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## Local demand, urbanization and Amazonian Metropolitan Regions impacts on deforestation of the Brazilian Amazon

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# **Local Demand, Urbanization and Amazonian Metropolitan Regions Impacts on Deforestation of the Brazilian Amazon**

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## **Abstract**

The paper estimates how much of the amazon deforestation is due to the consumption of goods and services from households who live within the amazon region itself, comparing it to deforestation driven by consumers who live outside amazon. As the Brazilian Amazon contains 5 big metropolitan regions, and in order to take into account this referred urbanization process, it not only compare the effects of demand from within and outside Brazilian Amazon, but also with the isolated effects from consumption of households who live within the metropolitan areas of Brazilian Amazon from the consumption of families who live within Amazon, but outside those metropolitan regions. Using an inter-regional input-output model with socioeconomic data, and crossing this database with information on land use transition from forest areas to agricultural and livestock land use, it finds robust evidence that these local demand vectors play an important role in terms of the deforestation they drive. Results show that even though local population from the Amazon region represents only 13% of total Brazilian population, it drives around 30% of the total deforestation taking place

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within the region, through its direct and indirect consumption of the output produced in forest areas. The demand from families who live within the Amazonia metropolitan regions is responsible for more than a half of this 30%, even though only 25% of Amazon population live in these areas. In per capita terms, results also show that the demand from one individual living within the Amazon region, but outside the metropolitan areas, generates 2.2 more deforestation than the consumption vector of one individual living outside Amazon, but within Brazil. For the consumption vector of one individual living within the Amazon metropolitan regions, the deforestation impact is even higher, it is 7.7 times the impact of the demand from one individual living outside Brazilian Amazon. The results concerning the economic multipliers and generators, as well as the ones focusing only on the output per sector driven by each regional demand vector also point to this same direction. Therefore, these results bring evidence that support the theoretical expectations from spatial economics that local demand and the urbanization process taking place within Brazilian Amazon play an important role in terms of the deforestation it might cause.

## 1 INTRODUCTION

Preservation of the Brazilian Amazon rainforest is certainly one of the most important topics discussed at the global environmental agenda in the last decade. Several aspects lead to its importance. First, recent analysts found evidence supporting that the Amazonian deforestation process is highly correlated to global warming and climate change. Imori et al. (2011), for example, use an Input-Output model, based on national data disaggregated into regions, to show that deforestation in the Brazilian Amazon is responsible for about 58% of total greenhouse gas emissions in Brazil, and about 2% of total global emissions, for the year of 2004. Second, still concerning the environmental aspect, as the Amazon rainforest is the largest remaining tropical forest in the globe, with a big share still untouched by humanity, it holds an immeasurable biodiversity, whose conservation is undoubtedly fundamental to global ecological equilibrium.

Economically, the region hosts most of the agricultural and cattle-raising frontiers in Brazil, providing strong capital-intensive cultivation of soybeans, whose exports have been boosting surpluses in the Brazilian trade balance in recent years (Morton et al. 2006; Vera-Diaz et al. 2009). Politically, it is considered an area of extreme strategic importance, due to the high concentration of natural resources, especially because of its huge potential for the mining of various kinds of minerals. An example of this political importance is the recent debate about the political establishment of a new state, called Carajás, which would split the State of Pará into two parts. This was seen by many as a political maneuver coming from large mining companies installed on site, seeking higher tax liens and other greater political advantages.

Given such economic and ecological complexity, recent analysts have been showing much evidence concerning the main drivers of deforestation in the region, and how to avoid it without compromising the region's economic development. In this regard, numerous studies indicate that the two main drivers of deforestation are the expansion of grains agriculture and pasture for livestock in recent years (see, e.g., Morton et al., 2006; Vera-Diaz et al., 2009). Project Catalyst (2008) points out that the main drivers of deforestation in South America are pastures for cattle raising (65%), subsistence agriculture (31%), forestry (3%) and intensive agriculture (1%). Chomitz & Thomas (2003), in turn, use a different approach, and find that natural weather conditions also contribute to deforestation. Specifically, they find that rainfall regimes tend to determine land use in the Amazon, and conclude that drier areas tend to be more rapidly deforested, especially due to the ease of using fire to clear the land for pastures.

Most of the time, analysts such as the ones cited above share a common feature: in economic terms, they mainly try to explain deforestation focusing on the “supply side” variables of the market. In other words, they base their conclusions and evidence on analyzing directly land-use transformation from forest regions into agricultural cultures or pastures; which techniques are employed in forest management practices; how local producers react to environmental policies and tax incentives for land occupation; or how such deforestation varies with changes in local infrastructure, and so on (see, eg, Walker et al. 2000; Binswanger 1991, Iglioni et al. 2009b).

However, despite making very important contributions, such studies, by themselves, might be considered incomplete because they lack analyzing effects from the “demand side” of economy. In other words, we may not be able to determine how

to deal with pressures that economic development exerts on the forest, without understanding how different regional demand vectors tend to push production among industries that practice deforestation. Or even, from a very simplistic point of view, it seems very important to measure and consider where and who is consuming the output produced in previously forested areas, because these seem to be, from a microeconomic perspective, the most basic economical determinants that motivate and drive deforestation and land-use change resulting from producers seeking to maximize profits and explore market demands.

These “demand-side” drivers become even more important if we take into account the demographic process that the region is currently experiencing. Findings based on IBGE census data indicate a large and growing process of urbanization taking place in the Brazilian Amazon in recent decades. Within the region, there are 5 major metropolitan areas, which currently account for nearly 30% of the total population of the Amazon. In these metropolitan areas, there are 3 major cities with over 1 million inhabitants, Manaus being the largest one, with 1.8 million inhabitants in 2010. Manaus is also the city that registered the fastest growth among the ten largest Brazilian cities between 2000 and 2010. Regarding the region’s composition, urbanization becomes evident: according to IBGE census data, the share of the population living in urban areas increased from 42% in 1970 to 71% in 2007, i.e., most of the region's population currently lives in urban areas. Moreover, the private services, which are typically concentrated in urban conglomerates, have increased participation in the composition of the region’s GDP from 30% in 1996 to 35% in 2007. As a whole, the Brazilian Amazon population, and consequently its local markets, grew by 29% between 1991 and 2010, a very large number when it comes to a region where currently over 20 million individuals live, especially considering that as a whole, the Brazilian population grew by 12% during the same period . Furthermore, according to the IBGE census database, among the 19 cities whose the population doubled in the last decade, ten are located in the Brazilian Amazon. Given this evidence of recent local demography changes in Brazilian Amazon, it seems urgent that analysts consider these “demand side” effects as soon as possible, especially in terms of the local land-use change that the growth of local demand associated with this urbanization process might bring.

From a theoretical perspective, economic theorists leave no doubt about the importance of the role played by these “demand side” effects in terms of land-use practice and decisions, i.e., over one region’s deforestation. Several theoretical models from Urban Economics, New Economic Geography, and Spatial Economics (see (Anselin (1988); Von Thünen (1826); Hotelling (1931); Gleaser (2008); Krugman (1991); Fujita & Thisse (2002); Igliori, (2009a)) indicate very clearly that when it comes to the matter of analyzing land-use dynamics, location decisions always take into account two fundamental determinants: the size of relevant markets, in terms of number of consumers; and the distance that those markets are from the productive units. Walker and Homma (1996), for example, when analyzing the contribution of these models to explain the dynamics of land cover by different industries, clearly conclude that the dynamics in one region is closely linked to transportation costs of disposing output and buying inputs, as well as to the development of local markets vis a vis exports to more distant ones.

From an environmental perspective, these models can be interpreted as suggesting that larger markets should impose greater impacts on deforestation in a given region by replacing forest coverage with land use for productive activities

designed to meet such demand. However, these models also indicate and recognize that markets located closer to the forest, even if smaller in terms of number of consumers, should also impose a significant impact on deforestation, due to the lower transportation costs of selling these goods locally instead of exporting farther (Igliori 2009a). In a simple perspective, this implies that it might be possible that smaller but closer markets may exert a deforestation pressure as big as, or even higher than, larger but farther markets.

