

Zant, Wouter

Working Paper

Trains, Trade and Transaction Costs: How does Domestic Trade by Rail affect Market Prices of Malawi Agricultural Commodities?

Tinbergen Institute Discussion Paper, No. 15-055/V

Provided in Cooperation with:

Tinbergen Institute, Amsterdam and Rotterdam

Suggested Citation: Zant, Wouter (2015) : Trains, Trade and Transaction Costs: How does Domestic Trade by Rail affect Market Prices of Malawi Agricultural Commodities?, Tinbergen Institute Discussion Paper, No. 15-055/V, Tinbergen Institute, Amsterdam and Rotterdam

This Version is available at:

<https://hdl.handle.net/10419/111732>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

TI 2015-055/V

Tinbergen Institute Discussion Paper



Trains, Trade and Transaction Costs: How does Domestic Trade by Rail affect Market Prices of Malawi Agricultural Commodities?

Wouter Zant

Faculty of Economics and Business Administration, VU University Amsterdam, and Tinbergen Institute, the Netherlands.

Tinbergen Institute is the graduate school and research institute in economics of Erasmus University Rotterdam, the University of Amsterdam and VU University Amsterdam.

More TI discussion papers can be downloaded at <http://www.tinbergen.nl>

Tinbergen Institute has two locations:

Tinbergen Institute Amsterdam
Gustav Mahlerplein 117
1082 MS Amsterdam
The Netherlands
Tel.: +31(0)20 525 1600

Tinbergen Institute Rotterdam
Burg. Oudlaan 50
3062 PA Rotterdam
The Netherlands
Tel.: +31(0)10 408 8900
Fax: +31(0)10 408 9031

Duisenberg school of finance is a collaboration of the Dutch financial sector and universities, with the ambition to support innovative research and offer top quality academic education in core areas of finance.

DSF research papers can be downloaded at: <http://www.dsf.nl/>

Duisenberg school of finance
Gustav Mahlerplein 117
1082 MS Amsterdam
The Netherlands
Tel.: +31(0)20 525 8579

Trains, Trade and Transaction Costs:

How does Domestic Trade by Rail affect Market Prices of Malawi Agricultural Commodities?

Wouter Zant*

Abstract

We measure the impact of low cost transport by rail in Malawi on the dispersion of agricultural commodities prices across markets, by exploiting the quasi experimental design of the nearly total collapse of domestic trade by rail in January 2003, due to the destruction of a railway bridge at Rivirivi, Balaka. Market pairs connected by rail when the railway line was operational, are intervention observations. Estimations are based on monthly market prices of four agricultural commodities (maize, groundnuts, rice and beans), in 27 local markets, for the period 1998-2006. Railway transport services explain a 11% to 18% reduction in price dispersion across markets. Geographical reach of trade varies by crop, most likely related to storability and geographical spread of production. Perishability appears to increase impact reflecting the lack of intertemporal arbitrage. Overall, impacts are, however, remarkably similar in size across commodities.

JEL code: D23, F14, N77, Q13, O18, O55

Key words: trade, crop prices, transaction costs, rail infrastructure, Malawi, sub Saharan Africa

* Wouter Zant is associated with VU University and a fellow of the Tinbergen Institute, both Amsterdam, The Netherlands. Email: wouter.zant@vu.nl. I am grateful to Hans Quené for assistance in collecting and constructing the data, and to Jasper Dekkers for constructing a useful map.

1. Introduction

In this study we investigate the hypothesis that low cost railway transport creates an opportunity for domestic trade in agricultural commodities, which enhances trade flows of agricultural produce from surplus to deficit areas and thereby reduces dispersion of agricultural commodity prices across markets. The empirical estimations consider monthly market prices for maize, rice, groundnuts and beans in the Malawi economy. For the purpose of this research we exploit a unique natural experiment, notably the disruption of a railway bridge in the heart of the Malawi rail network in January 2003, which caused the nearly total collapse of domestic trade and transport by train. This research is partly inspired by studies on the impact of mobile phone coverage on price dispersion (e.g. Aker, 2010; Jensen, 2007; Muto and Yamano, 2009; Fafchamps and Aker, 2014) and broadly related to a variety of work that investigates the impact of transaction costs (infrastructure) on economic activity and on the efficiency of markets. It is different from most of this research since it focuses exclusively on transport costs of a specific mode of transport, notably transport by rail. Since a natural experiment in transport infrastructure is a rare event (cf. Jacoby and Minten, 2008) and since experimental designs in infrastructure are usually not feasible, impact studies on railway services are uncommon. In fact, with the exception of a few historical studies, we are not aware of any attempt at measuring the effect of rail transport services on the dispersion of agricultural commodity prices empirically.

The remainder of the paper is organised as follows. In Section 2 we discuss the relevant literature, position our work in this literature and highlight our contribution. In Section 3 we briefly characterize the Malawi economy and we present developments in Malawi rail infrastructure and freight volumes over the years against the background of the collapse of domestic freight since January 2003. In this section we also justify the selection of agricultural

commodities and discuss the development of production, prices and price dispersion of these commodities. In Section 4 we set out the methodology underlying the empirical estimation and discuss the identification of impacts. In Section 5 we show and assess estimation results and in Section 6 we give a summary and conclusion.

2. What do we know from the literature?

The research in this paper contributes to a broader empirical literature on the impact of major infrastructural or institutional changes on transaction costs and, thereby, on the (efficient) operation of markets and economic behaviour. Transportation infrastructure is important to transaction costs and hence we start out with the work on the impact of investments in railways, which is typically long run and historical in nature. In an extensive and rigorous study, Donaldson investigates the economic impact of the colonial Indian railways from 1861-1930, using district-level data collected from archival sources (Donaldson, 2010). The construction of the railroad network is exploited for identification of impacts. Donaldson empirically tests several predictions derived from a general equilibrium trade model and finds that railroads reduce cost of trading, reduce price dispersion between regions, increase trade volumes and brought district economies close to the small open economy limit where local prices do not vary because of local shocks; that railroads increased welfare substantially (with 18%) and decreased income volatility; and that with the help of a general equilibrium trade model one may identify reduced trade costs as the key determinant for increased welfare. Other analyses of the impact of railways are related to the economic geography literature on the spatial distribution of economic activity¹: Jedwab and Moradi (2015) employ a 11 x 11km grid cell based dataset for eight distinct years, starting in 1891 up to 2000, for

¹ The debate centers around the question if the equilibrium of the distribution of economic activity across space is determined by locational fundamentals (geographical endowments) or by increasing returns (economies of scale and scope due to concentration and clustering of activities and (past) investments).

Ghana, where the years correspond with census years, and similarly for a larger set of 39 SSA countries. They show path dependence of economic activity and conclude that their evidence supports the existence of local increasing returns. Similar conclusions are drawn in another paper (Jedwab et al., 2014): Colonial railroad construction in Kenya, which started in 1896 and was completed in 1930, and its later demise in the 1960s, is assumed to provide an ideal natural experiment to identify the effects of infrastructure on economic change. A dataset of 473 locations for selected years (census years) in the period 1901-2009 is constructed for estimating the impact of rail connectivity on population growth. Railroads are shown to explain the persistence of the location of cities. Again evidence indicates path dependence and supports the existence of local increasing returns. Partly due to its identification strategy, much of this work is (very) long run in nature, requiring substantial data construction, and is concerned with population and urbanisation over centuries rather than income and welfare today: it does not specifically address (barriers to) economic development of currently poor countries. We are also not aware of any other study that investigates the development impact of rail infrastructure in contemporary and typical developing countries like those in sub-Saharan Africa.

Several contributions on the impact of road infrastructure are worth discussing: the impact of road infrastructure on labour markets (and education) is investigated for the US (Michaels, 2008) and Indonesia (Yamauchi et al., 2011), and on food collection, trade margins and traders' wages for Zaire (Minten and Kyle, 1999). Michaels uses the advent of the US Interstate Highway System, construction of which began in 1956 and was completed in 1975, as "a source of exogenous variation in trade barriers" to show an increase in trucking activity and retail sales of 7-10 percentage points, in connected relative to non-connected rural counties. In line with Hecksher-Ohlin, highways increase the wage bill of high skilled workers relative to low skilled

workers in counties where skill was abundant and reduced it where skills were scarce, but the size of this effect is small. Opening up to trade is not likely to explain a great deal of variation in the demand for skills. Identification – the key empirical challenge in measuring impacts of infrastructure – is covered by using (quality) improvements in road quality in Yamauchi et al. (2011). Combining household panel and village census data for Indonesia for the period 1995-2007 they measure the impact of improved connectivity on household income growth and non-agricultural labour supply. The growth of household income and non-agricultural labour supply, associated with improved connectivity, is claimed to be driven by post primary education and distance to economic centers. Education and quality of local roads are therefore concluded to be complementary, increasing labour transition to non-agricultural activities. Minten and Kyle (1999) observe that variation in food prices in Zaire, both across regions and between products, is large. They show transportation costs explain most of the differences in food prices between producer regions and urban Kinshasa, and that road quality is an important factor in the transportation costs. Poor quality roads double transport costs, and increase other transaction costs and uncertainty. Producer shares also decrease, and decrease faster, when transport costs increase. Hence, transport infrastructure is found to be a key determinant of variation in food prices. The impossibility of experimental designs in infrastructure has inspired a different methodology for measuring the impact of road infrastructure in Jacoby (2000) and Minten and Jacoby (2009): both exploit the economic impact of transport costs on various economic variables and economic behaviour (wages, value of agricultural land, household income, migration), in the absence of road infrastructure, to measure the potential gains of putting road infrastructure in place. The former (Jacoby, 2000) assumes that higher farm profits due to lower transport costs should capitalise into higher farmland values and wages. The relationship

between value of farmland and distance to agricultural markets, and wages and distance to market is exploited to measure the household benefits of a hypothetical road project. Empirical application to Nepal data support a substantial benefit to the poor which is, however, not large enough to reduce income equality. In Minten and Jacoby (2009) a procedure is proposed to estimate willingness to be pay for transport on the basis of household data. The endogenous road placement problem is circumvented by surveying a homogenous region with one market and with a large variation in transport costs of households due to the lack of roads and motorized transport. Endogeneity or selection of productivity and migration relative to transport costs is investigated. Empirical estimations based on Madagascar household data point at large gains in income for remote households but also that these gains are small relative to the improved non-farm earning opportunities in town.

Research on the impact of communication and information infrastructure has become immensely popular since the introduction of mobile phones in SSA. These studies focus on a specific type of transaction costs, notably information and search costs, and investigate how mobile phone services have impacted on access to and costs of information, on market prices and on economic behaviour. Often the rollout of mobile phone networks is used for the identification of impacts, but also experimental designs are documented. Jensen (2007) uses micro level survey data to show that price dispersion on fish markets in Kerala (India), has substantially reduced after the introduction of mobile phones. This reduction in price dispersion is claimed to have established a nearly perfect adherence to the Law of One Price. The evidence further supports increased fishermen's profits and consumer welfare due to mobile phones, while gains are also shared by smaller and poorer fishermen. Easy and timely access to information is also shown to prevent waste, inefficiency and spoilage of production of perishable crops (Jensen, 2007; see also Muto

and Yamano, 2009, on bananas). Aker (2010) uses market and trader level data to estimate the impact of mobile phones on price dispersion across grain markets in Niger. The empirical evidence on the introduction of mobile phone services in Niger between 2001 and 2006 supports a 10 to 16% reduction in price dispersion. The reduction in price dispersion is stronger for market pairs with higher transport costs, and larger once a critical mass of market pairs has mobile phone coverage. Reduction in search costs and inter market price dispersion is associated with improvements in trader and consumer welfare. The lower reduction in price dispersion compared to Jensen (2007) is attributed to better storability of grain and lesser perishability than fish.

Several researchers use similar identification strategies but do not restrict impacts to the efficiency of markets. Muto and Yamano (2009) investigate the reduction in marketing costs of agricultural commodities due to the introduction of a mobile phone network in Uganda using household data for 2003 and 2005. They investigate marketing and trade of maize and bananas and find that the improved information due to mobile phone coverage has induced market participation of farmers in remote areas who produce bananas. Their study does not find impacts of mobile phone expansion on maize marketing. Mobile phone services cannot avoid potential asymmetric information between traders and farmers which block potential benefits for farmers. Farmers' organizations are suggested to tackle this problem and to strengthen the bargaining power of farmers. Fafchamps and Minten (2012) estimate the benefits for farmers of SMS based agricultural information in Maharashtra, India, using a randomized controlled trial. The information includes prices, weather forecasts, crop advice and new items. They find no effect of this service on the prices received by farmers, value added, crop losses, crop choices and cultivation practices. These disappointing results are in line with the limited commercial take-up of the information service, but difficult to reconcile with previous investigations on the impact of information (see above). A

comparative advantage in transport is suggested as an explanation why benefits accrue in the first place to traders and not to producers.

Finally, a few researchers investigate the impact of changes in marketing infrastructure rather than communication or transport infrastructure. Goyal (2012) investigates the impact of a change in marketing of a major private company in the soy market in the central Indian state of Madhya Pradesh. The company aimed at an improvement in procurement efficiency of soybeans to be achieved by the creation of a direct marketing channel (internet kiosks and warehouses) and by a reduction in transaction costs. After the introduction of kiosks and warehouses, soybean prices increased, price dispersion decreased and area under soy cultivation increased. This study highlights the benefits from direct interaction between producers and processors in agricultural marketing. For a full welfare assessment, however, the loss to traders needs to be quantified. Zant (2014) investigates the supply response of tobacco growers in Malawi, both at the intensive and extensive margin. Access to market in tobacco is determined by proximity to an auction floor. The introduction of an additional auction floor in Malawi, and the associated reduction in transaction costs is exploited to identify supply responses of farmers. Improved access to auction floors is shown to lead to large production and area increases.

The contribution of the current study is to measure the impact of railway transport services on the dispersion of agricultural commodity prices across markets. For this purpose we exploit the quasi experimental design of the collapse of domestic freight due to the disruption of a crucial railway bridge. The exogenous shock in transport costs creates an ideal setting for plausible identification. The setting is exceptional, since natural experiments in infrastructure rarely take place. Alike most other studies we investigate the impact of transaction costs, but

different from other studies we focus exclusively on a specific type of transaction costs, notably costs of transport by rail, a relatively cheap mode of transport.

