pop. 87-09	(3) Workers	(4) Migrants
Panel A				
$\Delta \ln \text{MA}(t-10,t)$ - total × dist Bamako 1	0.044^a	0.102^a	0.072^a	0.112^a
	(0.009)	(0.015)	(0.019)	(0.032)
$\Delta \ln \text{MA}(t-10,t)$ - total × dist Bamako 2	0.064^a	0.070^a	0.053^a	0.024
	(0.010)	(0.013)	(0.015)	(0.022)
$\Delta \ln \text{MA}(t-10,t)$ - total × dist Bamako 3	0.028^a	0.065^a	0.048^a	-0.003
	(0.007)	(0.009)	(0.013)	(0.024)
Controls	Yes	Yes	Yes	Yes
Observations	27231	18154	18154	18154
Groups	9077	9077	9077	9077
R-sq	0.502	0.553	0.798	0.747
Panel B				
$\Delta \ln \text{MA}(t-10,t)$ - roads × dist Bamako 1	0.051^a	0.122^a	0.102^a	0.031
	(0.011)	(0.017)	(0.024)	(0.041)
$\Delta \ln \text{MA}(t-10,t)$ - roads × dist Bamako 2	0.057^a	0.079^a	0.072^a	0.062^b
	(0.011)	(0.015)	(0.017)	(0.028)
$\Delta \ln \text{MA}(t-10,t)$ - roads × dist Bamako 3	0.012	0.045^a	0.045^a	0.047
	(0.008)	(0.010)	(0.015)	(0.029)
$\Delta \ln \text{MA}(t-10,t)$ - pop × dist Bamako 1	0.031	0.074^a	0.032	0.221^a
	(0.019)	(0.026)	(0.031)	(0.049)
$\Delta \ln \text{MA}(t-10,t)$ - pop × dist Bamako 2	0.076^a	0.051^b	0.010	-0.062
	(0.021)	(0.023)	(0.031)	(0.042)
$\Delta \ln \text{MA}(t-10,t)$ - pop × dist Bamako 3	0.062^a	0.111^a	0.053^c	-0.125^a
	(0.014)	(0.020)	(0.027)	(0.046)
Controls	Yes	Yes	Yes	Yes
Observations	27231	18154	18154	18154
Groups	9077	9077	9077	9077
R-sq	0.502	0.554	0.798	0.748

Note: Fixed effects regressions of $\Delta \ln Y(t-10,t)$ on the total change in log market access between $t-10$ and t (Panel A), or the road and population components of change in log market access between $t-10$ and t (Panel B). Y: total population for the period 1976-2009 in column 1; total population for the period 1987-2009 in column 2; working population aged 15-64 in column 3; migrant population aged 15-64 in column 4. The coefficients shown are the interactions between the change in market access and distance to Bamako. Each regression also contains the relevant direct effects. With respect to the distance to Bamako, localities are classified in terciles (*dist Bamako 1*: from 0 to 218 km; *dist Bamako 2*: from 218 to 344 km, *dist Bamako 3*: from 344 to 751 km). All regressions control for $\ln Y$ in $t-10$, interacted with distance to Bamako. Additional controls: rainfall, number of public goods in $t-10$. Robust standard errors in parentheses. *c*: $p < 0.10$, *b*: $p < 0.05$, *a*: $p < 0.01$.

Table 6: Estimates of the impact of change in market access on employment growth by sector, 1987-2009

	(1) Agriculture	(2) Industry	(3) Services
Panel A			
$\Delta \ln \text{MA}(t-10,t)$ - total	0.043^{a}	0.104^{a}	0.249^{a}
	(0.010)	(0.014)	(0.017)
Controls	Yes	Yes	Yes
Observations	18154	18154	18154
Groups	9077	9077	9077
R-sq	0.780	0.655	0.658
Panel B			
$\Delta \ln \text{MA}(t-10,t)$ - roads	0.055^{a}	0.106^{a}	0.255^{a}
	(0.011)	(0.017)	(0.020)
$\Delta \ln \text{MA}(t-10,t)$ - pop	0.020	0.102^{a}	0.237^{a}
	(0.019)	(0.026)	(0.031)
Controls	Yes	Yes	Yes
Observations	18154	18154	18154
Groups	9077	9077	9077
R-sq	0.780	0.655	0.658