Moreover, urban economics modelers also argue that not only distance and transportation costs play an important role on determining these demand-side effects over land use, but urbanization rates taking place in different markets matter as well. Their main argument is that an urbanization process brings with it an increase in the population's consumption pattern, not only because of the greater proximity to markets and reduced transportation costs for inputs and outputs, but also because of positive shifts in the society's income level associated with higher productivity caused by increasing returns to scale and economies of agglomeration of various types (see, e.g., Fujita et al. 1999; Fujita and Thisse 2002; Gleaser 2008). Also, urbanization by itself already means a major expansion of the construction sector, with increased consumption of steel and other materials, which in turn elevates the natural resources consumption as inputs for this industry.

Ecological Footprint analysts agree with these messages brought by spatial economic analysts. Rees & Wackernagel (1996), for example, use this methodology to conclude that more urbanized areas of the globe exhaust more natural resources than rural areas, due to increased consumption patterns that these urbanized regions present when compared to rural undeveloped areas. A good example of these demand-side impacts over land use associated with urbanization processes are the effects of the strong urbanization process taking place in China in recent years. The expansion of Chinese cities can be held responsible for a great share of the increase in production of several industries around the world, and consequently for the generation of enormous environmental impacts associated with such an expansion, especially in terms of greenhouse gas emissions and consumption of natural resources as inputs for these industries.

With regard to mass media, on the one hand, although such effects of urbanization are still mostly being overlooked, a recent article in the New York Times (December 2012) constitutes one of the rare exceptions to this rule. This article, called "*Swallowing Rain Forest, Amazon Cities Surge In*" points and briefly describes the process of urbanization and population growth that the Amazon faces in recent decades, trying to show the consequences that this may bring in terms of deforestation. Although not an academic study, the authors of the report are clearly concerned about drawing their conclusions based on opinions of the scientific community. As an example, it has a statement by Phillip M. Fearnside, a renowned researcher of the Amazon region, in which he declares that "More population leads to more deforestation".

On the other hand, empirical literature on Brazilian Amazon is very incipient when it comes to this matter of considering the "demand-side" effects of different markets over deforestation in the Brazilian Amazon. Still, we note that there is a general belief, both in the literature and common practice, that Amazonian local markets are unimportant as drivers of deforestation and land-use change in the Brazilian Amazon region, mainly because they represent only a small share of the Brazilian population when compared to the southern regions of the country, and livestock and agricultural

output produced in the Amazon region are assumed to be sold to the big markets in southern Brazil, or even exported to other countries. However, it is important to emphasize that this is a “general belief” that lacks empirical support.

Nevertheless, there are some important exceptions to this rule. One of these very few exceptions is the article from Faminow (1997), in which the author points out that deforestation seems to be occurring simultaneously with large inner regional demographic changes. More specifically, the author shows that in recent decades, the urban population has been growing dramatically in the Brazilian Amazon region (twice as fast as the rest of the country, according to IBGE data), which in turn results in a major expansion of the “local” demand for agricultural and cattle beef outputs coming from local producers. In this sense, the author shows that this increase in local demand for beef has been accompanied by the expansion of pastures for cattle raised inside the region, or, in other words, local demand for cattle is increasingly being supplied by local producers. This local effect, argues the author, results from a structure of high transportation costs of beef imports produced in the rest of the country, which makes cattle raising inside the Brazilian Amazon a relatively profitable activity. Finally, as cattle raising is considered one of the main drivers of deforestation in terms of land use, Faminow (1997) concludes that this local demand has a severe impact in terms of deforestation, but still, for some reason, it is surprisingly being neglected by analysts so far, when it comes to possible explanations of deforestation taking place in the region.

Analysts also shed light on these urbanization and demand effects on deforestation, but usually treating it as a secondary result from the main analysis. Andersen et al. (2002) is one of these exceptions. Using econometric methods and Census data, the authors conclude that the local urban population and GDP growth in the Amazon region are increasingly important in explaining recent patterns of land use and deforestation. Using similar methodology and database, Iglioni (2009) finds that higher levels of local agglomeration (population and economic activity) contribute positively to increased deforestation and economic growth.

Even though these studies bring important contributions and are pioneers in the sense of bringing these local demand and urbanization effects into consideration, analysts still need a more detailed and complete approach to the subject. Besides not having such effects as the main focus in their studies, Andersen et al. (2002) and Iglioni (2009) do not cover the period from 2000 to 2010 in their analysis, because there were no census data pertaining to 2010 at the time of their analysis. And precisely during this period, the urbanization process taking place in Brazilian Amazon intensified. Faminow (1997), in turn, studies only the direct impacts of a single industry, cattle raising, on the local economy, without making any environmental links to deforestation or considering the multiplier effects with respect to other regions or other industries. Moreover, none of these analysts compare the impacts of local markets *vis a vis* foreign markets, in order to give feedback to future policies of land occupation and urbanization of the Brazilian Amazon.

In order to fill this gap in the literature, we attempt to make a contribution. In this paper, we have one main goal: to measure which deforestation and economic impacts are caused by the urbanization and local population growth in the Brazilian Amazon. More specifically, we use a hybrid Input-Output inter-regional model for Brazil, along with land-use transition data, to measure which are the demand driven impacts of the 5 big Metropolitan Regions within the Brazilian Amazon, comparing these results to those driven by the demand from the Rest of the Amazon, which

contains the non-urban share of the region, and also to those driven by the demand from the rest of Brazil and the rest of the world.

We structure this paper as follows. In Section 2, we provide details on the strategy adopted to achieve our goals, and a brief description of the database used. Section 3 provides socioeconomic information and historical background of the Brazilian Amazon. Section 4 describes the methodology, in Section 6 we discuss the results, and in Section 6, we conclude.

## **2 THEORETICAL BACKGROUND**

Before explaining the basic methodology of input-output models we used, we justify why we have chosen this methodology. The main goal of this analysis is to measure the size of the impacts that local demand and urbanization have on deforestation of the region's rainforest, comparing those to the impacts driven by the external demand from the Rest of Brazil and exports. In order to do this, first, we need a methodology that allows us to isolate the demand in the Amazon region and its most densely urbanized areas from the rest of Brazil. Second, in order to measure such impacts correctly, we need to take into account not only the "direct" deforestation caused by output needed to fulfill the final demand, but also the "indirect" deforestation driven by the production of inputs used in the whole production process of such outputs, in each sector and in each region.

The Inter-regional Input-Output Model has these two desirable characteristics. First, it allows us to do such a regional division, isolating the Amazon from the rest of Brazil, and, at the same time, isolating the Metropolitan areas of the Amazon (which, as will be justified later, will be our representation of the urbanization process) from the rest of the Amazon region. Second, the Input-Output methodology also allows us to focus on verifying how the demand from households living within a given region generates output and other positive externalities throughout the production chain of each sector in each region.

As an example, with the Inter-regional Input-Output Model, we can measure the size of the impact of deforestation in the Amazon region that the consumption of clothing accessories produced in São Paulo by households living within the Manaus Metropolitan Area. This is because the inter-regional input-output matrices account for, among other things, the livestock production that is required in the Amazon region to provide inputs to be consumed by the footwear industry in São Paulo. In this sense, the model approach is very similar to the footprint-calculation models (see REES & WALBIRGNE 1996), but with the advantage of being more complete and precise in economic terms.

### ***2.1 The single-region basic Leontief model***

The theoretical basis that adopted in this work is the Input-Output analysis, more specifically, an Inter-Regional model. However, for simplicity reasons, we first introduce a simple model with a single region, expanding this model to a multiple region one.