3. The Malawi economy, transport by rail and domestic trade in agricultural commodities

The Malawi economy

Malawi is a relatively small landlocked country in the south of Africa, measuring around 800km from north to south and around 150 km from east to west, bordering in the northwest with Zambia, in the northeast with Tanzania and in the south with Mozambique. A large lake, Lake Malawi, part of the Great Rift Valley, stretches from north to south, along a large part of the east border of the country. During the study period (1998-2006) the population increased from close to 10 mln to 13 mln. Most people live in rural areas: a small fraction (11% to 15%) lives in cities (Lilongwe in the center, Blantyre and Zomba in the south and Mzuzu in the north). More than 80% of the Malawi population depends for food and income on subsistence farming. The incidence of poverty is high: more than 50% of the population in Malawi is poor (poverty head count ratio, Integrated Household Survey 2005 (IHS-2), National Statistical Office), and poverty is extremely high in remote rural districts (e.g. Chitipa (67.2%) in the north, and Nsanje (76.0%) and Chikwawa (65.8%) in the south), and in the southern region at least 10%-points higher relative to other regions. The key food crop is maize, followed with a distance by cassava, rice, groundnuts and beans. Malawi suffers from occasional food shortages due to drought and poor harvests (see Zant, 2012, 2013). Tobacco is by far the most important cash crop. Tobacco cultivation dates back to the colonial period, just like the other major cash crops, sugar and tea. Tobacco, however, has become nearly completely smallholder based in the course of the 1990s (see Zant, 2014), while tea and sugar production is mainly on account of estates. Nearly every

city, town or larger village has one or more markets for agricultural food crops on a regular basis, often daily or weekly. Both local farmers and traders operate on these markets. The major export crops are marketed in a different way (e.g. through auctions in the case of tea and tobacco, through a large processing company in the case of sugar (Llovo)).

Railway infrastructure, transport of goods by rail and the January 2003 collapse of trade by rail

The Malawi rail network consists of a rail line with a total within Malawi length of 797 km, running from Zambia in the west², to the east via Lilongwe (and Salima), and next to the south where – in the district of Balaka – the line splits into a line further south to Blantyre and Beira in Mozambique, and a line to the east, to Nacala in Mozambique (see map of Malawi in Appendix 1). The rail network has not been fully operational over the last decades, amongst other things because of civil war in Mozambique, destruction by floods and poor maintenance. However, transport of goods by rail remains an attractive alternative, especially for bulk products, as unit transport costs (costs per ton per km) by train is only a fraction of the cost of road transport. The (potential) importance of the railway for domestic trade in the Malawi economy is acknowledged by the data on trade flows and by policy documents and studies: *“Rail transportation is also an important mode of transport for rural farmers who usually use the train to move their farm produce to main markets in the cities or trading centers. Such commodities include tomatoes, pigeon peas and other vegetables. In 2006, CEAR (Central East African Railways) recorded approximately 480,000 passengers moved largely from smallholder farmers. Since 2000, CEAR moved over 250,000 tons of local products to main markets locally but has been experiencing reduced usage by the locals to transport their commodities using rail transportation.”* (taken from ‘Millennium Challenge Corporation: Malawi Compact Program Development (2011 – 2016), Project Concept Paper For

² The railway line only runs around 25 km into Zambian territory (at Chipata) and has no connection with the Zambian railway network.

The Transport Sector: Promoting Economic Growth And Poverty Reduction Through Addressing Transport Infrastructure Constraints In Malawi', Millennium Challenge Account - Malawi Country Office Secretariat).

What can we learn from data on transport by rail? Figure 1 shows the development of total freight in 1000 ton kilometer transported by rail on a monthly basis from January 2001 to December 2007. We observe a number of remarkable developments from the CEAR data on aggregate trade volumes. Despite the huge fluctuations in freight, the figure clearly reveals a structural break in trade volume, starting in January 2003, when a nearly total collapse of domestic trade occurred. The collapse is further corroborated by the development of domestic freight (Figure 2a) and, somewhat less pronounced, by the development of passenger trade (Figure 2b).

Figure 1 Collapse of (all) trade by rail, monthlies

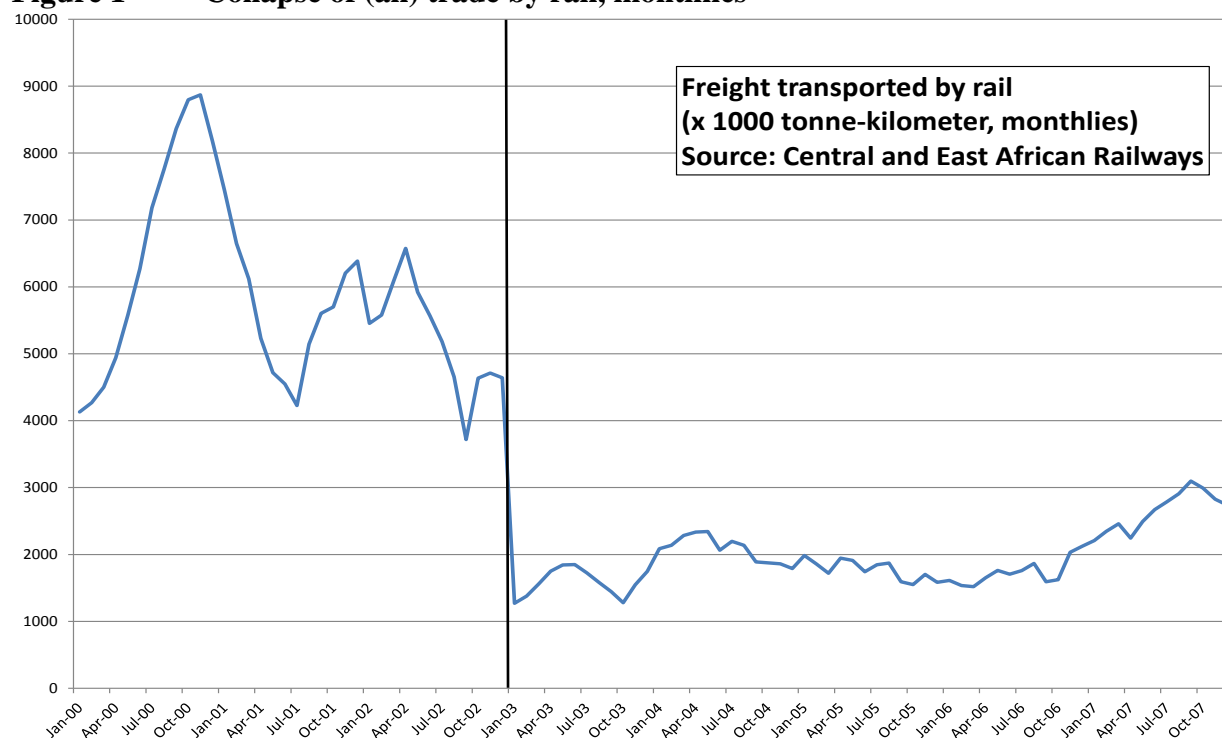
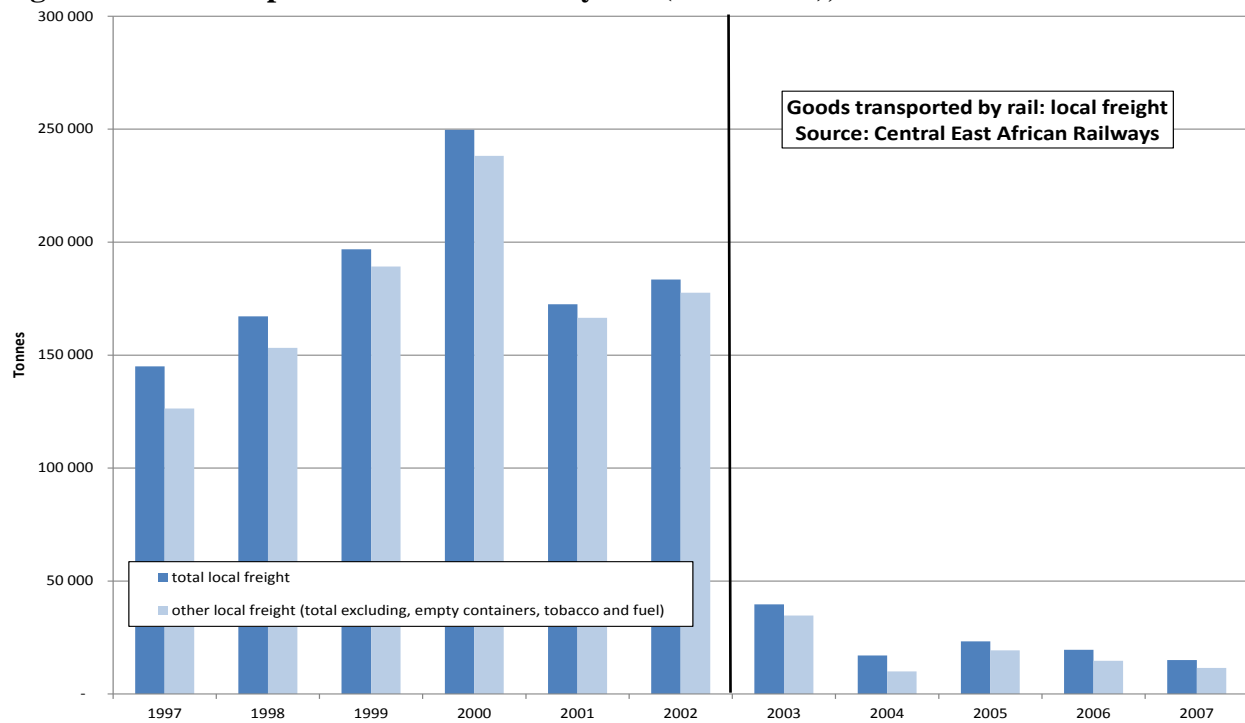
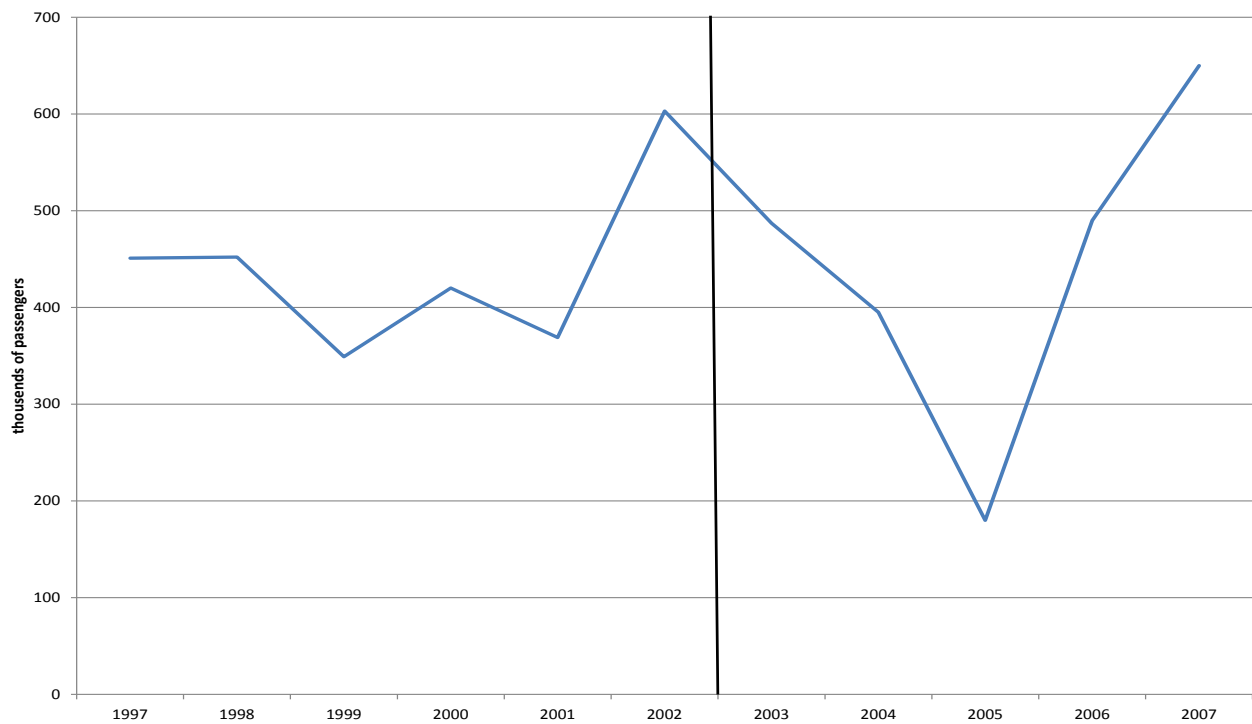


Figure 2a Collapse of domestic trade by rail (local trade), annuals*



* For the year 2004 we only have data on aggregate tonnage: composition is computed by interpolation

Figure 2b Collapse of number of (domestic) rail passengers



The collapse in rail transport expressed in the figures was fully on account of the disruption of a bridge at RiviRivi in Balaka district, at a crucial location in the rail network (see map of Malawi in Appendix 1; the railway bridge is indicated with an asterisk), which in turn was caused by a tropical storm. In January 2003 a severe tropical storm, named Delfina, developed into a damaging tropical cyclone that affected southeastern Africa. Delfina started at the northwest coast of Madagascar on December 30, 2002 and intensified while moving westward before hitting northeastern Mozambique on December 31. The storm weakened while moving inland by January 1, 2003, into Mozambique and Malawi. By January 9 Delfina had died out. In Malawi, the storm's remnants caused flooding in seven provinces in a number of locations. Delfina damaged roads, and, most importantly for our study, destroyed a railway bridge at RiviRivi, in Balaka district. Also a train derailed due to effects from the storm, which cut rail travel between northern Mozambique and neighboring Malawi. The storm further destroyed several thousands of houses, and around 30,000 people were forced to leave their homes. The floods affected substantial properties, damaging large areas of agricultural land in the midst of a food shortage. Delfina killed eight people in Malawi, prompting President Bakili Muluzi to declare the country as a disaster area on January 11. The Rivirivi railway bridge was repaired and rail transport operations were resumed in May 2005, close to two and a half years later³.

The dramatic sequence of events has created an interesting opportunity to measure the impact of rail transport services on markets. Ideally one would need detailed records of bilateral trade flows by rail, including prices by market and traded quantities of agricultural products by source and destination, both before and after the disaster had taken place, in order to investigate impact rigorously. Unfortunately, such data on trade by rail are not available. As a matter of fact, we also do not know to what extent trade by rail in agricultural commodities takes place in the form

³ Personal communication of the author with CEAR staff (CEAR = Central and East African Railway).

of passenger trade – farmers and traders travelling by train to nearby town and city markets for selling their produce or stocks – or in the form of formal freight⁴. What is available is data on market prices of agricultural commodities for a large number of markets in Malawi. Hence, in this study we will focus on the impact of railway services on market prices of agricultural products. A certain degree of speculation in the postulated impact of railway transport services on market prices of agricultural commodities remains. However, in this respect our work compares favorably with (most) research on the impact of mobile phones: at least we know that there has been freight of agricultural products transported by rail. And do the researchers on the impact of mobile phones know if market information is exchanged over the phone?