Note: OLS (columns 1 to 3) and fixed effects (columns 4 to 6) regressions of $\Delta \ln Y(t-10,t)$ on the total change in log market access between $t-10$ and t (Panel A), or the road and population components of change in log market access between $t-10$ and t (Panel B). Y: number of workers aged 15-64 in agriculture in column 1; number of workers aged 15-64 in industry in column 2; number of workers aged 15-64 in services in column 3. All regressions control for $\ln Y$ in $t-10$. Additional controls: rainfall, number of public goods in $t-10$. Robust standard errors in parentheses. c: $p < 0.10$, b: $p < 0.05$, a: $p < 0.01$.

Table 7: Estimates of the heterogeneous impact of change in market access on employment growth by sector, by category of locality, 1987-2009

	(1) Agriculture	(2) Industry	(3) Services
Panel A			
$\Delta \ln \text{MA}(t-10,t)$ - total $\times$ rural 1	0.046^a	0.104^a	0.255^a
	(0.010)	(0.014)	(0.017)
$\Delta \ln \text{MA}(t-10,t)$ - total $\times$ rural 2	-0.007	0.060	0.126^b
	(0.034)	(0.063)	(0.060)
$\Delta \ln \text{MA}(t-10,t)$ - total $\times$ urban	0.012	-0.033	0.066
	(0.060)	(0.072)	(0.081)
Controls	Yes	Yes	Yes
Observations	18154	18154	18154
Groups	9077	9077	9077
R-sq	0.781	0.663	0.659
Panel B			
$\Delta \ln \text{MA}(t-10,t)$ - roads $\times$ rural 1	0.061^a	0.107^a	0.267^a
	(0.011)	(0.017)	(0.020)
$\Delta \ln \text{MA}(t-10,t)$ - roads $\times$ rural 2	-0.044	0.035	0.041
	(0.039)	(0.066)	(0.066)
$\Delta \ln \text{MA}(t-10,t)$ - roads $\times$ urban	-0.078	-0.173	-0.135
	(0.116)	(0.118)	(0.135)
$\Delta \ln \text{MA}(t-10,t)$ - pop $\times$ rural 1	0.015	0.098^a	0.232^a
	(0.019)	(0.026)	(0.032)
$\Delta \ln \text{MA}(t-10,t)$ - pop $\times$ rural 2	0.157^b	0.181	0.484^a
	(0.067)	(0.170)	(0.127)
$\Delta \ln \text{MA}(t-10,t)$ - pop $\times$ urban	0.206^c	0.323^c	0.544^b
	(0.112)	(0.185)	(0.229)
Controls	Yes	Yes	Yes
Observations	18154	18154	18154
Groups	9077	9077	9077
R-sq	0.781	0.663	0.659

Note: Fixed effects regressions of $\Delta \ln Y(t-10,t)$ on the total change in log market access between $t-10$ and t (Panel A), or the road and population components of change in log market access between $t-10$ and t (Panel B). Y: number of workers aged 15-64 in agriculture in column 1; number of workers aged 15-64 in industry in column 2; number of workers aged 15-64 in services in column 3. The coefficients shown are the interactions between the change in market access and the category of the locality. Each regression also contains the relevant direct effects. Localities belong to one of three categories: *rural 1* for localities with less than 2500 inhabitants, *rural 2* for localities with at least 2500 inhabitants and a density lower than 250 people per km2, as well as localities with less than 5000 inhabitants and a density higher than 250 people per km2, *urban* for localities with at least 5000 inhabitants and a density higher than 250 people per km2. All regressions control for $\ln Y$ in $t-10$, interacted with locality categories. Additional controls: rainfall, number of public goods in $t-10$. Robust standard errors in parentheses. c: $p < 0.10$, b: $p < 0.05$, a: $p < 0.01$.