The Leontief basic model with a single-region methodology is based on a system of simultaneous equations that represent the flows of goods and services between sectors and agents in the economy, with such flows explained by technological and



economic factors (Miller and Blair, 2009). This system can be represented in matrix terms by:

$$X = AX + Y \quad (1)$$

where:

$X$  is a  $(n \times 1)$  vector and represents the total output produced by each of the  $n$  sectors,  $Y$  is a  $(n \times 1)$  vector representing the values of the final demands of families, government, and exports for output of each sector,  $A$  is an  $(n \times n)$  matrix that contains the technical coefficients of production. These coefficients represent, for each sector  $j$ ,  $\forall j \in [1, n]$ , the proportion of inputs that  $j$  bought from each sector  $i$ , in order to produce one additional unit of output  $j$ . Here the first important assumption of input-output models is: these coefficients are assumed to be fixed for any amount of inputs used or output produced, and also regardless of the branch of the supply chain for which the output is being produced.. In other words, we assume constant returns to scale. In the Results Section we discuss what implications this first assumption brings to our results.

Manipulating Equation (1), we get:

$$(I - A)X = Y \quad (2)$$

or

$$X = (I - A)^{-1}Y = BY \quad (3)$$

where

$(I - A)^{-1} = B$ , and  $B$  is the Leontief inverse matrix, also called matrix of direct and indirect coefficients, in which each element,  $b_{ij}$ , represents the total production in sector  $i$  needed to meet a unit of final demand of sector  $j$ , considering the total output needed to fulfill the final demand, and also the inputs used in the intermediate consumption by sector  $j$ .

From the Leontief inverse matrix  $B$ , we can calculate Type 1 multipliers for each sector, which are given by:

$$P_j = \sum_{i=1}^n b_{ij} \quad (4)$$

where  $P_j$  represents the total output generated in all sectors, resulting from an additional unit of final demand of sector  $j$ .

Also from matrix  $B$ , we can calculate the employment, value added, and deforestation, generators for each sector  $i$  of the economy. Here, we use deforestation as an example, but employment and value added generators can be calculated by a very similar procedure. In this sense, we use  $V_i$ , the total amount produced by sector  $i$  in a given year. In order to calculate the deforestation generator for sector  $j$ , we first calculate the deforestation coefficient of sector  $i$ , which is given by:

$$v_i = \frac{V_i}{X_i} \quad (5)$$

Which tells us how much the deforestation sector  $j$  produces directly per monetary unit of output produced. Given this coefficient, we use the Leontief inverse matrix to calculate how much deforestation is generated both directly and indirectly in all sectors, for each additional unit of final demand required by sector  $j$ . In order to do that, we calculate:

$$GV_j = \sum_{i=1}^n b_{ij} v_i \quad (6)$$

where  $GV_j$  is the deforestation generator of sector  $j$ .

One possible extension that can be applied for the multipliers and generators is to incorporate into the input-output system the income that families receive in the production process to fulfill the final demands. These effects are called induced multipliers.

## 2.2 The interregional input-output model

Let us now consider an inter-regional input-output model, which is the one we use in this study. For simplicity, we describe a model with only two regions, L and M, but we emphasize that the extension for a model with  $n$  regions is straightforward and follows the same methodology (see Miller and Blair, 2009).

Thus, consider the matrices and vectors from the basic Leontief model, but now partitioned to represent the two regions, L and M. As Guilhoto (2009) shows, we can write these as follows:

$$A = \begin{bmatrix} A^{LL} & \vdots & A^{LM} \\ \dots & \dots & \dots \\ A^{ML} & \vdots & A^{MM} \end{bmatrix} \quad (7)$$

$$Y = \begin{bmatrix} Y^L \\ \dots \\ Y^M \end{bmatrix} \quad (8)$$

$$X = \begin{bmatrix} X^L \\ \dots \\ X^M \end{bmatrix} \quad (9)$$

where  $A^{ML}$  represents an  $n \times n$  matrix,  $n$  being the number of sectors of the economy. Each element  $a_{ij}^{ML}$  is now the technical coefficient, which represents how much industry  $j$  from region L buys from sector  $i$  in region M,  $\forall i, j \in [1, n]$ . The same interpretation is valid for  $A^{LL}$ ,  $A^{MM}$ ,  $A^{LM}$  and  $a_{ij}^{LL}$ ,  $a_{ij}^{MM}$ ,  $a_{ij}^{LM}$ . Similarly,  $x_j^L$  represents the total output

from sector  $j$  in region L, while  $y_j^L$  represents the final demand vector from sector  $j$  in region L.

Thus, following the same reasoning of the basic Leontief model with a single region, Guilhoto (2009) also shows that we can write the system as:

$$\left\{ \begin{bmatrix} I & \vdots & 0 \\ \dots & \dots & \dots \\ 0 & \vdots & I \end{bmatrix} - \begin{bmatrix} A^{LL} & \vdots & A^{LM} \\ \dots & \dots & \dots \\ A^{ML} & \vdots & A^{MM} \end{bmatrix} \right\} \begin{bmatrix} X^L \\ \dots \\ X^M \end{bmatrix} = \begin{bmatrix} Y^L \\ \dots \\ Y^M \end{bmatrix} \quad (10)$$

Thus,

$$(I - A^{LL})X^L - A^{LM}X^M = Y^L \quad (11)$$

and

$$-A^{ML}X^L - (I - A^{MM})X^M = Y^M \quad (12)$$

Equations 11 and 12 describe the inter-regional input-output system of equations to be estimated. In matrix notation, Miller and Blair (2009) show that this system can be written in the form  $X = BY$ , in which  $X$  and  $Y$  may be rewritten by:

$$B = \begin{bmatrix} B^{LL} & B^{LM} \\ B^{ML} & B^{MM} \end{bmatrix} \quad (13)$$

where  $B$  is the inverse Leontief matrix from the inter-regional input-output system. Again,  $B^{ML}$ ,  $B^{LM}$ ,  $B^{MM}$ ,  $B^{LL}$  are  $n \times n$  matrices,  $n$  being the number of sectors of the economy, and each element  $b_{ij}^{ML}$  represents the amount of output needed to be produced in sector  $i$  from region M to fulfill one unit of final demand from sector  $j$  in region L,  $\forall i, j \in [1, n]$ .

Given the Leontief inverse matrix of the interregional system, Miller and Blair (2009) and Guilhoto (2009) show that it is possible to calculate the multipliers and generators of employment, value added, and deforestation generators similarly to the ones from the basic single region Leontief model already presented.

### 3 STRATEGY AND DATABASE

#### 3.1 Regional division of the interregional input-output system

In order to analyze what are the impacts of the urbanization and local demand growth processes taking place in the Brazilian Amazon in terms of deforestation and also economically, we adopted the following strategy: we built an inter-regional input output model, in which we divided Brazil into 3 regions:

- Region 1: constituted the 5 Metropolitan Regions<sup>2</sup> of the Brazilian Amazon<sup>3</sup>, which are the Cuiabá-Várzea Grande Urban Conglomerate, the Metropolitan Region of Manaus, Macapá Metropolitan Region, the Grande São Luís Metropolitan Region, and the Metropolitan Region of Belém.

- Region 2: Rest of the Brazilian Amazon.

- Region 3: Rest of Brazil.

Figure 1 is a map of these 3 regions. Note that they are not contiguous in geographic terms, for the Metropolitan regions are not neighbors within the Brazilian Amazon, due to the fact that the region occupies a large extended territory, and as such, its population is spread among many different cities.

The reason why we adopted this criterion of division of Brazilian territory between the three chosen regions is straightforward and simple. We hope to measure two types of demand impacts on deforestation: (1) the impacts that local markets exert, i.e., the impacts from the demand of local consumers within the Brazilian Amazon as a whole; (2) the impacts of the urbanization taking place in the Brazilian Amazon. For this reason, we initially split the Brazilian Amazon from the rest of Brazil (Region 3), so we could isolate the vectors of demand for each of these two regions (Amazon vs the Rest of Brazil). Then, in order to isolate the effects urbanization in the Amazon from local rural demand vectors, we split the Brazilian Amazon into two regions: Region 1, which encompasses the Amazonian Metropolitan Regions, and Region 2, which encompasses the rest of the Brazilian Amazon, excluding those metropolitan areas.