Malawi markets for agricultural commodities: production, prices, domestic trade and demand

In the empirical part we look at prices of a few specific crops, notably maize, rice, groundnuts and beans. These food crops are all important crops in the Malawi context, where maize takes an outstanding position accounting for 50 to 60% of the diet of most people in Malawi and is produced by nearly all farm households. Maize, rice and beans is primarily consumed domestically, although in case of bumper crops small quantities are exported. Groundnuts are partly exported, but the bulk of production is consumed domestically. Rather than having records of transport by rail of either maize, rice, groundnuts or beans, we simply assume that such trade takes place, most likely on a small scale, by farmers and local traders. There is a remarkable even spread of production of these crops over Malawi: they are cultivated in all Malawi districts, with the exception of rice, (see Appendix 4). Groundnut cultivation is most concentrated in the central

⁴ Fafchamps et al, 2005 reports that in their 2000 Malawi trader survey none of the traders made use of transport by train. It should be noted, however, that the impact that we are after, also concerns farmers who take up trading activities, or, more precisely, farmers who take the trouble of selling their output in a nearby town or city to fetch a higher price rather than selling at the farm gate or the local market. Evidence on Ugandan coffee farmers suggests that such activities are not uncommon (see Fafchamps and Vargas-Hill, 2005). A nearby railway station may make this proposition even more profitable for a farmer.

region and least in the southern region, and cultivation of pulses is most concentrated in the southern region and least in the north and central region. Whatever the cause of the even distribution of production – high transport and trading costs, inefficient agriculture, little comparative advantage of regions – it may also, and simultaneously, limit the scope for domestic trade. Supply from local production will often be / may quickly become the cheaper and the preferred alternative, rather than “imports” from neighboring regions and districts. In the end the (relative) balance between supply from local production and demand over the season determines the scope for trade. Seasonality in production and constant demand easily translates into seasonality in prices. Prices are low in the months after harvesting (April-June), and subsequently increase continuously to reach (very) high levels just before the next harvest is available. Differences between highs and lows often are larger than 100%. Seasonality in prices is more pronounced in urban areas, due to higher income, larger population and lower local supply. Seasonality in prices of maize, rice, groundnuts and beans is confirmed by the data (see Appendix 3) and also identified in other research (see e.g. Kaminski e.a. , 2014). The pronounced and regular pattern suggest unexploited arbitrage opportunities, both intertemporal and across markets: especially with regularity and high predictability in seasonal prices potential gains from trade appear feasible. Price seasonality in Malawi is on average largest in maize, smallest in rice, and groundnuts and beans are in between⁵. Maize is also an exception in terms of value: all three other crops are (relatively) high value crops: rice, beans, and groundnut prices are on average 4 to 5 times the price of maize, with groundnuts on the high and rice on the low side, and with distinct variations by year and market (see Appendix 3). Trade costs of high value

⁵ We calculate seasonality in prices by dividing the monthly price with the season average price. The season average is a centered 12 months average with a moving window. This resulting number which measures the extent to which current prices diverge from its season average, is dimensionless and automatically takes account of price changes over time.

crops will be proportionally smaller, which may induce farmers (rather than traders) to prefer to sell these commodities on distant markets. An additional incentive for trade will only arise if the margin on trade is also proportionally higher or fixed costs of trade are independent of the value of the traded crop.

Although transport of agricultural produce by rail is a cheap and thereby attractive alternative⁶, the dominant mode of transport of trade in agricultural products in Malawi is transport by road⁷. The predominantly small scale domestic trading business is undertaken by farmers, small, medium and large traders, wholesalers, maize processing firms and ADMARC. The dispersion of the size distribution of trader businesses and the prevalence of many small scale businesses suggest constant returns to scale in trade (Fafchamps et al. 2005). Most “district to district” trade of maize is from farmers to small and medium traders, and occasionally to larger traders and wholesalers. Around 75% of all traders buy directly from farmers and sell as a retailer (Fafchamps et al. 2005). Trading channels vary by location, but the bulk of maize trade is in the hands of the private sector. Survey data indicate that average distance between purchase location and sale location of maize transactions is around 55km with a maximum of 200km (Fafchamps et al. 2005). For a variety of reasons domestic transport costs of transport by truck are very high: the main causes include poor (secondary) roads, high petrol prices, relatively inefficient small loads / no scale economies, no backloads, and undercapitalized and inefficient back-to-back funding (see Lall, 2008; Zant, 2013). Cheap transport services in Malawi would create large welfare gains and certainly enhance the scope for economic growth. If fully

⁶ Donaldson (2010) claims that road transport is 4.5 times more costly relative to rail transport (per unit distance freight rate of road transport relative to rail transport). Of course, the severely limited geographical reach of the current Malawi rail network and the poor and unreliable service delivery in the past do not make railway services currently a particularly favorable alternative.

⁷ The dominant mode of transport in domestic trade varies by country. In India for example the dominant mode of transport is rail (van Leemput, 2014) and in Zaire road and river (Minten en Kyle, 1999). Most often, various modes complement each other.

operational, the (extended) railway system in Malawi is an attractive and cheap alternative and an interesting complement for transporting agricultural output, and for enhancing welfare of smallholder farmers.

4. Measuring the impact of railway services on dispersion of market prices

Theoretical considerations

Costs of railway transport are relatively low compared to transport costs with trucks by road which is the standard mode of transport in Malawi. Farmers and traders in Malawi based in areas near to a railway station are likely to (have) benefit(ted) from these cheap transport services. The lower transport costs enhances trade of agricultural commodities markets along the railway line, as it increases flows of goods from surplus to deficit areas. The increase in trade by rail will raise the low prices in surplus areas and it will reduce the high prices in deficit areas. Hence, availability of railway transport services should reduce price dispersion across markets along the railway line. The key mechanism that drives this process is standard profit maximising producer behaviour with transaction costs.

Empirical specification

For the estimation of impacts we apply a difference-in-difference strategy and use the following regression model:

$$Y_{jk,t} = \beta_0 + \beta_1 Y_{jk,t-1} + \beta_2 \text{connected by rail}_{jk,t} + \sum_j \beta_j X_{jk,t} + \beta_3 \text{time}_t + \omega_l + \varphi_t + \eta_{jk} + \zeta_{jk,t}$$

where $Y_{jk,t}$ is the dispersion of prices across markets j and k , at time t , ‘*connected by rail*’ is a variable with a value ($\ln(\text{distance})$) if both markets are less than 20 km away from a railway station and 0 otherwise, $X_{jk,t}$ is a vector of market pair variables at time t , affecting the dispersion

of prices across markets j and k , $time$ is a general time trend, ω_l , φ_t and η_{jk} are market, time and market pair fixed effects and $\zeta_{jk,t}$ is a iid error term with a zero mean and a constant variance. In the estimated specification we have included the lagged dependent variable as explanatory variable in order to filter out lagged responses. The vector of $X_{jk,t}$ variables are assumed to be determinants of price dispersion between markets j and k , associated with either transaction costs (like transport costs, gasoline prices and economies of scale), or (relative) local supply and demand balances. In the data description we discuss the covariates used in estimations in detail. In the basic estimation we restrict the $X_{jk,t}$ variables to the distance between markets, reflecting transport costs. In the estimated equations we interacted a time trend with markets⁸, and seasonality with markets. The data description in the previous section supports a crop and market specific seasonal price pattern. Annual fixed effects are included to control for country wide variations in agricultural production between years (caused by bumper crops and droughts). We have specified the interactions applied in the estimations further in the empirical section.

Identification strategy

The exogenous collapse of railway transport services due to the disruption of the railway bridge at Rivirivi, documented in a previous section, creates a quasi-experimental design that offers an opportunity to identify the impact of railway services on the dispersion of agricultural commodity prices. The regression equation represents a difference in difference model with markets connected by rail when the railway was operational, as intervention observations. The coefficient of interest in the regression equation is β_2 : this coefficient reflects the impact of the availability of railway transport services on the dispersion of agricultural commodity prices. We expect the dispersion of these prices to be lower in the locations near the railway line. The

⁸ We discarded the option to interact a time trend with market pairs since this leads to a drastic reduction of the degrees of freedom.

underlying hypothesis is that a railway infrastructure implies an opportunity for trade at low costs which positively effects domestic trade, notably flows of goods from surplus to deficit area. The increase in trade by rail will raise prices in surplus areas, or at least dampen further reductions, and it will reduce prices in deficit areas, or at least slow down the price increase. Consequently, the increased trade is likely to reduce price fluctuations in both locations, and thereby price dispersion across locations. Hence, we expect β_2 to be negative: a reduction in dispersion of prices across markets that are linked with each other by the railway, is likely to take place.

Intervention locations

Interventions in this study are the market pairs that are connected with each other by rail, when the railway is operational. For this purpose we have calculated the distance between markets and the nearest railway station. All markets that are less than 20km away from the nearest railway station, are assumed to be connected by rail. Practically this implies we have 10 intervention locations⁹, implying 45 intervention market pairs (see Appendix 5 for a list with markets, distance to station and latitude-longitude coordinates). We have verified the robustness of the estimation results by taking different cut-off distances (less than 10km: 8 intervention locations / 28 intervention market pairs; and less than 30km: 13 intervention locations / 78 intervention market pairs). In the estimation section we have documented the outcome of these checks.

Data

For the empirical work we use monthly retail market prices of agricultural commodities taken from the Agro-Economic Survey, of the Ministry of Agriculture and Food Security. We have these data for a long period (from 1991/92 to 2008/09), for a large number of markets (around

⁹ These markets are (in alphabetical order): Bangula, Lilongwe, Limbe, Liwonde, Lizulu, Luchenza, Lunzu, Mchinji, Ntaja, and Salima (see also map of Malawi, Appendix 1).

70) and for a large number of agricultural commodities and livestock products. However, for the purpose of this study we use a limited subset: we use only maize, rice, groundnuts and beans prices, for those markets (27 in total) that have the most complete price series. Additionally, empirical estimations are restricted to the period 1997/98 to 2006/2007, the period that covers a number of years before and after the collapse of the rail transport. The price data are not complete, and, more troublesome, especially the period of key interest to our research (around January 2003), a substantial drop in the completeness of the data occurs, most likely due to the food crisis at the time (see Appendix 2). In the assessment of the estimations we have treated this issue with caution.

All distances used in the empirical part are distances as the crow flies, calculated using standard *Great Circle Distances*, and based on latitude-longitude coordinates of locations (markets, railway stations). We are aware that distance measured as the crow flies differs from road distance and that road distance is the relevant concept for transport costs. However, since we do not exactly know the (changes in) road distance at the time, we rather avoid the likely but uncertain error, and prefer the clear and transparent approximation of distance.

We include the following three additional covariates ($X_{jk,t}$) in the estimation: rainfall, population density and per capita (gross) income. Rainfall is an annual index of crop season rainfall in mm. normalised with the long run average crop season rainfall in mm. Rainfall is recorded in around 30 weather stations and attributed to markets on the basis of proximity. We expect that above average rainfall increases crop production and the availability of agricultural commodities after harvest, and increased supply will reduce prices. Hence, we expect current crop season rainfall to have a negative impact on next year price. In terms of price dispersion we expect that a large difference in rainfall between locations increases price dispersion. Rainfall

data are from Department of Climate Change and Meteorological Services, Ministry of Natural Resources, Energy and Environment in Blantyre. Population density is the number of people per square kilometer, by Extension Planning Area (EPA) or district / Rural Development Project (RDP). Population size varies between districts, but moves only very gradually over time. Higher population densities are associated with more trade, and more efficient trade (see Fafchamps et al. 2005). Hence, we expect price dispersion between locations to decrease the larger the population density in both locations. Population data are from the National Statistical Office in Zomba and district area is taken from www.geohive.com. Per capita income is a constructed annual variable by district: in order to calculate gross income from agriculture we multiply agricultural production with average retail market prices, both by crop season and district and summed over crops and livestock products¹⁰. All prices are deflated with the consumer price index for rural areas (source: National Statistical Office, Zomba, Malawi). Then we exploit data on rural and urban population by district: we first calculate the per capita agricultural income by using rural population data by district. Next, we assume that the highest per capita agricultural income in the region is related to per capita income of the urban population: we impute n times the region highest per capita income to the urban population, to construct (average) per capita income by year and by district, where n reflects the productivity differences between urban and rural workers¹¹. There is a multitude of explicit and implicit assumptions in this per capita income calculation with many arbitrary elements, which many researcher will label as “heroic”. Nevertheless the constructed data should give a sensible order of magnitude for per capita

¹⁰ We distinguish the crops maize (local, composite and hybrid), rice, millet, sorghum, cassava, sweet potatoes, groundnuts, pulses, cotton, tobacco, tea and sugar, and the livestock products steak, pork, mutton and goat meat.

¹¹ Urban population only refers to a fraction of the population of the districts of Lilongwe, Blantyre, Zomba and Mzimba. We use $n = 1.5$; However, a range of values varying between 1 and 3 did not fundamentally change the estimation results. We cannot calibrate the value of n with GDP data because of the subsistence character of the Malawi economy: home consumed production is included in our per capita income concept but it does not show up in per capita GDP.

income. Per capita income reflects demand and we expect that a higher per capita income increases demand and pushes up prices of agricultural commodities. Large differences in income between locations will, *ceteris paribus*, increase price dispersion. All covariates are expressed in terms of the absolute value of the natural logarithm of their relative values ($|\ln(x_k/x_j)|$). Covariates have, in different degrees, large fixed effect components: we expect that these variables will interact with included fixed effects.

5. Estimations and discussion

Other empirical issues

In running the estimations we have assumed that the impact of railway services is geographically restricted. Additionally we have assumed that the period without railway services between the market pairs connected by rail is restricted. This is justified as follows. Transport costs are different from search costs in the sense that transport costs increase more or less proportionally with transport distance while this is not necessarily the case for search costs. As a result the impact of availability of transport services is spatially restricted: transport costs, hence prices of traded goods, are high for markets that are a large distance away and there is a clear trade-off between “import” and local supply: local production or the use of close local substitutes could be cheaper alternatives than “import” from far away locations, especially if there is no advantage from specialization and if the traded agricultural product may be produced anywhere. Therefore we assume that (potential) domestic trade only takes place between markets that are located a limited distance away from each other. How far this distance is needs to be investigated empirically. Aggregate data on freight by rail indicate that the average distance of freight by rail in case of local freight is 80-115 km and in case of export or import freight, 180-220km. For

domestic passengers the average distance travelled varies from 40 to 80km. Survey data on domestic trade and domestic traders, generally using (pick-up) trucks as mode of transport, indicate that average distance between location of purchase and sale location of maize transactions is around 55km with a maximum of 200km (Fafchamps et al., 2005).

The distance over which crops are traded is likely to be influenced by perishability / storability of crops, whether the crop is a high value or low value crop, the geographical spread of production (and consumption) and how large expected gains from trade are. Since high value crops have relatively smaller transport costs, these crops are likely to be traded over longer distances. Next, trade in perishable crops is, by nature, spatially restricted: these crops simply degenerate if transported over long distances and thereby become unsaleable¹². Conversely, storable crops are more suitable to be traded over longer distances. Trade over longer distances may arise if production area is more dispersed and/or more remote from consumption locations. Finally, the size of the expected gains from trade will influence the distances over which agricultural commodities are traded. The larger the gains the larger the distance over which crops are traded. These expected gains from trade depend on the difference in prices in each location, which in turn depends on differences in the supply and demand balance across locations¹³. Large imbalances between local production and local demand will potentially give rise to higher prices. Seasonality in production will also lead to seasonality in prices, which will be more pronounced if demand is higher. Hence, differences in seasonality of prices across locations will affect expected gains from trade.