Table 8: Estimates of the heterogeneous impact of change in market access on employment growth by sector, by terciles of distance to Bamako, 1987-2009

	(1) Agriculture	(2) Industry	(3) Services
Panel A			
$\Delta \ln \text{MA}(t-10,t)$ - total × dist Bamako 1	0.042^{b}	0.150^{a}	0.391^{a}
	(0.021)	(0.030)	(0.039)
$\Delta \ln \text{MA}(t-10,t)$ - total × dist Bamako 2	0.052^{a}	0.068^{a}	0.199^{a}
	(0.016)	(0.020)	(0.023)
$\Delta \ln \text{MA}(t-10,t)$ - total × dist Bamako 3	0.034^{b}	0.113^{a}	0.221^{a}
	(0.014)	(0.024)	(0.026)
Controls	Yes	Yes	Yes
Observations	18154	18154	18154
Groups	9077	9077	9077
R-sq	0.781	0.657	0.659
Panel B			
$\Delta \ln \text{MA}(t-10,t)$ - roads × dist Bamako 1	0.079^{a}	0.142^{a}	0.413^{a}
	(0.027)	(0.040)	(0.053)
$\Delta \ln \text{MA}(t-10,t)$ - roads × dist Bamako 2	0.069^{a}	0.089^{a}	0.206^{a}
	(0.018)	(0.025)	(0.028)
$\Delta \ln \text{MA}(t-10,t)$ - roads × dist Bamako 3	0.028^{c}	0.099^{a}	0.234^{a}
	(0.016)	(0.028)	(0.031)
$\Delta \ln \text{MA}(t-10,t)$ - pop × dist Bamako 1	-0.009	0.161^{a}	0.363^{a}
	(0.034)	(0.047)	(0.060)
$\Delta \ln \text{MA}(t-10,t)$ - pop × dist Bamako 2	0.016	0.020	0.184^{a}
	(0.032)	(0.040)	(0.051)
$\Delta \ln \text{MA}(t-10,t)$ - pop × dist Bamako 3	0.049	0.146^{a}	0.188^{a}
	(0.030)	(0.047)	(0.049)
Controls	Yes	Yes	Yes
Observations	18154	18154	18154
Groups	9077	9077	9077
R-sq	0.781	0.657	0.659

Note: Fixed effects regressions of $\Delta \ln Y(t-10,t)$ on the total change in log market access between $t-10$ and t (Panel A), or the road and population components of change in log market access between $t-10$ and t (Panel B). Y: number of workers aged 15-64 in agriculture in column 1; number of workers aged 15-64 in industry in column 2; number of workers aged 15-64 in services in column 3. The coefficients shown are the interactions between the change in market access and distance to Bamako. Each regression also contains the relevant direct effects. With respect to the distance to Bamako, localities are classified in terciles (*dist Bamako 1*: from 0 to 218 km; *dist Bamako 2*: from 218 to 344 km, *dist Bamako 3*: from 344 to 751 km). All regressions control for $\ln Y$ in $t-10$, interacted with distance to Bamako. Additional controls: rainfall, number of public goods in $t-10$. Robust standard errors in parentheses. c: $p < 0.10$, b: $p < 0.05$, a: $p < 0.01$.