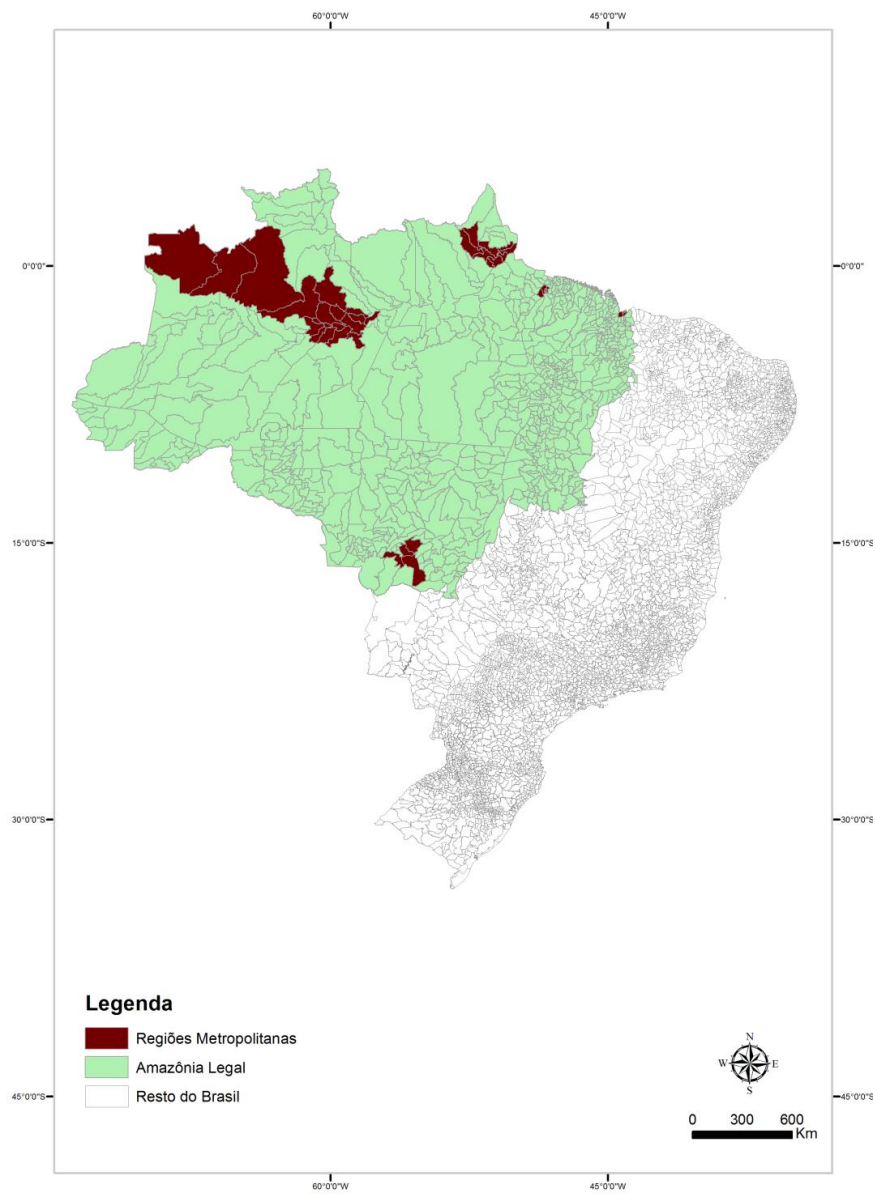
Separating Regions 1 and 2 in order to isolate the effects of urbanization effects was motivated by the fact that metropolitan areas represent the most urbanized areas of the Brazilian Amazon, in addition to being the largest urban conglomerations within the area. This statement can be easily checked using the IBGE 2010 Census, by which we calculated that 90.4% of the population of Region 1 live within the urban areas of the municipalities, while in the Rest of the Amazon (Region 2), this percentage is only around 60%. Moreover, in 2010, more than 6 million inhabitants of the Amazon live in metropolitan areas, from an overall of 24.4 million inhabitants. Thus, Region 1 seems to represent well the most densely urbanized Brazilian Amazon, and thus by isolating it from the rest of the Amazon we can capture the effects of urbanization in the Amazon region separately from the effects of local demand vectors as a whole (urban or rural), with respect to the Brazilian Amazon deforestation. Of course, ideally, the urbanization effects would be more precisely captured if we could split the local demand vector from the Amazon region as a whole into two: the urban population demand, and the rural population demand. Unfortunately, the level of data disaggregation does not allow us to do so; therefore, our strategy of isolating the Metropolitan Regions may be considered the best strategy, given data restrictions.

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<sup>2</sup> Due to data issues, we were not able to build Region 1 considering only the municipalities within each of the 5 Metropolitan Regions. A detailed discussion of this matter, along with the possible consequences to our results, along with a list of all municipalities from Region 1 detailing which of them belong to the Metropolitan Regions defined by IBGE can be found at Appendix A.

<sup>3</sup> Many researchers argue that these 5 Metropolitan regions may not be the only real Metropolitan regions within the Brazilian Amazon, as representatives of urban conglomerates. Due to that in Appendix A we briefly discuss the reasons and possible consequences of our choice of using only these 5 regions.

**Figure 1: Metropolitan Regions of Brazilian Amazon, Rest of Brazilian Amazon, Rest of Brazil**



Source: IBGE and Research data.

Therefore, adapting Equation (13) to represent the interregional Leontief inverse matrix that we use in this article, we have:

$$B_3 = \begin{bmatrix} B^{RMAM \times RMAM} & B^{RMAM \times REAM} & B^{RMAM \times RBR} \\ B^{REAM \times RMAM} & B^{REAM \times REAM} & B^{REAM \times RBR} \\ B^{RBR \times RMAM} & B^{RBR \times REAM} & B^{RBR \times RBR} \end{bmatrix} \quad (14)$$

where  $B_3$  is the Leontief interregional inverse matrix with the 3 regions described above, and each element  $b_{ij}^{ML}$  from  $B^{ML}$ , represents the amount of output needed to be produced in sector  $i$  from region M to fulfill one additional unit of final demand from sector  $j$  in region L,  $\forall i, j \in [1, n]$ ,  $n$  being the number of sectors in the economy, and M or L being one of the three regions described in this section.

### 3.2 Sectoral division and aggregation

The data sources used to construct the input-output interregional system were the IBGE Regional and National Accounts, using the Guilhoto and Sesso Filho (2005) methodology. With this methodology, first, we built an inter-regional input-output system for Brazil, with 56 industries and 558 Micro regions, for the 2004. We then aggregated these micro regions into the 3 Regions described above and we aggregated the 56 industries into 32 sectors.

For this sectorial aggregation, we isolate sectors that present stronger relationships with deforestation, and group industries that produce similar goods and services, and are less directly correlated with deforestation into fewer sectors. More specifically, first we isolate the sectors that exert direct pressure on deforestation, i.e., those that compete directly with the forest for land use, which are Agriculture and Livestock. Then, we isolate the sectors that are, according to our data and the literature, the main consumers of inputs produced by these two, thus isolating those sectors that exert the greatest indirect deforestation. Finally, we group into a smaller number of industries those sectors whose output is similar in terms of the characteristics of the good and services produced, and also in terms of consumption of inputs produced by Agriculture and Livestock. As examples, we kept Agriculture, Forestry, Forestry and Livestock, Fisheries isolated, while we aggregated the various industries related to specific kind of services into one industry which we called Services. We did the same kind of aggregation to Chemical Products of diverse industries, which we grouped into one single sector called Chemicals. Appendix A.2 provides the complete map of sectoral aggregation. To accomplish these aggregations, we followed the methodology described in Miller and Blair (2009).

The reason for using this aggregation is to facilitate the visualization of our results. This is because, on the one hand, inter-regional input-output models have the very desirable feature of capturing all multiplier effects between sectors and regions generated due to intermediate consumption among industries per unit of final goods consumed in each region and each sector; on the other hand, this same completeness of sectors and regions generates many results, making it difficult to read and interpret them.