With the disruption of the railway bridge at Rivirivi, Balaka a period started without railway services for markets along the railway line. The start of this period is 100% accurate. However, it

¹² We ignore the possibility of cooled transport which is not feasible for the typical SSA farmer / trader.

¹³ Availability of information on prices in several markets is obviously a key determinant of trade flows. Several studies highlight the importance of search costs and the availability of price information (see literature review).

is not clear when this period ended. From personal communication with CEAR staff (CEAR = Central East African Railway) we know that the Rivirivi railway bridge was repaired and rail transport operations were resumed in May 2005. However, in the course of time the lack of railways services will lead to adjustments like the use of alternative modes of transport, increased local cultivation of food and shifts to local substitutes. The speed of adjustment will depend on the availability of cheap alternative modes of transport, supply response of local production and the resilience of demand to shift to other crops. These adjustments are likely to have taken place since domestic trade did not recover after rail transport operations were resumed. In the estimations we have assumed on the basis of data on passenger and freight transport by rail (see Section 3), that the period in which the railway is effectively not operational, is at least 2 years and at most 3 years. The minimum of 2 years is further motivated by the limited availability of price data around 2003 (see Appendix 2). The maximum of 3 years is motivated by the fading out of the impact (see estimation section) and is determined empirically, using a grid procedure.

Estimation results of a basic specification

The basic result of this investigation is summarized in Table 1. The estimations confirm a statistically significant reduction in the dispersion of agricultural commodity prices across markets of around 11-14%. The size of the reduction is remarkably similar across commodities. Lagged dependent variables, included in order to filter out lagged responses, are positive and statistically significant in all estimations. Higher order lags are included if statistically significant at the 1% level: this strategy should control for potential higher order autocorrelation. Only in the case of estimations for rice including a two months lagged dependent turned out to be necessary. The inclusion of the lagged dependent variable allows the distinction of short and long run

impact, where the long run impact is calculated as $\beta_2/(1 - \beta_1)$, using the notation from the regression model. Long run impacts range from a reduction of 14% to 18%. These results point at substantial welfare effects for consumers, from the enhanced efficiency of markets for agricultural commodities. The reduction in price dispersion is also likely to affect growth since lower food prices in subsistence economies constitute an important transmission mechanism to higher productivity (see De Janvry and Sadoulet, 2010).

Table 1 Impact (ATE) of rail transport services on market prices: selected output

dependent variable: $\ln(\text{abs}(p_{jt} - p_{kt}))$				
crop / commodity	(1) maize	(2) rice	(3) groundnuts	(4) beans
connected by rail	-0.106*** (0.0400)	-0.129*** (0.0457)	-0.117*** (0.0442)	-0.137*** (0.0425)
lagged dependent variable (t-1)	0.223*** (0.0320)	0.139*** (0.0234)	0.289*** (0.0198)	0.224*** (0.0397)
lagged dependent variable (t-2)		0.099*** (0.0258)		
$\ln(\text{distance})$	1.467*** (0.4378)	0.388*** (0.0625)	0.578* (0.2956)	0.864** (0.4291)
season x market dummies	yes	yes	yes	yes
time trend x market dummies	yes	yes	yes	yes
market pair dummies	yes	yes	yes	yes
year dummies	yes	yes	yes	yes
covariates	no	no	no	no
R ²	0.3723	0.4027	0.3895	0.4430
max trading distance (km)	110	160	140	110
sample period	1/00-4/05	1/99-12/04	1/99-12/04	1/00-4/05
months before 1/03 and after 12/02	36; 28	48; 24	48; 24	36; 28
number of observations	1826	2494	2684	1846
no. of intervention pairs	196	366	152	189
no. of control pairs connected by rail	161	121	58	136
no. of other controls (not connected)	1469	2007	2474	1521
long term impact	-0.137	-0.170	-0.165	-0.177

Note to table: *connected by rail* has the value $\ln(\text{distance})$ if both markets are less than 20km away from a railway station, while the railway was operational, and zero elsewhere (in case of groundnuts less than 10km). Prices are deflated with the rural consumer price index (source: National Statistical Office, Zomba, Malawi). Robust standard errors in parentheses below the coefficient are clustered by market pairs. *p < 0.10, **p < 0.05, ***p < 0.01. The long term effect is calculated as $\beta_2/(1 - \beta_1)$ (see regression model above).

Selecting the sample of observations: maximum trading distance and speed of adjustment

From the selected estimations in Table 1 we notice that the maximum trading distance and the sample period varies by crop¹⁴. Since we do not know exactly the most appropriate values of the maximum trading distance and the relevant period before and after the date of disruption (January 2003), we determine these empirically using a simple grid procedure: we estimate with a maximum trading distance varying from 70km to 200km (with a 10km step), and with 2 to 5 years before, and 2 to 4 years after January 2003. We use this procedure in order to find, simultaneously, the appropriate maximum trading distance and relevant period, but also to assess the robustness of the estimations. Extensive, but still limited, output of this exercise is reported in Table 2a to 2d.

On the basis of the tables and the underlying estimations we have the following observations. For all four commodities we observe sets of estimations with statistically significant ATEs with the required negative sign, around a specific combination of maximum trading distance and sample period. The regularity of these estimation outcomes – both across commodities and for each individual commodity, across combinations – offers comfort in and credibility of the estimations. For all commodities we see impacts disintegrate if the period without railway services is extended to the year 2006 (not shown, available from the author on request¹⁵): apparently the period effectively without railway services – i.e. the period with effectively higher dispersion of agricultural market prices – is limited to the years 2003, 2004 and 2005. This is consistent since railway services resumed operations in May 2005. In fact, this motivated us to include estimations that exactly matched this period (January 2003 to April 2005), which further

¹⁴ In fact, for Table 1 we have deliberately cherry picked estimation results (as all of us do!) from the estimations reported in the current section (see Table 2 to 2d): for each commodity we have selected the estimation result where the ATE is around the median of estimated ATEs that are statistically significant at the 95% level or higher.

¹⁵ Additionally, with a maximum trading distance of 70km or less, and with only two full years of observations on both sides of the turning point (January 2003) the estimations tend to generate spurious outcomes.

improved estimations in the case of beans, groundnuts and, especially, maize. Next, the impact in the case of rice is significant with a relatively large maximum trading distance of 160-180 km., opposed to around 100 km. for maize and beans. Groundnuts is in between. In the case of rice this is possibly the result of the uneven spread of rice cultivation, compared to the other commodities. Also good storability (of rice and groundnuts) will make trade over longer distances easier. The impact coefficients of all commodities with the exception of beans are around -11%, while in the case of beans, the impact is slightly stronger, around -14%. We assume that this should be associated with the higher perishability of beans, and the related reduced scope for intertemporal arbitrage (relative to storable commodities). Other studies also confirm a higher impact in case of perishable crops (see e.g. Jensen 2007; Muto and Yamano, 2009; Aker and Fafchamps, 2014). Also, in the case of beans, estimation results tend to disintegrate quicker with more years before and after the turning point (January 2003).

Table 2a Impact (ATE) with samples varying over time and geographical space

Impact of railway transport on price dispersion across markets: maize						
domestic trade between markets within a maximum distance of:						
Period	months before, after	80km	90km	100km	110km	120km
1/98-12/04	60,24	-0.098* (.058) 1191; 0.3857	-0.078 (.054) 1449; 0.3731	-0.115** (.049) 1678; 0.3311	-0.107** (.042) 2024; 0.3190	-0.072 (.044) 2288; 0.3049
1/99-12/04	48,24	-0.132** (.061) 1067; 0.4135	-0.125** (.059) 1310; 0.3995	-0.153*** (.054) 1519; 0.3583	-0.134*** (.044) 1820; 0.3396	-0.092* (.049) 2054; 0.3225
1/00-12/04	36,24	-0.117* (.065) 919; 0.4677	-0.105 (.063) 1144; 0.4448	-0.140*** (.051) 1330; 0.4067	-0.111** (.043) 1584; 0.3833	-0.068 (.048) 1794; 0.3605
1/98-12/05	60,36	-0.082 (.051) 1614; 0.3139	-0.063 (.042) 2009; 0.3025	-0.086* (.044) 2306; 0.2763	-.068* (.035) 2772; 0.2620	-0.050 (.035) 3123; 0.2549
1/99-12/05	48,36	-0.100 (.060) 1490; 0.3212	-0.076 (.050) 1870; 0.3091	-0.104** (.049) 2147; 0.2862	-0.076* (.040) 2568; 0.2683	-0.059 (.038) 2889; 0.2598
1/00-12/05	36,36	-.092 (.059) 1342; 0.3521	-0.059 (.051) 1704; 0.3341	-0.098** (.049) 1958; 0.3158	-0.059 (.040) 2332; 0.2937	-0.043 (.039) 2629; 0.2812
1/98-4/05	60,28	-0.114** (.052) 1329; 0.3849	-0.109** (.047) 1630; 0.3738	-0.127*** (.047) 1882; 0.3351	-0.106*** (.039) 2266; 0.3223	-0.076* (.041) 2558; 0.3124

1/99-4/05	48,28	-0.151 ^{***} (.053)	-0.149 ^{***} (.049)	-0.162 ^{***} (.051)	-0.128 ^{***} (.041)	-0.094 ^{**} (.044)
		1205; 0.4049	1491; 0.3932	1723; 0.3564	2062; 0.3383	2324; 0.3268
1/00-4/05	36,28	-0.143 ^{***} (.050)	-0.122 ^{**} (.046)	-0.148 ^{***} (.049)	-0.106 ^{***} (.040)	-0.072 [*] (.043)
		1057; 0.4446	1325; 0.4262	1534; 0.3939	1826; 0.3723	2064; 0.3557

Note to table: The table reports Population Average Treatment Effects (ATE) with data that are restricted to market pairs within a range of specified maximum distance of each other and restricted to a varying pre- and post-intervention sample period. *p < 0.10, **p < 0.05, ***p < 0.01. Next to the ATE coefficient in brackets are robust standard errors clustered by market pairs, and below the coefficient the number of observations and R². Estimated specification is identical to the specification reported in Table 1.

Table 2b Impact (ATE) with samples varying over time and geographical space

Impact of railway transport on price dispersion across markets: rice

		domestic trade between markets within a maximum distance of:				
Period	months before, after	140km	150km	160km	170km	180km
1/98-12/04	60,24	-0.070 (.045)	-0.097 ^{**} (.048)	-0.110 ^{**} (.048)	-0.079 [*] (.045)	-0.078 [*] (.040)
		2529; 0.4011	2678; 0.3923	2791; 0.3900	3086; 0.3806	3292; 0.3665
1/99-12/04	48,24	-0.100 ^{**} (.044)	-0.124 ^{***} (.047)	-0.129 ^{***} (.046)	-0.088 ^{**} (.043)	-0.082 ^{**} (.040)
		2259; 0.4146	2393; 0.4038	2494; 0.4027	2752; 0.3939	2938; 0.3789
1/00-12/04	36,24	-0.061 (.052)	-0.081 (.053)	-0.082 (.052)	-0.064 (.044)	-0.055 (.040)
		1892; 0.4353	2007; 0.4225	2102; 0.4264	2317; 0.4188	2476; 0.4065
1/98-12/05	60,36	-0.060 (.039)	-0.078 [*] (.040)	-0.086 ^{**} (.040)	-0.065 [*] (.034)	-0.066 ^{**} (.031)
		3305; 0.3838	3506; 0.3787	3647; 0.3775	4036; 0.3719	4308; 0.3615
1/99-12/05	48,36	-0.070 [*] (.037)	-0.087 ^{**} (.038)	-0.090 ^{**} (.037)	-0.063 ^{**} (.033)	-0.060 ^{**} (.030)
		3035; 0.3906	3221; 0.3852	3350; 0.3856	3702; 0.3816	3954; 0.3719
1/00-12/05	36,36	-0.034 (.041)	-0.050 (.041)	-0.050 (.040)	-0.033 (.035)	-0.029 (.031)
		2668; 0.4039	2835; 0.3990	2958; 0.4035	3267; 0.4007	3492; 0.3921
1/98-4/05	60,28	-0.062 (.041)	-0.084 [*] (.043)	-0.097 ^{**} (.043)	-0.074 ^{**} (.037)	-0.076 ^{**} (.035)
		2761; 0.3926	2924; 0.3840	3045; 0.3818	3372; 0.3750	3595; 0.3631
1/99-4/05	48,28	-0.075 [*] (.041)	-0.094 ^{**} (.042)	-0.101 ^{**} (.041)	-0.072 ^{**} (.037)	-0.070 ^{**} (.034)
		2491; 0.4004	2639; 0.3904	2748; 0.3900	3038; 0.3841	3241; 0.3727
1/00-4/05	36,28	-0.033 (.045)	-0.050 (.045)	-0.052 (.045)	-0.040 (.038)	-0.038 (.034)
		2124; 0.4157	2253; 0.4061	2356; 0.4102	2603; 0.4046	2779; 0.3953

Note to table: see previous table

Table 2c Impact (ATE) with samples varying over time and geographical space

Impact of railway transport on price dispersion across markets: groundnuts

		domestic trade between markets within a maximum distance of:				
period	months before, after	80km	100km	120km	140km	160km
1/99-12/04	48,24	-0.104 (.071)	-0.090 (.058)	-0.126 ^{***} (.047)	-0.117 ^{***} (.044)	-0.110 ^{**} (.043)
		1118; 0.4750	1599; 0.4528	2193; 0.4134	2684; 0.3895	2968; 0.3785
1/00-12/04	36,24	-0.110 (.081)	-0.127 [*] (.075)	-0.143 ^{**} (.058)	-0.120 ^{**} (.058)	-0.111 [*] (.059)
		959; 0.5493	1375; 0.5164	1867; 0.4620	2276; 0.4295	2524; 0.4192
1/01-12/04	24,24	-0.103 (.107)	-0.130 (.083)	-0.187 ^{***} (.061)	-0.129 [*] (.070)	-0.115 (.072)

		758; 0.5781	1107; 0.5380	1497; 0.4855	1817; 0.4493	2026; 0.4359
1/99-12/05	48,36	-0.085 (.051)	-0.084** (.036)	-0.039 (.049)	-0.044 (.047)	-0.027 (.047)
		1416; 0.4500	2063; 0.4216	2801; 0.3831	3450; 0.3597	3824; 0.3545
1/00-12/05	36,36	-0.101 (.063)	-0.131*** (.043)	-0.054 (.058)	-0.048 (.055)	-0.025 (.056)
		1257; 0.5054	1839; 0.4663	2475; 0.4158	3042; 0.3855	3380; 0.3819
1/01-12/05	24,36	-0.107 (.077)	-0.161*** (.045)	-0.070 (.064)	-0.037 (.064)	-0.007 (.065)
		1056; 0.5360	1571; 0.4807	2105; 0.4291	2583; 0.3924	2882; 0.3859
1/99-4/05	48,28	-0.115 (.074)	-0.092 (.058)	-0.104** (.047)	-0.103** (.046)	-.090** (.044)
		1181; 0.4555	1706; 0.4389	2331; 0.3962	2857; 0.3667	3161; 0.3592
1/00-4/05	36,28	-0.117 (.082)	-0.137** (.067)	-0.121** (.056)	-0.112* (.057)	-.094* (.057)
		1022; 0.5193	1482; 0.4947	2005; 0.4389	2449; 0.4012	2717; 0.3948
1/01-4/05	24,28	-0.135 (.108)	-0.172** (.072)	-0.153** (.063)	-0.110 (.067)	-0.085 (.069)
		821; .5492	1214; 0.5128	1635; 0.4571	1990; 0.4147	2219; 0.4045