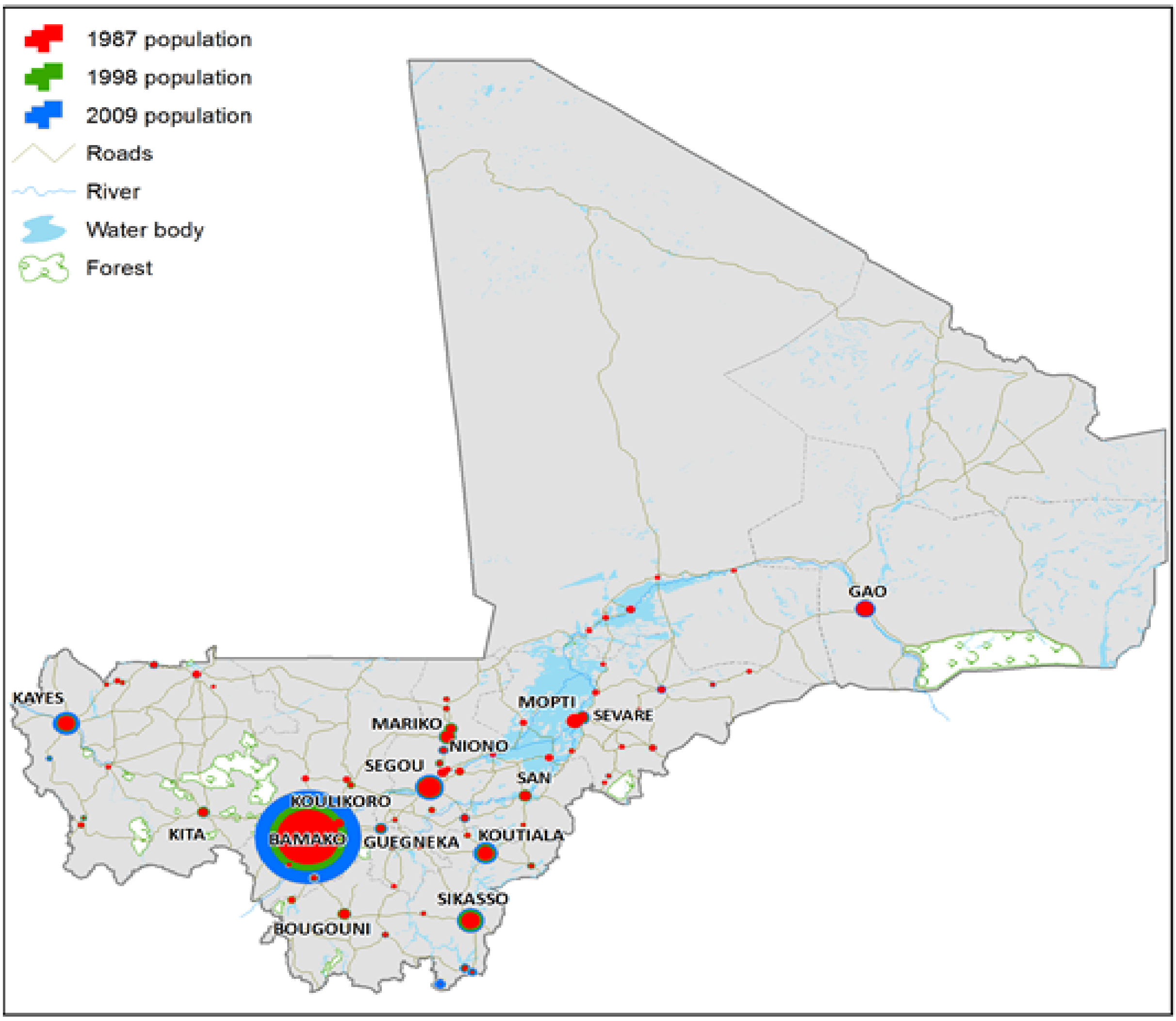
Table 9: Estimates of the impact of improved roads on growth of total population, working population and migrant population, rural settlements, 1998-2009

	(1) Population	(2) Workers	(3) Migrants
A - Market access			
$\Delta \ln \text{MA}(t-10,t)$ - roads	0.026^{a}	0.046^{a}	0.062^{a}
	(0.008)	(0.011)	(0.020)
$\Delta \ln \text{MA}(t-10,t)$ - pop	0.020	0.038	0.191^{a}
	(0.019)	(0.026)	(0.044)
Observations	8721	8721	8721
B - Road upgrade, DID			
Treatment	0.044^{b}	0.039	0.192^{a}
	(0.020)	(0.029)	(0.053)
Observations	7819	7819	7819
C - Paved road, DID			
Treatment	0.065^{a}	0.080^{b}	0.198^{a}
	(0.025)	(0.037)	(0.063)
Observations	7819	7819	7819
D - Road upgrade, SDID			
Treatment	0.042^{b}	0.033	0.176^{a}
	(0.020)	(0.030)	(0.055)
Observations	7819	7819	7819
E - Paved road, SDID			
Treatment	0.046^{c}	0.037	0.147^{b}
	(0.026)	(0.039)	(0.067)
Observations	6433	6433	6433