Moreover, the aggregation criteria we adopted do not bring large biases to the results. The reason for that is because our main result, which is measured in terms of deforestation cause by each Region's demand, occurs in two ways: directly by the sectors of Agriculture and Livestock, due to competition for land use between forests and those two sectors, and indirectly by the other industries, through consumption of the output of those two sectors as intermediates in the production process. This means that in terms of deforestation, when we aggregate sectors that are not Agriculture or Livestock, we are aggregating the intermediate consumption that those sectors demand from the first two, thus, in general, we do not underestimate the multiplier effects across sectors directly related to deforestation itself. This argument becomes clearer in the next sections, when describe in detail the methodology by which we measure the impact of each Region's demand in terms of deforestation.

### 3.3 Deforestation data

In order to calculate the deforestation impacts of each demand vector, using an input-output system, we not only need to access deforestation data within the Amazon region, but also to map how this deforested land was replaced by land use for Livestock and Agriculture production. The reason is because the input-output modeling allows us to measure how much all sectors and final demand from each region in the economy consume from Livestock and Agriculture, and thus, by knowing how much forest covered area was turned into pastures or agricultural land, we can also estimate how much of this land-use change (deforestation) was driven by the consumption from families of each region, not only by their direct consumption of Agricultural and Livestock output, but also by their consumption of every good or service produced in the economy.

Thus, the exact deforestation database we needed for these calculations was one providing estimations of land conversion in Brazilian Amazon. More specifically, we needed data on land conversion from forest-covered areas within the Amazon region, which had turned into pastures or agricultural land in 2004, which is the year of our inter-regional input-output tables.

We obtained these land-conversion data from the Second Brazilian Inventory of Emissions and Anthropogenic Removals of Greenhouse Gases, published in 2010, which contains, among other information, data on land transitions from 1994 to 2002, as shown in Table 1.

**Table 1: Deforestation and Land Transition from 1994-2002**

		Land Use in 2002 (ha)					Total in 1994
		Forest Area	Reforestation	Pasture Area (for Livestock)	Agriculture and Forestry	Other Uses	
Land use in 1994 (ha)	Forest Area	345,400,858	27,264	15,294,488	2,275,242	45,847	<b>363,043,701</b>
	Reforestation	56	295,252	187	7,184	1	<b>30,268</b>
	Pasture Area (for Livestock)	772,591	12,296	25,791,281	987,198	67,368	<b>27,630,735</b>
	Agriculture and Forestry	73,057	753	1,332,935	3,083,190	5,626	<b>4,495,560</b>
	Other Uses	318	9,165	1,138,408	68,270	23,047,234	<b>24,263,398</b>
Total in 2002		<b>346,246,879</b>	<b>344,731</b>	<b>43,557,300</b>	<b>6,421,083</b>	<b>23,166,079</b>	<b>419,736,073</b>

Source: Brazilian Ministry of Science and Technology

Concerning deforestation, Table 1 shows that between 1994 and 2002, 15,294,488 hectares of forest area turned into pasture for livestock production, while 772,591 of pasture area for livestock has turned into forest area. Thus, we found that Livestock production was responsible for 14,521,897 hectares of deforestation from 1994 to 2002 in the Amazon region, which is the difference between 15,294,488 and 772,591. Making similar calculations, we estimate that in this same period, the Agriculture and Forestry sector is responsible for 1,970,281 hectares of deforestation in the Amazon region. Thus, the annual average deforestation caused by the Livestock and the Agriculture and Forestry sectors are, respectively, 1,613,544 and 218,920 hectares per year.

As this is one of the only sources of land-use transition for Brazil, and there is no such data available for 2004, for our calculations, we assume that deforestation caused by these two sectors in 2004 is exactly these annual average values. We are aware that this may not represent the exact deforestation caused by these two sectors in this year, however, this is the only available method so far to estimate this indicators.

#### **4 POPULATION, HISTORY, SOCIOECONOMIC, AND ENVIRONMENTAL BACKGROUND**

To analyze the impact of the local demand of the Brazilian Amazon is a task that first deserves some historical analysis. This is because most of the historical occupation of the Amazonian territory results from direct government policies, which began around 1960 and were used to encourage migrants to occupy the land. It is true that before this period, there was significant migration into the region, due to the Portuguese colonization. One important example was the immigration wave coming from the northeast region of Brazil in the 1870s, in which about 300 000 northeasters moved in "pushed by the misery of the great droughts of the northeast" (Tom Amazon Project, 2011). However, in terms of migration flows and urbanization of the Amazon region, we set the decade of 1960 as the starting point of occupation of the region. During this period, the Brazilian dictatorial government set development policies, clearly aiming to "integrate" the Amazon regions into the rest of Brazilian economy. Programs of direct intervention in population flows such as the "Land without men for men without land" encouraged the departure of big miners from the region, granting broad slices of land for explorers, the construction of roads through the forest, large-scale government investment in industry and agriculture, etc.

In the beginning of the 1990s, however, the international economic crisis, which affected heavily all Latin-American countries, along with the recent emerging environmental concerns on deforestation caused those explicit occupation policies to lose strength. (see Andersen et al. 2002). However, regional population not only continued to expand, but, in fact, urbanization and population growth rates were never as big as they are currently.. IBGE Census data show that urban population jumped from 42% to 71% from the 1970s to 2010 in the region. In the last decade, overall population in the Amazon region grew 20%, while in the rest of Brazil it grew only by 10%. Ten among the 19 cities that doubled their population in the last ten years are located in the Brazilian Amazon, with Manaus, a city with 1.7 million inhabitants, being one of them.

In terms of the regional division we adopt in this study, such historical background results, currently, in the current socioeconomic configuration described in Table 2.



**Table 2: Socioeconomic Data**

Socio-economic Data	Amazon Metropolita Regions		Rest of Amazon		Rest of Brazil	
	Absolute value	% of Brazil	Absolute value	% of Brazil	Absolute value	% of Brazil
Population (2007)	6,294,629	3.32%	18,856,584	9.96%	164,224,392	86.72%
Agriculture and Livestock GDP (thousand 2008 R\$)	1,326,061	0.88%	32,286,665	21.47%	116,776,385	77.65%
Share of Agriculture and Livestock GDP over the region Total GDP	1.40%	-	21.89%	-	4.20%	-
Industry GDP (thousand 2008 R\$)	24,706,486	3.44%	29,702,860	4.13%	664,160,609	92.43%
Share of Industry GDP over the region Total GDP	26.03%	-	20.14%	-	23.90%	-
Services GDP (thousand 2008 R\$)	51,886,648	3.05%	74,006,624	4.35%	1,575,958,292	92.60%
Share of Services GDP over the region Total GDP	54.67%	-	50.18%	-	56.70%	-
Government GDP (thousand 2008 R\$)	16,994,976	3.77%	11,491,458	2.55%	422,486,918	93.68%
Share of Government GDP over the region Total GDP	17.91%	-	7.79%	-	15.20%	-
Total GDP (thousand 2008 R\$)	94,914,171	3.14%	147,487,607	4.88%	2,779,382,204	91.98%
GDP per capita* (R\$ per person)	15,079	-	7,822	-	16,924	-

Source: Ipeadata

In Table 2, we show that 25% of the Brazilian Amazon population live within metropolitan areas, a number far from negligible for a region still considered by many as "wild" and agricultural. In economic terms, it is true that the Rest of the Amazon (discounting the metropolitan areas) has a higher relative participation of agriculture and livestock on GDP than the rest of Brazil. However, this same share for the region's metropolitan areas presents itself with a value much closer to the Rest of Brazil. Again, these first results show that the urbanization process taking place in the Amazon region seems to be relevant for the local economy, and thus, some impacts in terms of deforestation are to be expected.

Another aspect that calls attention is the fact that the GDP per capita from the Rest of the Amazon is about half of the Amazon Metropolitan region's area. Moreover, the value of this variable for the Rest of Brazil is the same as the Amazon Metropolitan Areas. This confirms what urban economists predict (see Fujita & Thisse, 1999): urbanization is usually accompanied by, or even the source of growth and development. One of the reasons why the region is passing through such a process is the very fact that migration flows from rural areas to urbanized centers are motivated by the development and growth that urbanization might bring. This deserves further research, and is complementary to our results.