Note to table: see previous table

Table 2d Impact (ATE) with samples varying over time and geographical space

Impact of railway transport on price dispersion across markets: beans

		domestic trade between markets within a maximum distance of:				
Period	months before, after	80km	90km	100km	110km	120km
1/99-12/04	48,24	-0.114* (.064)	-0.112** (.050)	-0.115** (.048)	-0.127*** (.037)	-0.046 (.055)
		1186; 0.4987	1461; 0.4981	1704; 0.4793	2054; 0.4637	2313; 0.4420
1/00-12/04	36,24	-0.145* (.072)	-0.134** (.055)	-0.122** (.049)	-0.135*** (.038)	-0.051 (.056)
		978; 0.4980	1217; 0.4910	1420; 0.4714	1699; 0.4589	1920; 0.4427
1/01-12/04	24,24	-0.198*** (.058)	-0.217*** (.063)	-0.184*** (.054)	-0.174*** (.047)	-0.074 (.077)
		723; 0.5365	912; 0.5146	1063; 0.4991	1262; 0.4880	1436; 0.4706
1/99-12/05	48,36	-0.103* (.056)	-0.095* (.051)	-0.097** (.044)	-0.121*** (.036)	-0.060 (.046)
		1483; 0.4562	1886; 0.4665	2175; 0.4480	2616; 0.4302	2931; 0.4093
1/00-12/05	36,36	-0.119* (.066)	-0.109* (.057)	-0.107** (.045)	-0.127*** (.039)	-0.073 (.045)
		1275; 0.4590	1642; 0.4623	1891; 0.4440	2261; 0.4290	2538; 0.4131
1/01-12/05	24,36	-0.191*** (.069)	-0.187*** (.066)	-0.179*** (.051)	-0.203*** (.047)	-0.142** (.055)
		1020; 0.4864	1337; 0.4862	1534; 0.4700	1824; 0.4541	2054; 0.4356
1/99-4/05	48,28	-0.115* (.061)	-0.123** (.054)	-0.120** (.048)	-0.128*** (.039)	-0.050 (.052)
		1260; .4855	1573; 0.4844	1827; 0.4635	2201; 0.4484	2471; 0.4303
1/00-4/05	36,28	-0.139* (.069)	-0.141** (.063)	-0.126** (.052)	-0.137*** (.043)	-0.060 (.053)
		1052; 0.4849	1329; 0.4768	1543; 0.4547	1846; 0.4430	2078; 0.4298
1/01-4/05	24,28	-0.202*** (.056)	-0.249*** (.077)	-0.210*** (.064)	-0.222*** (.058)	-0.130 (.077)
		797; 0.5146	1024; 0.4918	1186; 0.4735	1409; 0.4637	1594; 0.4485

Note to table: see previous table

A number of other robustness checks are implemented. We have repeated the estimations underlying Table 1 and 2 with inclusion of covariates, notably (relative) per capita gross income,

(the sum of market pairs) population density and (relative) rainfall. Estimated impacts are very similar to the ones reported in Table 1 and 2, and in a substantial number of instances statistical significance of impacts improves (selected estimations are reported in the Appendix). Apparently the covariates are either independent of the intervention variable or well captured by the set of fixed effects applied in the basic estimations (or both). The performance of covariates themselves is mixed. In a few estimations coefficients of covariates are fully well-behaved in terms of statistical significance and expected signs of coefficients, in some estimations coefficients are partially well behaved, but also not well-behaved coefficients are generated. We attribute this to measurements error in the construction of covariates and / or interaction of covariates with fixed effects. We will not further pursue this issue in this study¹⁶.

Finally, we have re-run the estimations with a smaller / larger number of intervention locations (see previous section). The outcome of this exercise shows that the estimated impact remains more or less the same with a smaller number of intervention points, but deteriorates substantially with a larger number of intervention points. In the case of groundnuts only estimations with intervention location less than 10 km from a railway station, generated sensible results.

Alternative explanations and potential threats

As the railway track in Malawi was not randomly constructed, outcomes may be the result of differences in markets already existing and not related to the railway line. For this reason – as is standard in similar type of exercises – we need to show that variables have similar means and distributions before the intervention. Table 3 shows the differences in unconditional means and

¹⁶ By omitting selected observations (less than 1% of the sample size) it appeared feasible to squeeze well-behaved coefficients for covariates out of the estimations. We verified this for selected specifications for each commodity in order to be sure that the covariates are sensible determinants of price dispersion.

distributions for the outcomes and covariates outside the intervention period (January 2003 to April 2005).

The statistics in the table reveal a mixed picture and are not completely supportive to the objective of this exercise. Most means tests of the variables outside the intervention period are indeterminate. With the exception of population density we both cannot confirm that means are statistically the same, nor can we confirm that these means are statistically different. Quite a number of distribution tests suggest that distributions are different. But how surprising is this? The railway line is constructed, ages ago in colonial times, connecting main towns and cities, where major economic activities were taking place. Cheap railway transport has created opportunities and has induced (and still induces) further economic activity. This all is likely to be different for places *not* located along the railway line. In view of this, the outcome reported in Table 3 is not strange. Although we hoped for another test result, such a test result would be too good to be true, a knife-edge outcome and odd to expect. In fact, one should be somewhat suspicious if tests suggest equality of pre-intervention variables in similar natural experiment contexts. Does it mean we need to discard the whole previous exercise? The impact estimations should still be valid, as long as we can adequately condition the variation in price level and dispersion on relevant covariates. This brings us back to the estimations reported in Table 1 and 2.

Table 3 Comparison of treated and untreated observables outside the intervention period*

	unconditional mean (SE)		difference in means	diff. in distributions	
	connected by rail	not connected by rail	F test (p-value)	D-statistic	p-value
market pair data					
maize price:	4.096	4.338	F(1,75): 0.51	0.0466	0.801
p _j -p _k	(0.252)	(0.228)	(0.4770)		
rice price:	16.474	17.774	F(1,212): 0.47	0.0515	0.410
p _j -p _k	(1.642)	(0.964)	(0.4964)		
groundnuts price:	41.697	45.797	F(1,103):0.43	0.1433	0.027
p _j -p _k	(5.960)	(1.982)	(0.5154)		
beans price:	34.665	36.706	F(1,75): 0.29	0.0475	0.177
p _j -p _k	(3.322)	(1.888)	(0.5948)		
distance	4.568	4.550	F(1,121): 0.03	0.0935	0.000
dist _{jk}	(0.101)	(0.049)	(0.8719)		
rainfall:	0.178	0.190	F(1,121): 0.38	0.1073	0.000
rf _j -rf _k	(0.017)	(0.010)	(0.5393)		
population density:	10.706	10.176	F(1,21): 8.97	0.3162	0.000
pd _j +pd _k	(0.156)	(0.082)	(0.0033)		
pc gross income:	0.570	0.501	F(1,121): 0.55	0.1892	0.000
gi _j -gi _k	(0.086)	(0.037)	(0.4611)		
market data					
maize price:	3.180	3.152	F(1,26):0.55	0.1069	0.107
p _j	(0.0189)	(0.032)	(0.4662)		
rice price:	4.507	4.557	F(1,26): 1.19	0.1039	0.130
p _j	(0.036)	(0.028)	(0.2852)		
groundnuts price:	4.865	4.844	F(1,26): 0.06	0.0829	0.460
p _j	(0.072)	(0.0500)	(0.8074)		
beans price:	4.795	4.751	F(1,26): 0.30	0.1445	0.011
p _j	(0.054)	(0.057)	(0.5855)		
rainfall:	-.0353	0.004	F(1,26): 0.85	0.2303	0.000
rf _j	(0.036)	(0.022)	(0.3652)		
population density:	5.407	4.828	F(1,26):5.95	0.4826	0.000
pd _j	(0.206)	(0.117)	(0.0219)		
pc gross income:	6.913	6.817	F(1,26): 0.29	0.1913	0.0000
gi _j	(0.152)	(0.095)	(0.5957)		

* Outside the intervention period means from January 2003 to April 2005. Market pairs “connected by rail” are market pairs where *both* markets are located within a distance of 20 km from a railway station. Market pairs “not connected by rail” are market pairs of which at least one market is located more than 20 km away from a railway station. The number of markets is 27 and hence the (potential) number of market pairs 351, but practically much less due to maximum trading distance. Robust standard errors are clustered by market pairs (upper panel) or markets (lower panel). Prices are deflated with the rural consumer price index (source: National Statistical Office, Zomba, Malawi).

6. Summary and conclusion

In this study we have measured the impact of railway services on the dispersion of market prices of agricultural commodities in Malawi. For this purpose we have exploited the quasi experimental design of the nearly total collapse of domestic trade by rail in January 2003, due to the destruction of a railway bridge at Rivirivi, Balaka. Estimations are based on monthly market prices of four agricultural commodities (maize, groundnuts, rice and beans), in 27 local markets, for the period 1998-2006. The measured impact varies from a reduction in price dispersion of 11% to 14% in the short run, to 14% and 18% in the long run. Perishable and low value crops (respectively beans and maize) tend to be traded over smaller distances, and storable high value crops over larger distances (rice and groundnuts). There is some support for a relatively larger impact on perishable commodities (beans) reflecting the limited scope for intertemporal arbitrage. Results depend critically on the maximum distance between market pairs, the period included before and after the collapse and which markets are assumed to be connected by rail. Estimations are robust for including covariates that reflect local demand and supply conditions and trade opportunities.

References

- Aker, J.C., 2010, 'Information for Markets Near and Far: Mobile Phones and Agricultural Markets in Niger', *American Economic Journal: Applied Economics*, 2 (July), 46-59.
- Donaldson, D., 2010, 'Railroads of the Raj: Estimating the Impact of Transportation Infrastructure', Asia Research Centre, Working Paper 41 (also forthcoming in *American Economic Review*).
- Fafchamps, M. E. Gabre-Madhin and B. Minten, 2005, 'Increasing Returns and Market Efficiency in Agricultural Trade', *Journal of Development Economics*, 78, 406-442.
- Fafchamps, M. and R. Vargas-Hill, 2005, 'Selling at the Farmgate or Travelling to the Market', *American Journal of Agricultural Economics*, 87, 3, August, 717-734.
- Fafchamps, M. and B. Minten, 2012, 'Impact of SMS-Based Agricultural Information on Indian Farmers', *World Bank Economic Review*, 27, February, 1-32.
- Fafchamps, M. and J.C.Aker, 2014, 'Mobile Phone Coverage and Producer Markets: Evidence from West Africa', *World Bank Economic Review*, Advance Access published October 8, 2014, 1-31.
- Gabre-Madhin, E., M. Fafchamps, R. Kachule, B. Goura Soule and Z. Kahn, 2001, Volume 2, 'Impact of Agricultural Market Reforms on Smallholder Farmers in Benin and Malawi', report prepared for the Deutsche Gesellschaft Für Technische Zusammenarbeit (GTZ).
- Goyal, A., 2010, 'Information, Direct Access to Farmers and Rural Market Performance in Central India', *American Economic Journal: Applied Economics*, 2 (July), 22-45.
- Jedwab, R. and A.Moradi, 2015, 'The Permanent Effects of Transportation Revolutions in Poor Countries: Evidence from Africa', *Review of Economics and Statistics*, forthcoming.
- Jedwab, R., E. Kerby and A.Moradi, 2014, 'History, Path Dependence and Development:

- Evidence from Colonial Railroads, Settlers and Cities in Kenya', mimeo.
- Jacoby, H.G., 2000, 'Access to Markets and the Benefits of Rural Roads', *The Economic Journal*, 110, 713-737.
- Jacoby, H.G. and B. Minten, 2008, 'On measuring the Benefits of Lower Transport Costs', World Bank, Policy Research Working Paper 4484.
- De Janvry, A. And E. Sadoulet, 2010, 'Agriculture for Development in Africa: Business-as Usual or New Departures', *Journal of African Economies*, 19, AERC, Sup. 2, ii7-ii39.
- Jensen, R., 2007, 'The Digital Divide: Information (Technology), Market Performance, and Welfare in the South Indian Fisheries Sector', *Quarterly Journal of Economics*, 72, 3, 879-924.
- Kaminski, J., L. Christiaensen and C.L. Gilbert, C.L, 2014, 'The End of Seasonality? New Insights from Sub-Saharan Africa', *World Bank*, Policy Research Working Paper 6907.
- Kherallah, M, N. Minot, R. Kachule, B. Goura Soule, P. Berry, 2001, Volume 1, 'Impact of Agricultural Market Reforms on Smallholder Farmers in Benin and Malawi', report prepared for the Deutsche Gesellschaft Für Technische Zusammenarbeit (GTZ).
- Leemput, E. van, 2014, 'A passage to India: Quantifying Internal and External Barriers to Trade', working paper.
- Michaels, G., 2008, 'The Effect of Trade on the Demand for Skill: Evidence from the Interstate Highway System', *Review of Economics and Statistics*, 90, 4, 683-701
- Millennium Challenge Corporation, 'Millennium Challenge Corporation: Malawi Compact Program Development (2011 – 2016), Project Concept Paper For The Transport Sector: Promoting Economic Growth And Poverty Reduction Through Addressing Transport Infrastructure Constraints In Malawi', Millennium Challenge Account - Malawi Country

- Office Secretariat (website www.mca-m.gov.mw/index.php/concept-papers, accessed September 2013).
- Minten, B. and S. Kyle, 1999, 'The effect of Distance and Road Quality on Food Collection, Marketing Margins, and Traders' Wages: Evidence from the Former Zaire', *Journal of Development Economics*, 60, 467-495.
- Muto, M. and T. Yamano, 2009, 'The Impact of Mobile Phone Coverage Expansion on Market Participation: Panel Data Evidence from Uganda', *World Development*, 37, 12, 1887-1896.
- Yamauchi, F. , 2014, 'Roads, Labour Markets, and Human Capital, Evidence from Rural Indonesia', World Bank Policy Research Working Paper 7139.
- Yamauchi, F., M. Muto, S. Chowdurry, R.Dewina and S.Sumaryanto, 2011, 'Are Schooling and Roads Complementary? Evidence from Income Dynamics in Rural Indonesia', *World Development*, 39, 12, 2232-2244.
- Zant, W., 2012, 'The economics of food aid under subsistence farming with an application to Malawi', *Food Policy*, 37, 1, 124-141.
- Zant, W., 2013, 'How is the Liberalization of Food Markets Progressing? Market Integration and Transaction Costs in Subsistence Economies', *World Bank Economic Review*, 2013, 27, 1, January, 28-54.
- Zant, W., 2014, 'How does Market Access affect Smallholder Behavior? The Case of Tobacco Marketing in Malawi', *Tinbergen Institute*, Discussion Paper 12-088/V.