Note: Results for rural settlements (localities with less than 2500 inhabitants in 1998) for the period 1998-2009. *Panel A:* OLS regressions of $\Delta \ln Y(t-10,t)$ on the road and population components of change in log market access between $t-10$ and t. *Panel B:* Difference-in-difference estimate of an improvement of road quality between $t-10$ and t on $\Delta \ln Y(t-10,t)$. The treatment group (n=651) includes localities for which the nearest road was upgraded to *improved* or *paved*. The control group (n=7168) includes localities for which the nearest road remained either *earthen* or *improved*. Localities for which the nearest road was already *paved* in 1998 are excluded (n=902). *Panel C:* Difference-in-difference estimate of the nearest road being paved between $t-10$ and t on $\Delta \ln Y(t-10,t)$. The treatment group (n=431) includes localities for which the nearest road was upgraded to *paved*. The control group (n=7388) includes localities for which the nearest road was upgraded to *improved*, or remained either *earthen* or *improved*. Localities for which the nearest road was already *paved* in 1998 are excluded (n=902). *Panel D:* Semi-parametric difference-in-difference estimate of an improvement of road quality between $t-10$ and t on $\Delta \ln Y(t-10,t)$. The treatment and control groups are the same as in Panel B. *Panel E:* Semi-parametric difference-in-difference estimate of the nearest road being paved between $t-10$ and t on $\Delta \ln Y(t-10,t)$. The treatment and control groups are the same as in Panel C. Y: total population in column 1; working population aged 15-64 in column 2; migrant population aged 15-64 in column 3. All regressions in Panels A, B and C control for $\ln Y$ in $t-10$, distance to the nearest road, region dummies, latitude and longitude, log of population density in $t-10$, average rainfall between $t-10$ and t, number of public goods in $t-10$. The propensity score used for SDID estimates (Panels D and E) is estimated with the following covariates: $\ln Y$ in $t-10$, distance to the nearest road, region dummies, latitude and longitude, log of population density in $t-10$, average rainfall between $t-10$ and t, number of public goods in $t-10$. Robust standard errors in parentheses. *c*: $p < 0.10$, *b*: $p < 0.05$, *a*: $p < 0.01$.