In terms of size, the Metropolitan regions of the Amazon represent only 3.3% of the total Brazilian population, and so, is apparently a small number. The total population of the Amazon region, seems small compared to the total population of Brazil as a whole, in a range of only 13.3%. However, we have to keep in mind that the deforestation caused by this local population may not be as small as its relative size, especially due to the fact that this population lives much closer to the forest than the rest of Brazil. In fact, in the following sections, we measure the size of these impacts, as this is the main goal of this study, and we show that, in terms of deforestation, this local population represents a value much higher than 3.3% for the Metropolitan regions, or 10.0 % for the Rest of the Amazon. As we will see, both closeness to the forest and the urbanization process seem to play an important role when it comes to deforestation impacts, especially when the size of such impacts is compared to the relative population size.

Table 3 shows the overall information of the two Regions into which we divided the Brazilian Amazon:

**Table 3 Forest cover and Deforestation**

Forest Data	Amazon Metropolitan Regions		Rest of Amazon		Total Brazilian Amazon
	Km <sup>2</sup>	% (over total Brazilian Amazon)	Km <sup>2</sup>	% (over total Brazilian Amazon)	
Total Area	507,588	10.03%	4,551,353	89.97%	5,058,941
"Original"* Forest Area	371,005	9.85%	3,394,329	90.15%	3,765,334
% ("Original"* Forest Area/ Total Area)	73.09%	-	74.58%	-	74.43%
Remanescent Forest Area	354,917	11.69%	2,680,161	88.31%	3,035,078
% (Remanescent Forest Area/ "Original"* Forest Area)	95.66%	-	78.96%	-	80.61%
Acumulated Deforestation	16,088	2.20%	714,238	97.80%	730,327
% (Acumulated Deforestation/ "Original"* Forest Area)	4.34%	-	21.04%	-	19.40%
Increase do Deforestation in 2008/2007	210	1.57%	13,134	98.43%	13,343
% ( Increase do Deforestation in 2008/2007 / Area de Forest Remanescent)	0.06%	-	0.49%	-	0.44%

\*\* Original\* refers to the area covered by forest in 1988, the first year of data collection from PRODES.

Source: PRODES (INPE)

It is noteworthy that the majority (88%) of the forest is located outside the Metropolitan regions. However, even though Metropolitan regions are typically urbanized areas, they still hold about 12% of the Amazon forest in their municipalities' area. Moreover, it is interesting to note that deforestation is four times bigger outside the Metropolitan regions. Thus, given this evidence, we investigate the impacts that the Metropolitan Regions have on the Rest of the Amazon, in terms of deforestation and economics, because the forest is particularly concentrated outside the Metropolitan areas, exactly where the deforestation rate is also higher.

## 5 RESULTS

### 5.1 The 3 regions productive structure

Before we move on to measuring and analyzing the impact of m local demand vectors and the urbanization of the Metropolitan Regions of Amazon on deforestation, we initially describe the productive structure of the three regions as a basis for analysis and conclusions. To show this productive structure and their characteristics, we calculated, from the input-output matrices, the production multipliers, the employment and value-added generators, always considering multipliers of Type II, that is, including the direct, indirect, and induced multiplier effects.

Figures 2 - 10 show respectively, the Output Multipliers, Employment generators, value added generators for 32 sectors in each region, all calculated with the 3-region inter-regional input-output model, previously explained. One general result is the fact that it is easy to note that the two Amazon regions present a larger dependence on the Rest of Brazil, than the Rest of Brazil does on the Amazon as a whole. As the Amazon region represents only 13% of total Brazilian population, this was an expected result, for in this sense, Amazon is a relatively small economy within a much larger one. However, as we will see later, this does not mean that the local demands impacts are

negligible; on the contrary, they seem to be very important for the deforestation process dynamics.

In the case of multipliers, for example, the figures reflect how much one additional unit of families consumption of goods produced by sector  $j$  from one of the three regions generates in terms of total output in the economy of the three regions as a whole, incorporating the direct production of sector  $j$  itself to meet this additional unit of final demand, the output indirectly generated in all sectors that supply inputs to industry  $j$ , and also the additional consumption in all sectors and regions generated by the increase in household income, which in turn was generated through all production process of those direct and indirect effects, as these households are the owners of labor and capital involved in the economy's productive chain.

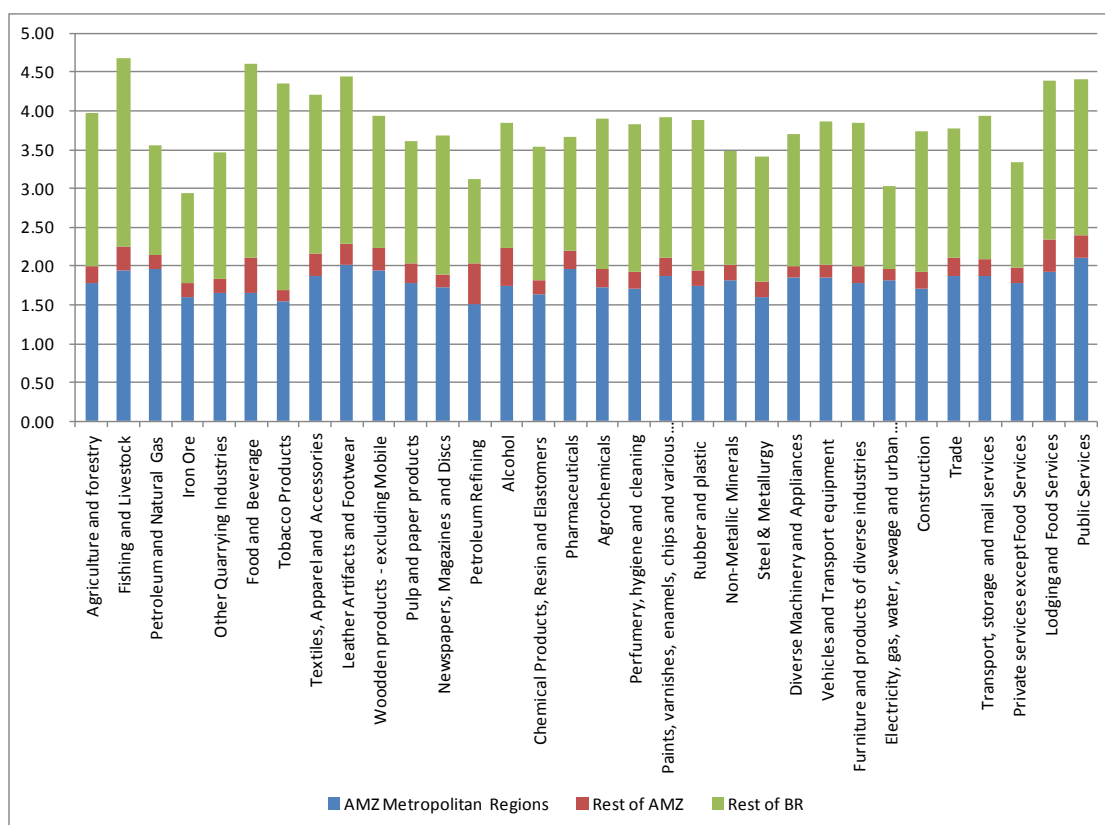
Interpretation of the figures is fairly straightforward, and we explain through an example: the first column of Figure 2, shows that an additional unit of final demand (measured in thousands reais) for Agriculture and Forestry stemming from families of the Amazon Metropolitan Regions (Region 1) results in a total production of approximately 4 thousand Reais in Brazil as a whole, being 1.77 generated in the Amazon Metropolitan regions themselves, 0.22 generated in the Rest of the Amazon, and 1.96 generated in the Rest of Brazil. A similar interpretation applies to the generator figures (employment or value added): the first column of Figure 5 indicates that for every thousand dollars of additional demand from families of the Metropolitan areas of the Amazon for Agriculture and Forestry, 120 jobs are generated in these Metropolitan Areas, 11 jobs are created in the Rest of the Amazon, and 48 jobs in the rest of Brazil.