APPENDICES

Appendix 1 Railways and markets

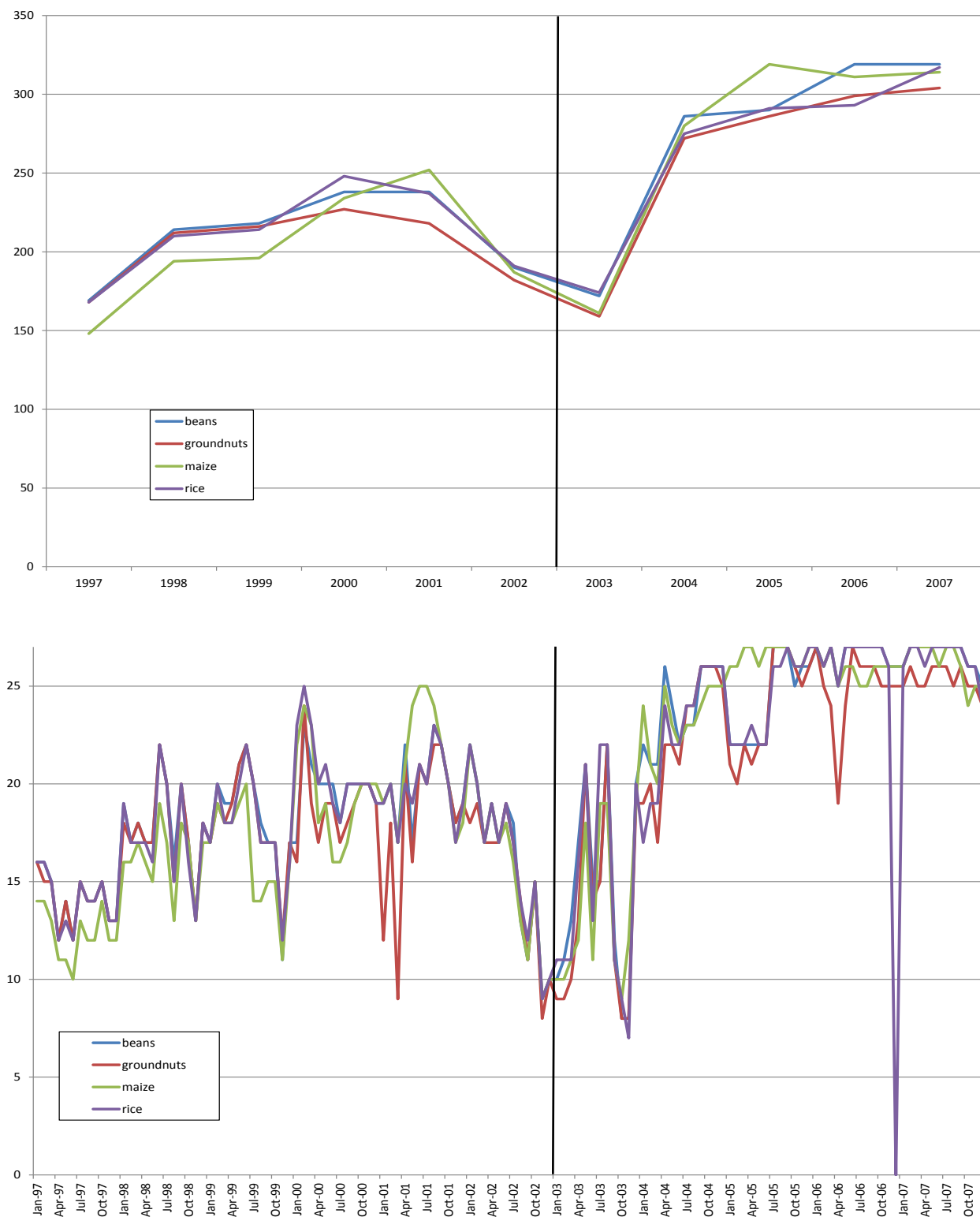
Figure A1 Malawi railway network and selected agricultural markets



Source: VU SPINlab; Note to Figure: the asterisk on the map indicates the railway bridge at Rivirivi, Balaka

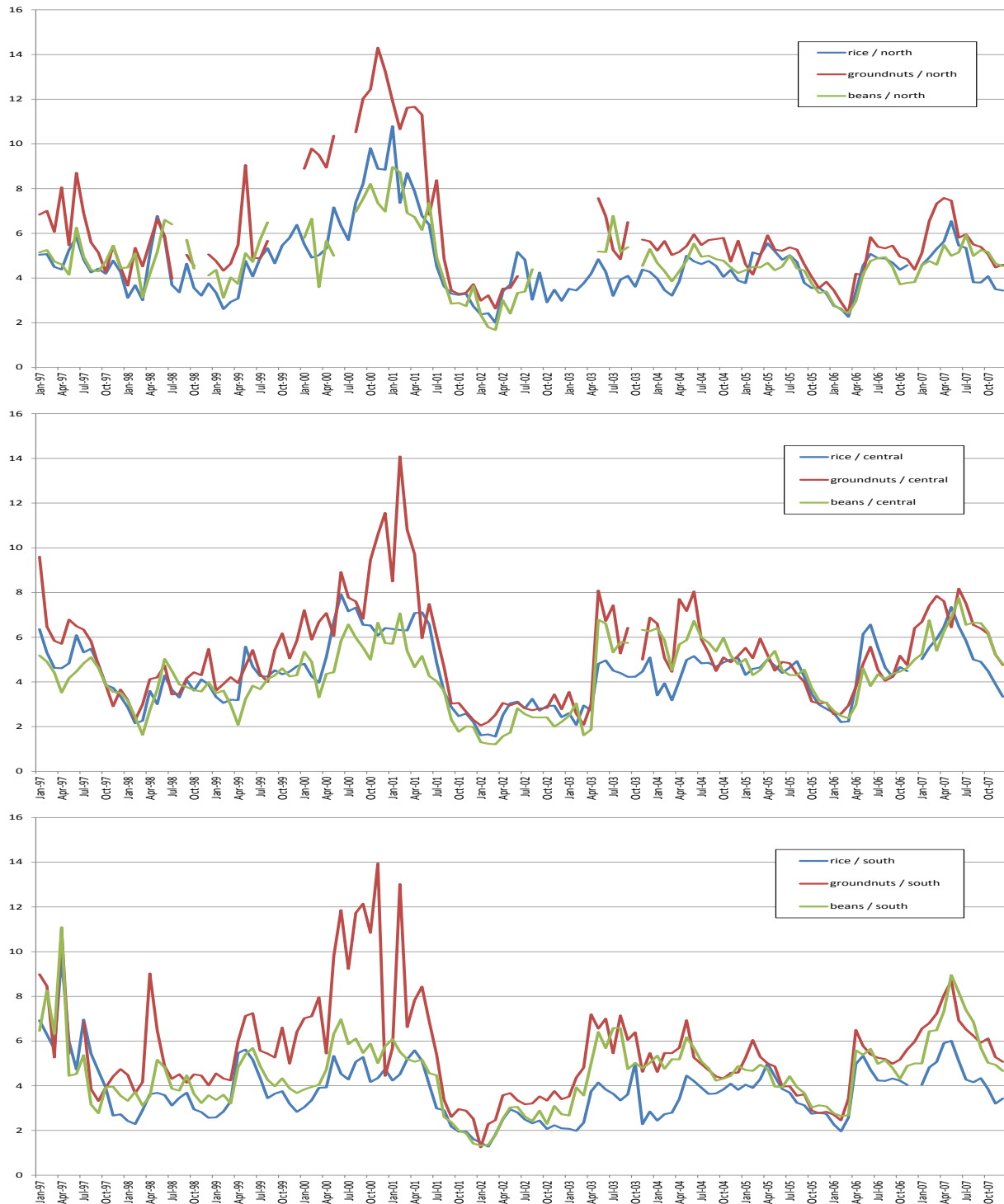
Appendix 2 Availability of market price data of agricultural commodities (27 markets)

Figure A2 Number of market price observations per year (upper) and per month (lower)



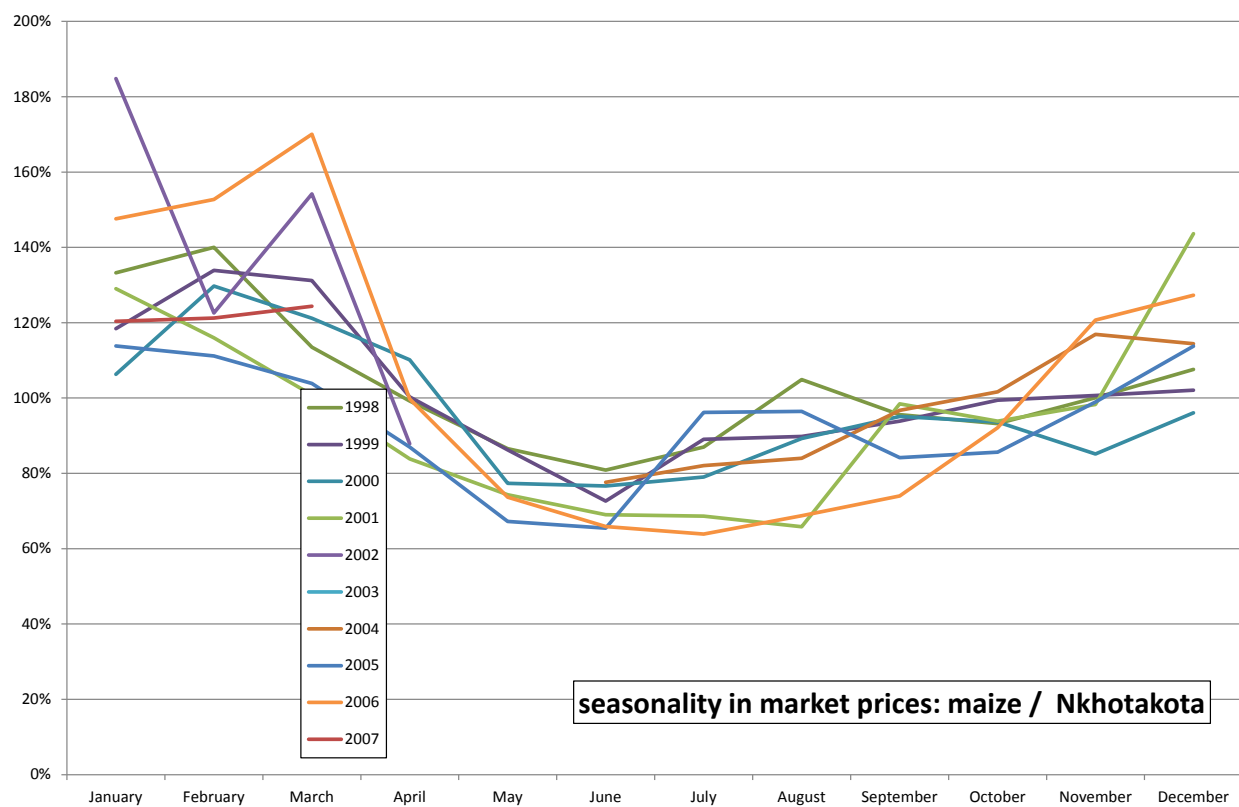
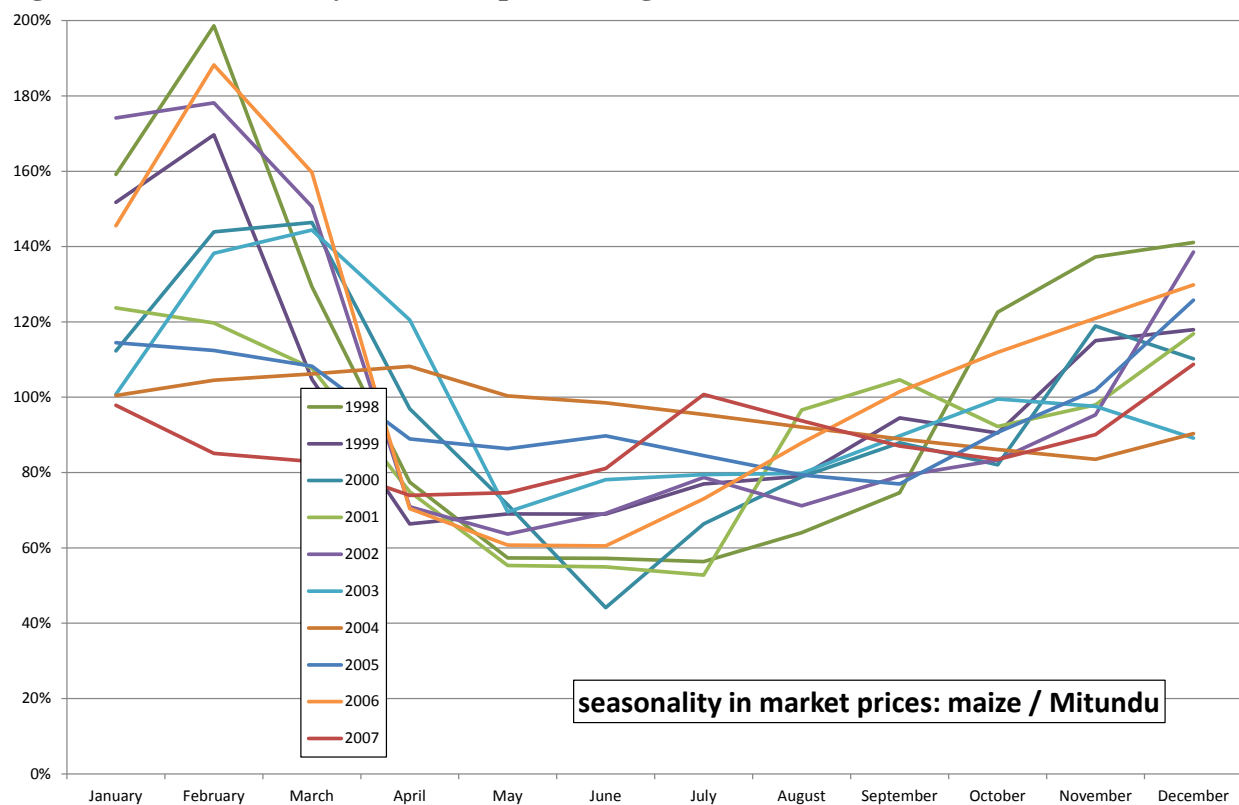
Appendix 3 Prices of agricultural commodities