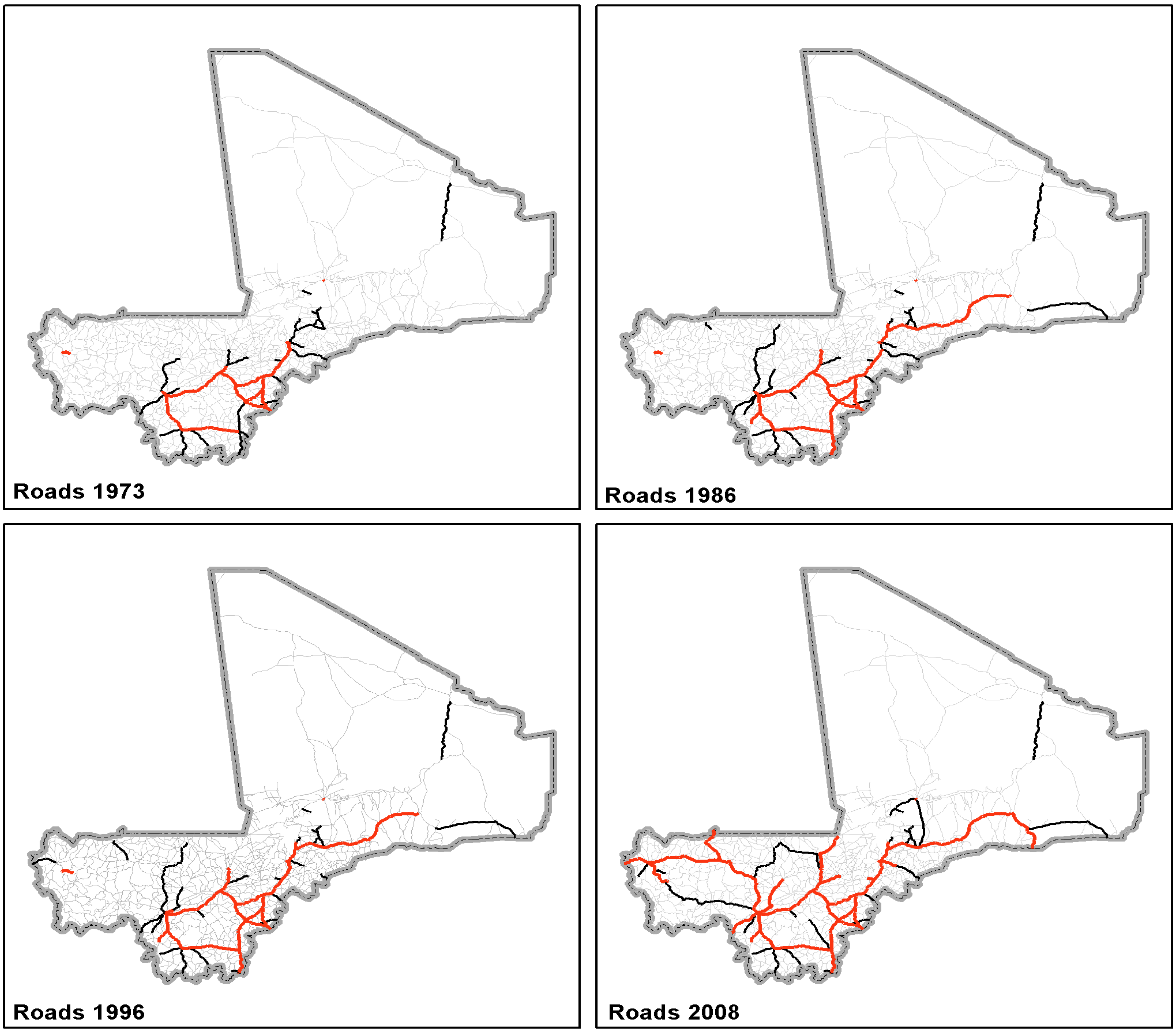
Appendix

Figure 1: The unbalanced population growth of urban places in Mali (1987–2009)



Source: COD-FOD ONU, AICD (2009), INSTAT (1987, 1998 et 2009) and authors' own calculations.

Figure 2: Road network improvement in Mali (1973–2008)



Source: Jedwab and Storeygard (2016). Note: Red lines represent paved roads. Black lines represent improved roads. Light grey lines represent earthen roads.

Table 10: Descriptive statistics on Malian localities: population, migrants and employment, 1976-2009

	Localities	Population	Workers	Migrants	Agriculture	Industry	Services
1976							
Rural settlements	8925	459	.	.	.	.	.
Rural towns	128	3788	.	.	.	.	.
Urban	24	38007	.	.	.	.	.
1987							
Rural settlements	8850	540	201	13	90.9	3.1	5.9
Rural towns	189	3899	1369	260	85.0	1.3	13.6
Urban	38	37447	9747	8870	50.2	2.6	47.1
1998							
Rural settlements	8721	634	211	15	92.9	3.0	4.1
Rural towns	312	3818	1149	170	87.5	3.2	9.4
Urban	44	46910	11651	10223	47.9	10.1	42.0
2009							
Rural settlements	8420	796	230	12	88.2	3.7	8.1
Rural towns	588	4002	1079	134	80.7	4.5	14.9
Urban	69	55939	15437	11393	41.0	12.2	46.8

Note: Rural settlements are localities with less than 2500 inhabitants; rural towns are localities with at least 2500 inhabitants and a density lower than 250 people per km2, as well as localities with less than 5000 inhabitants and a density higher than 250 people per km2; urban localities have at least 5000 inhabitants and a density higher than 250 people per km2. *Localities* is the number of localities in each category. *Population* is the average population of localities in each category. *Workers* is the average working population aged 15-64. *Migrants* is the average number of individuals aged 15-64 who were not born in their current region of residence. *Agriculture*, *Industry*, *Services*: average share of each sector in total employment of localities in each category. *Agriculture* includes agriculture, livestock raising and fishing; *Industry* includes mining, manufacturing, construction and utilities; *Services* includes commerce, financial services, transportation services, public and private administration, other services.