From Figures 2 – 5, in terms of output multipliers, we note that the Metropolitan areas of the Amazon generate spillovers in the Rest of the Amazon in the same proportion as the rest of the Amazon generates for the metropolitan areas, in general, for all sectors. Bearing in mind that the population of MR's accounts for only 25% of the Amazon as a whole, this is a first evidence that the spatial economics theory prediction that highly urbanized areas tend to have high growth rates due to increasing returns to scale and agglomeration economies (see Fujita & Krugman, 1999) seem to be correct when it comes to Brazilian Amazon. Sectorally, it is easy to notice that in both Amazon Regions, Livestock and Fishery as well as the Food and Beverages sectors present the largest output multipliers. As analysts indicate Cattle Livestock is the main direct deforestation driver, and also the food and beverage sector is closely connected to Cattle Ranching as an intermediate buyer, so that we interpret this as a first evidence that in terms of deforestation, local demand from the Amazon area might present considerable impacts in terms of deforestation.

In terms of employment generation, Figures 5, 6, and 7 go in the very same direction of the results from the output multipliers: Sectors highly linked to Agriculture, Livestock, and Food tend to be the ones that generate more jobs in all regions. Furthermore, Figure 5 shows that increases in consumption of Food and Beverages, and also of Fuels (Ethanol and Petroleum Refining) in the metropolitan areas of the Amazon tend to cause an increase in employment in the Rest of the Amazon larger than the average increase caused by other sectors. This evidence is similar to the output multipliers figures, and therefore supports the argument that the metropolitan areas may have significant impact in terms of deforestation related to the demand for agricultural and livestock products.

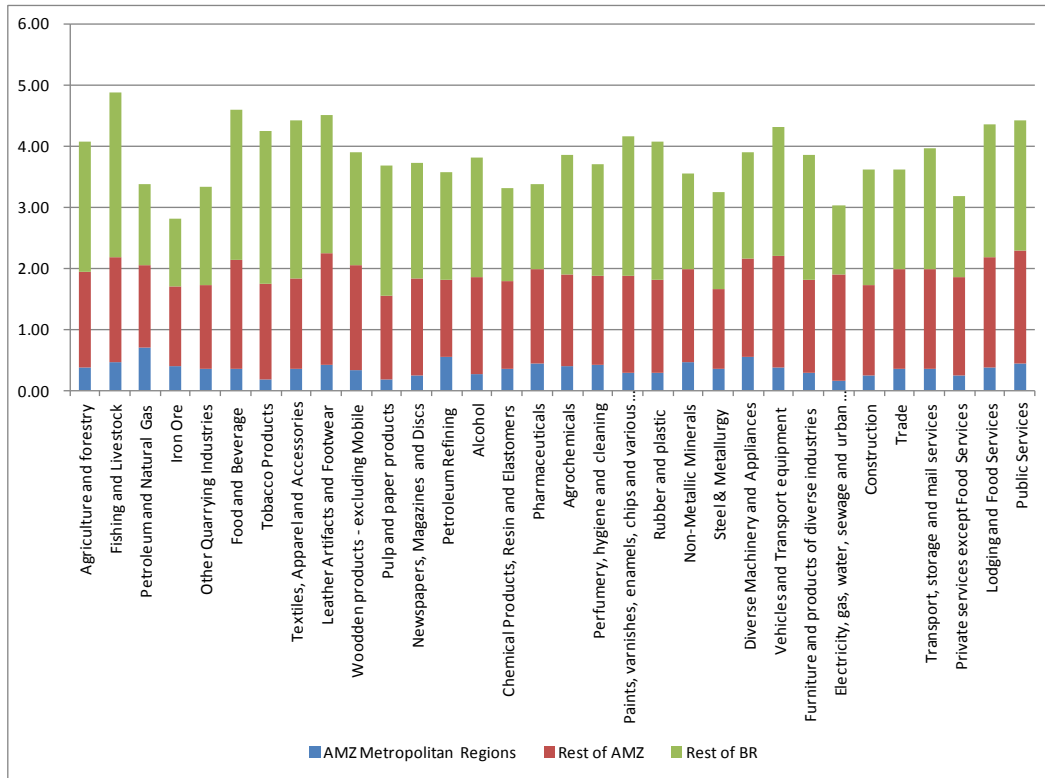
Regarding generation of added value, a similar picture is observed. For all regions, in general, Agriculture and Livestock are the ones that show higher value of production. However, unlike the output multipliers and employment generators, generation of added value by Services sectors is, in general, higher than in the previous indicators. This confirms the tendency of urbanization that Brazil and the Amazon region is going through in the last decades, because the development of the Services sectors is, in general, closely connected to urbanization processes, since Urban areas tend to present a higher participation of services in the GDP composition. Finally, we note again that the demand for food and beverages metropolitan areas have greater impact on the generation of value added from the Rest of the Amazon than the demands of other sectors, representing the same line of argument already explained above.