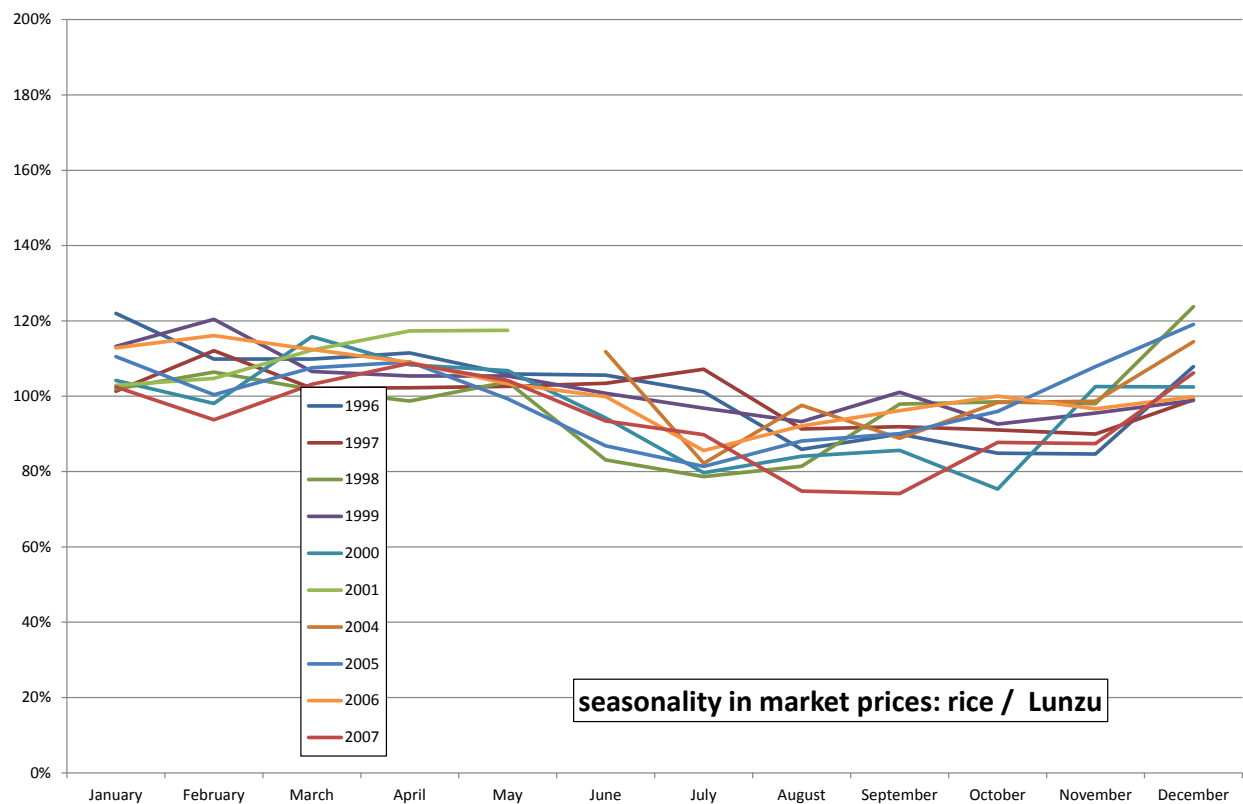
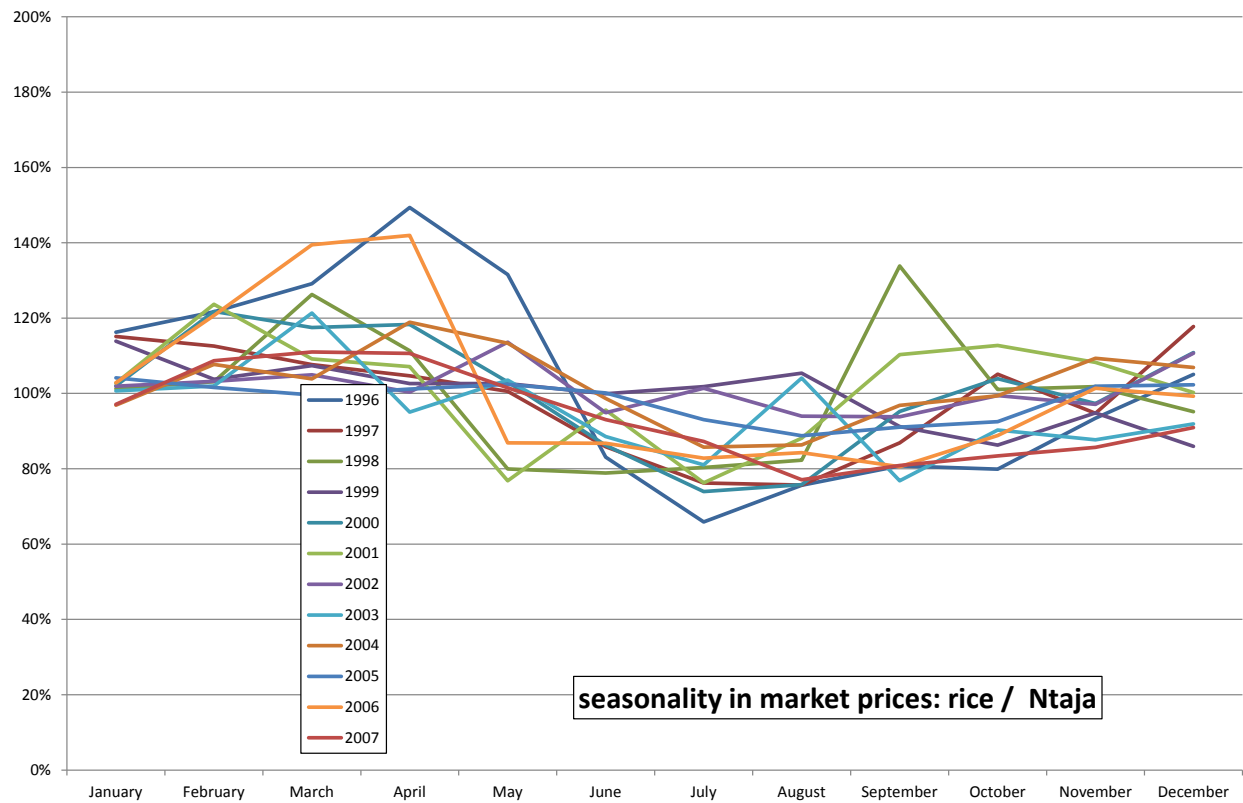
Figure A3 Rice, groundnuts and bean prices relative to maize prices

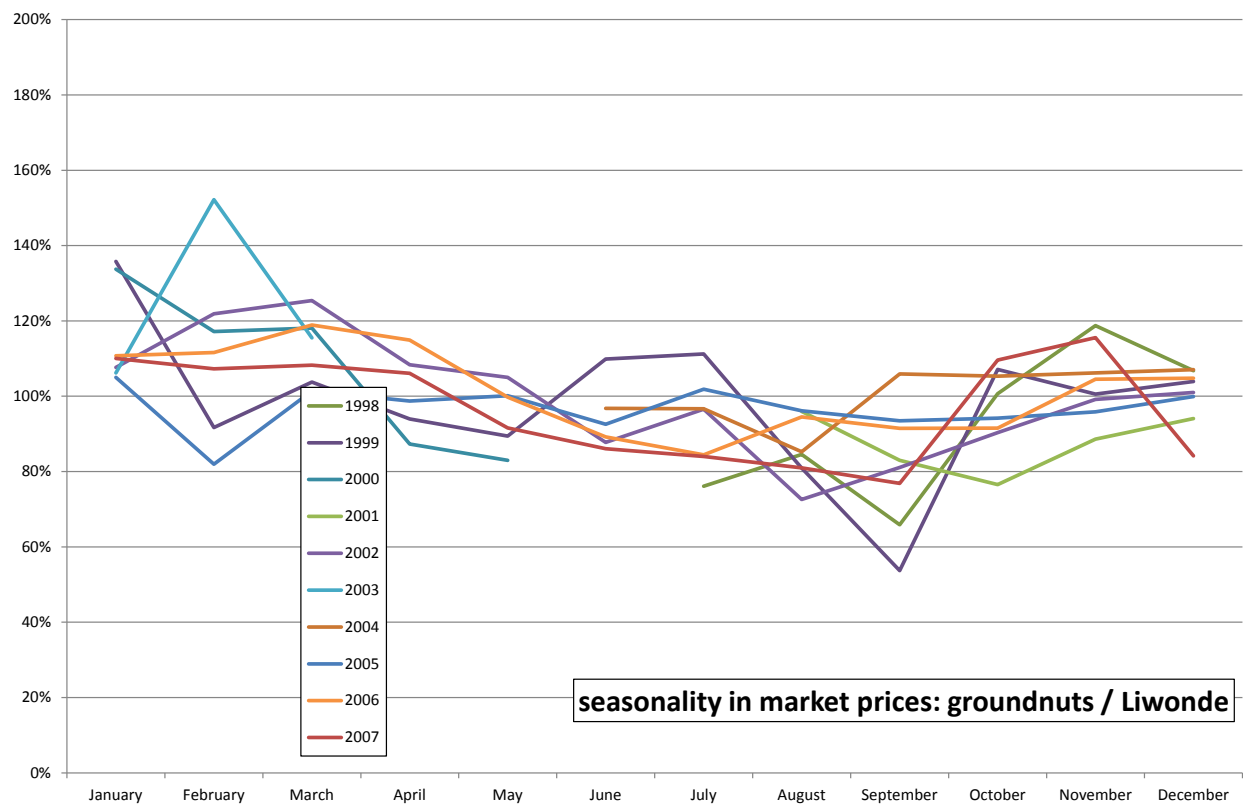
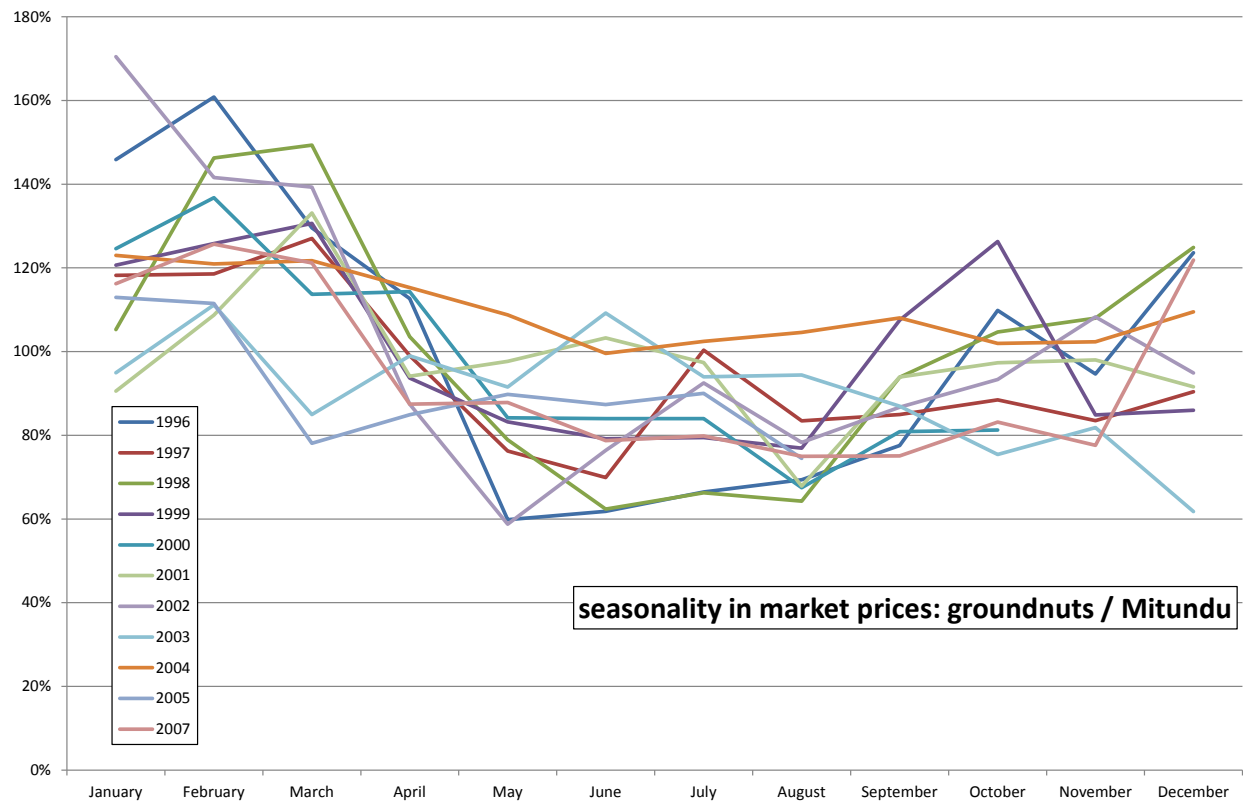


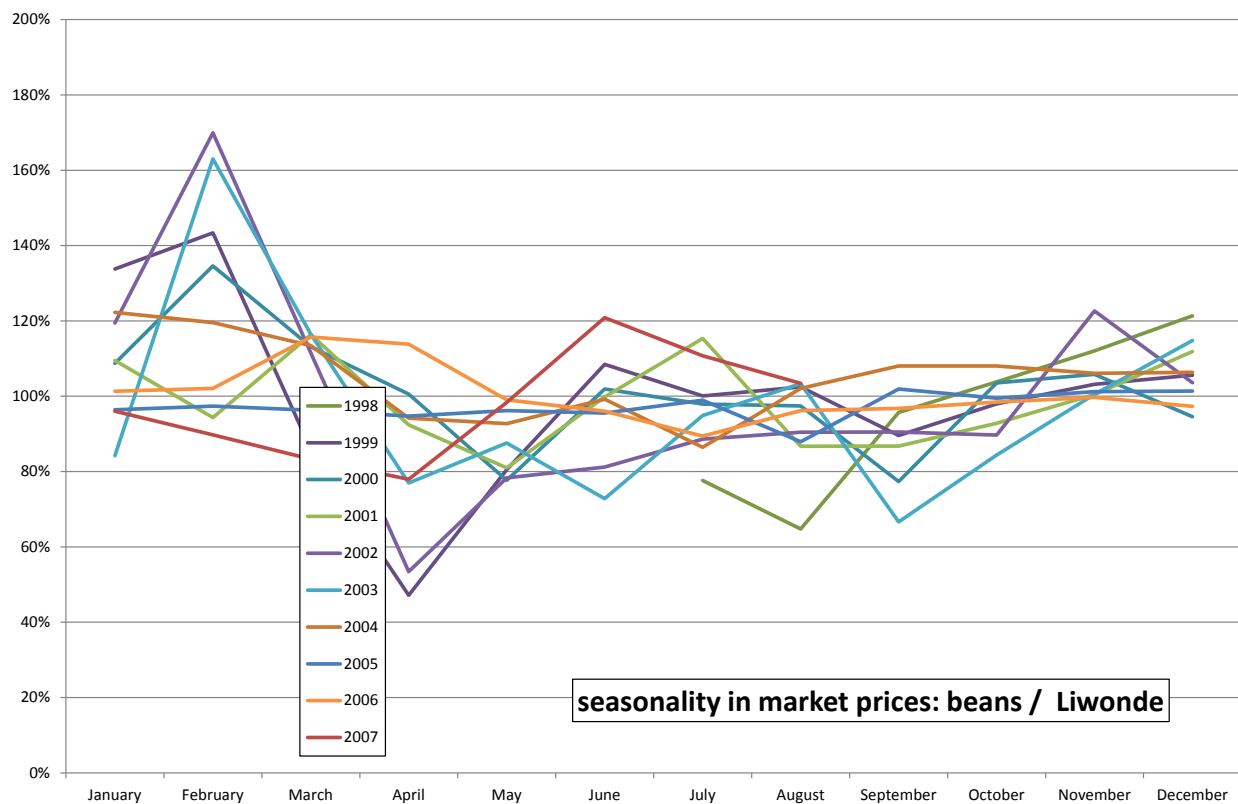
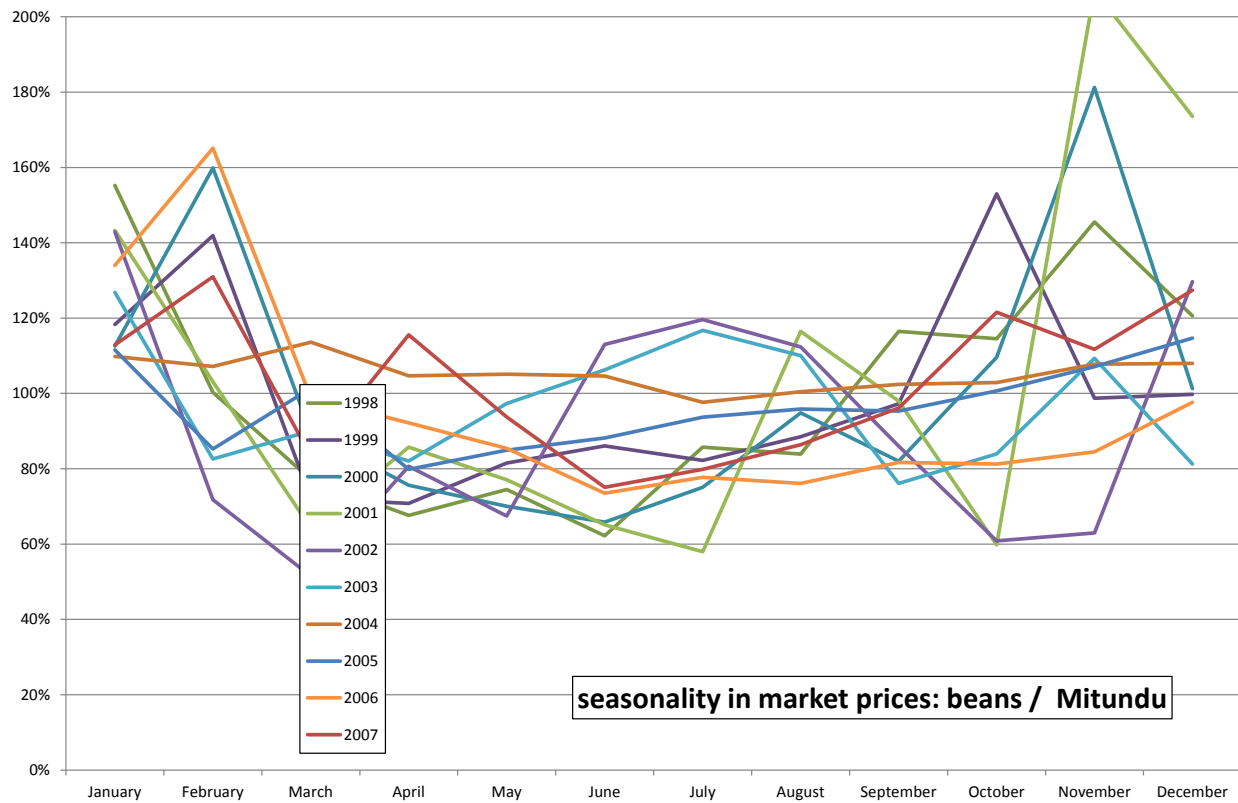
Note to figure: monthly price series of rice, groundnuts and beans are expressed relative to maize prices, for each month and each market and these relative prices are averaged over all markets.

Figure A4 Seasonality of market prices of agricultural commodities









Appendix 4 Geographical distribution of crop production

Figure A6 Per capita production by district (averages of annuals 1995/96-2007/08)

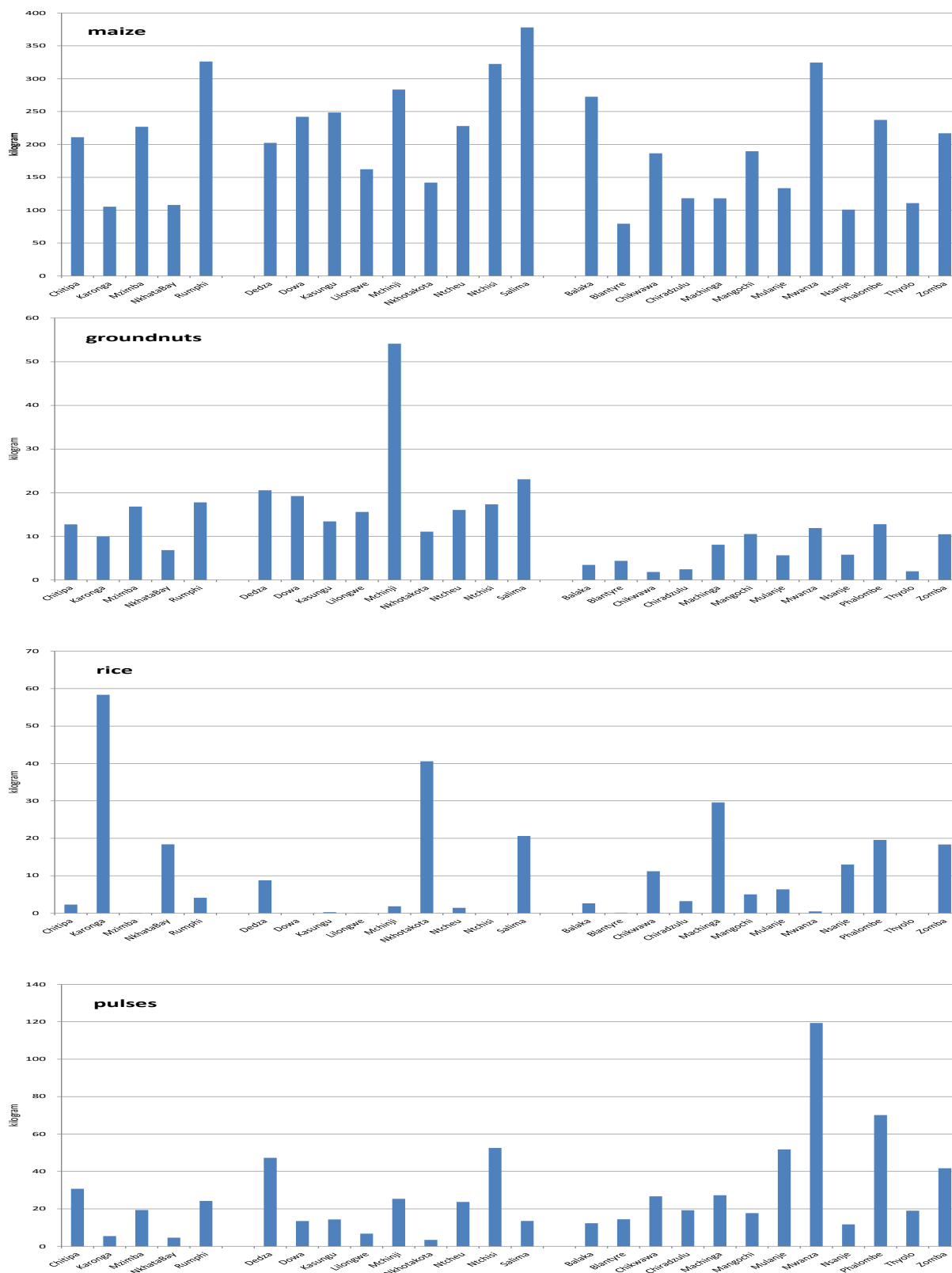
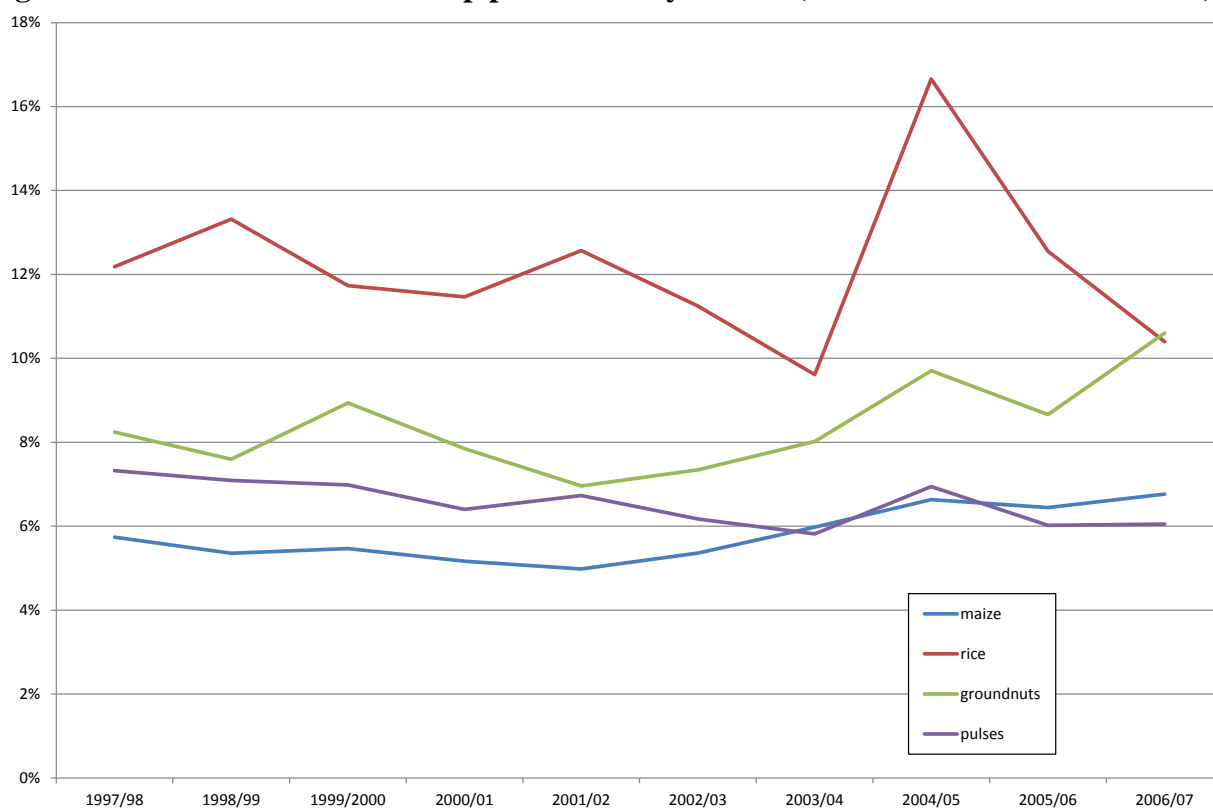


Figure A7 Concentration of crop production by district (Hirschman-Herfindhal index)



Appendix 5 Markets: location names, district, coordinates and distance to railway station

market	district/RDP*	coordinates		distance to nearest railway station
		latitude	longitude	
Chitipa	Chitipa	-9.69958	33.27001	459.6
Karonga	Karonga	-9.93926	33.92713	431.4
Mzimba	Mzimba	-11.8946	33.59682	225.2
Mzuzu	Mzimba	-11.4561	34.01450	263.0
Nkhatabay	Nkhata Bay	-11.6074	34.29762	242.6
Rumphi	Rumphi	-11.0155	33.85760	314.4
Chimbiya	Ntcheu	-15.0822	34.58972	39.5
Dowa	Dowa	-13.6532	33.93434	32.1
Kasungu	Kasungu	-13.0332	33.48348	104.4
Lilongwe	Lilongwe	-13.9810	33.78668	5.8
Lizulu	Ntcheu	-14.4377	34.42248	19.3
Mchinji	Mchinji	-13.7998	32.88052	1.6
Mitundu	Lilongwe	-14.2418	33.77091	24.4
Nkhotakota	Nkhotakota	-12.9254	34.28384	96.8
Ntchisi	Ntchisi	-13.3761	33.86522	63.8
Salima	Salima	-13.7796	34.45818	2.7
Bangula	Nsanje	-16.5817	35.11641	4.0
Limbe	Blantyre	-15.8082	35.05741	1.2
Liwonde	Machinga	-15.0662	35.23374	0.2
Luchenza	Thyolo	-16.0018	35.30928	0.7
Lunzu	Blantyre	-15.6515	35.02027	3.4
Mangochi	Mangochi	-14.4777	35.26370	57.5
Namwera	Mangochi	-14.3449	35.48377	72.2
Nchalo	Chikwawa	-16.2727	34.86774	40.5
Nsanje	Nsanje	-16.9213	35.26095	22.6
Ntaja	Machinga	-14.8667	35.52608	16.9
Zomba	Zomba	-15.3805	35.33286	27.0

Note to table: RDP = Rural Development Project; Source: own calculations using lat-lon coordinates from www.geonames.org. Distance Nsanja-railway station = distance Nasanje to Tengani station, which is the nearest station.

Appendix 6 Estimation including covariates

Table A6-1 Impact (ATE) of rail transport services on market prices: selected output

dependent variable: $\ln(\text{abs}(p_{it}-p_{kt}))$				
crop / commodity	(1) maize	(2) rice	(3) groundnuts	(4) beans
connected by rail	-0.107*** (0.0393)	-0.123*** (0.0455)	-0.118** (0.0457)	-0.137*** (0.0416)
lagged dependent variable (t-1)	0.223*** (0.0320)	0.133*** (0.0237)	0.2885*** (0.0199)	0.225*** (0.0398)
lagged dependent variable (t-2)		0.093*** (0.0251)		
$\ln(\text{distance})$	6.668 (32.23)	8.713** (3.356)	0.022 (0.1381)	0.174 (0.2845)
season x market dummies	yes	yes	yes	yes
time trend x market dummies	yes	yes	yes	yes
market pair dummies	yes	yes	yes	yes
year dummies	yes	yes	yes	yes
covariates	yes	yes	yes	yes
R^2	0.3726	0.4069	0.3895	0.4438
max trading distance (km)	110	160	140	110
sample period	1/00-4/05	1/99-12/04	1/99-12/04	1/00-4/05
months before 1/03 and after 12/02	36; 28	48; 24	48; 24	36; 28
number of observations	1826	2494	2684	1846
no. of intervention pairs	196	366	152	189
no. of control pairs connected by rail	161	121	58	136
no. of other controls (not connected)	1469	2007	2474	1521
long term impact	-0.138	-0.172	-0.166	-0.177

Note to table: *connected by rail* has the value $\ln(\text{distance})$ if both markets are less than 20km away from a railway station, while the railway was operational, and zero elsewhere (in case of groundnuts less than 10km). Prices are deflated with the rural consumer price index (source: National Statistical Office, Zomba, Malawi). Covariates are (the difference across markets) of rainfall, population density and per capita gross real income. Robust standard errors in parentheses below the coefficient are clustered by market pairs. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The long term effect is calculated as $\beta_2/(1 - \beta_1)$ (see regression model above).