**Figure 2 - Output Multipliers – Metropolitan Regions of the Amazon**



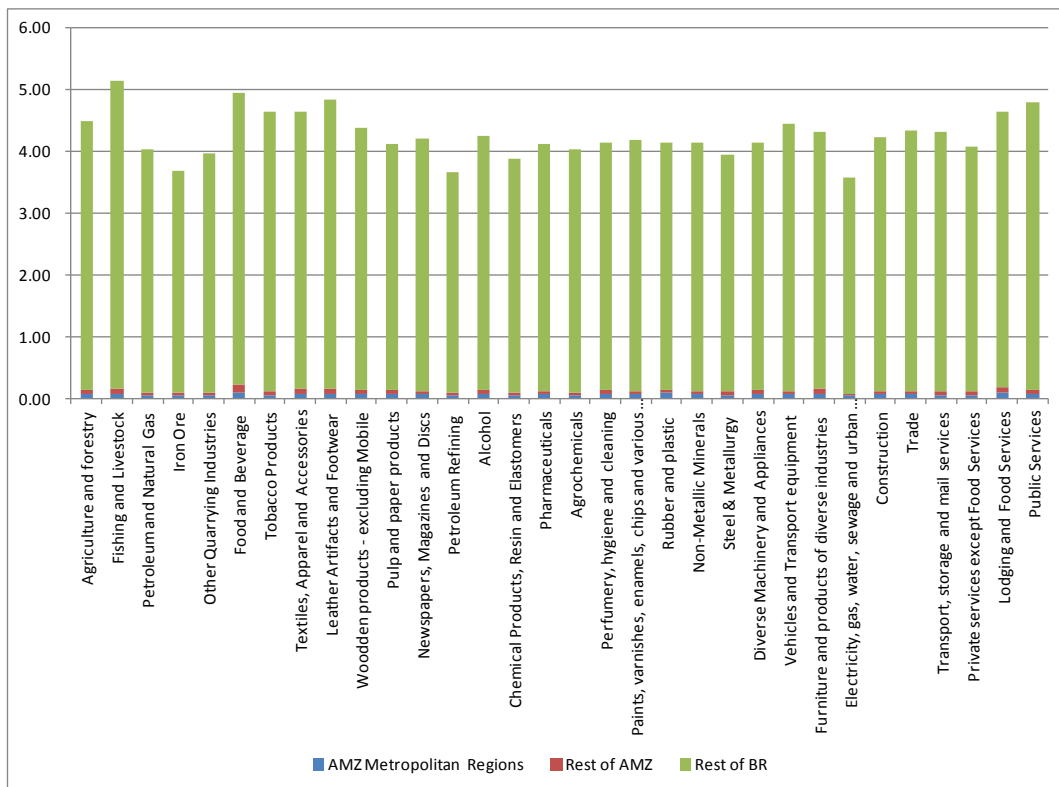
Source: Research Data

**Figure 3 - Output Multipliers 1– Rest of the Amazon**



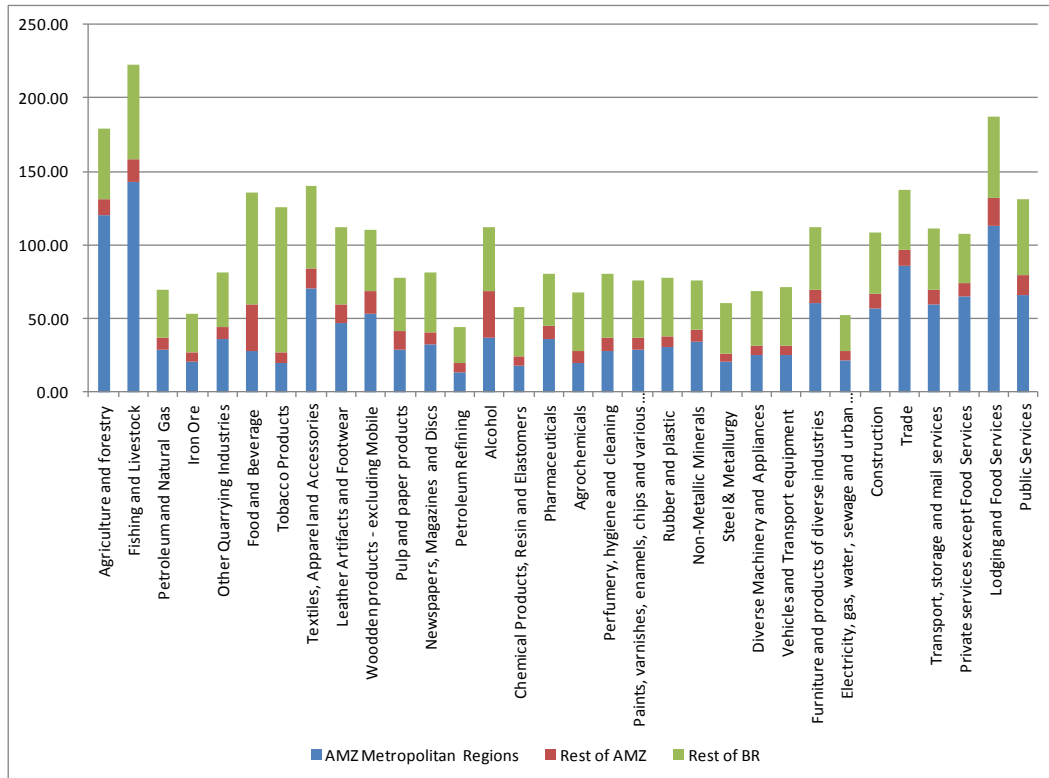
Source: Research Data

**Figure 4 - Output Multipliers - Rest of Brazil**



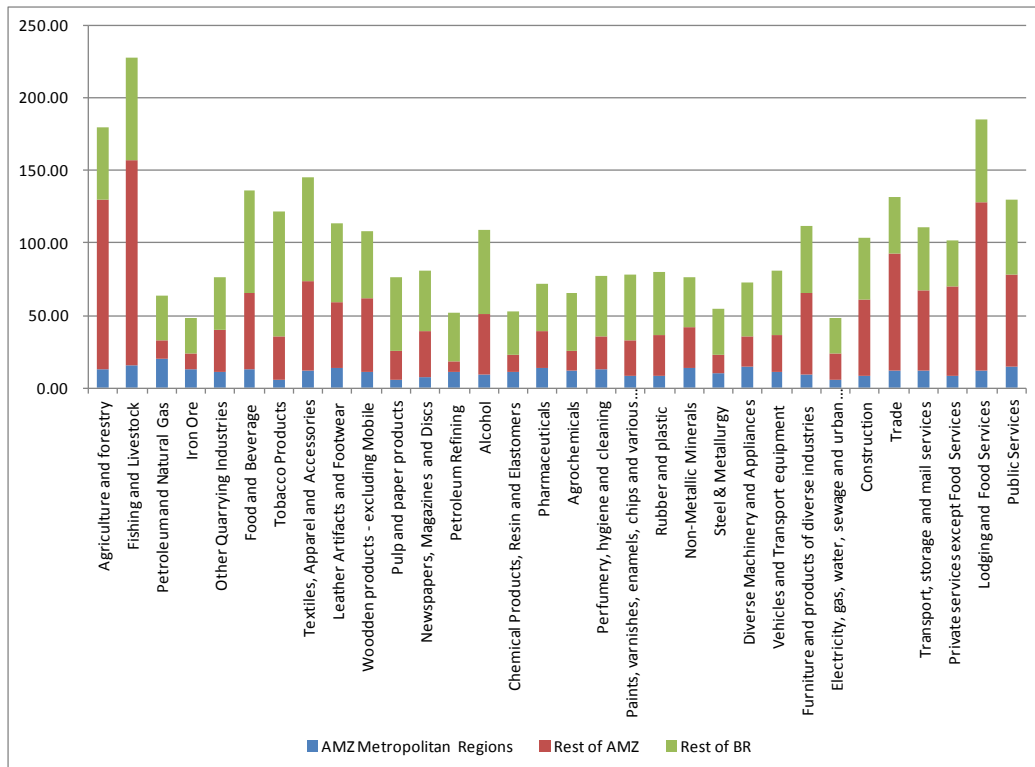
Source: Research Data

**Figure 5 - Employment Generator - Metropolitan Regions for the Amazon**



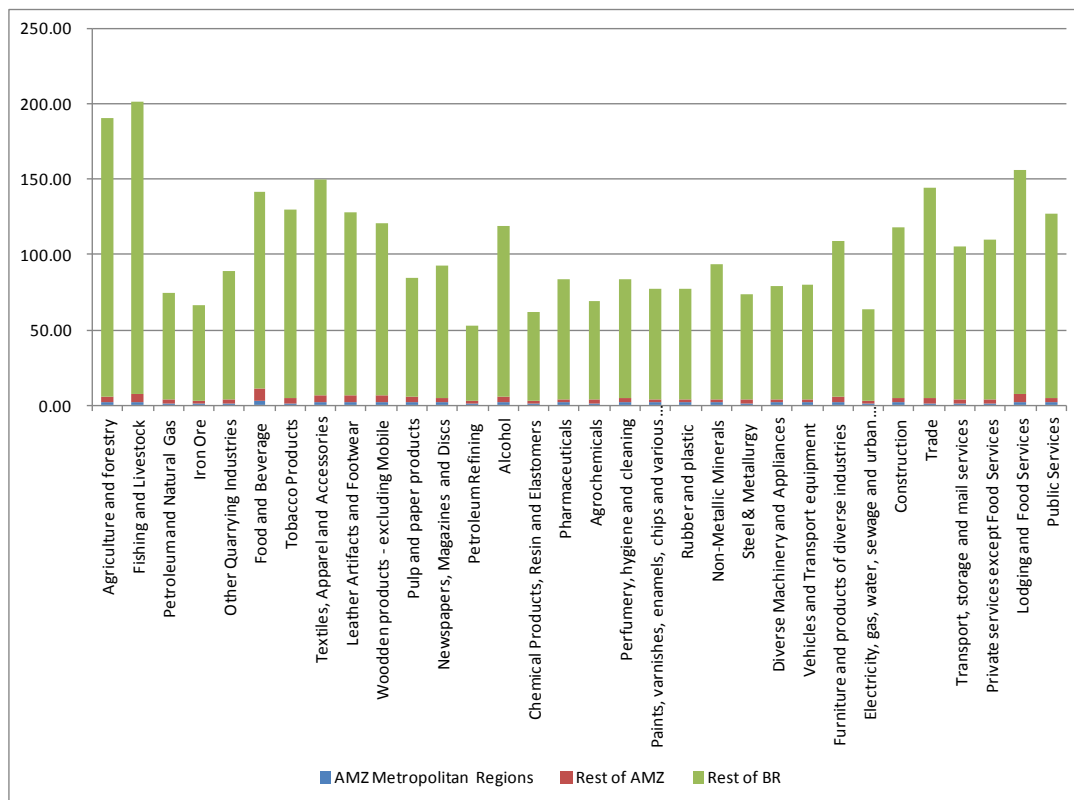
Source: Research Data

**Figure 6 - Employment Generator - Rest of the Amazon**



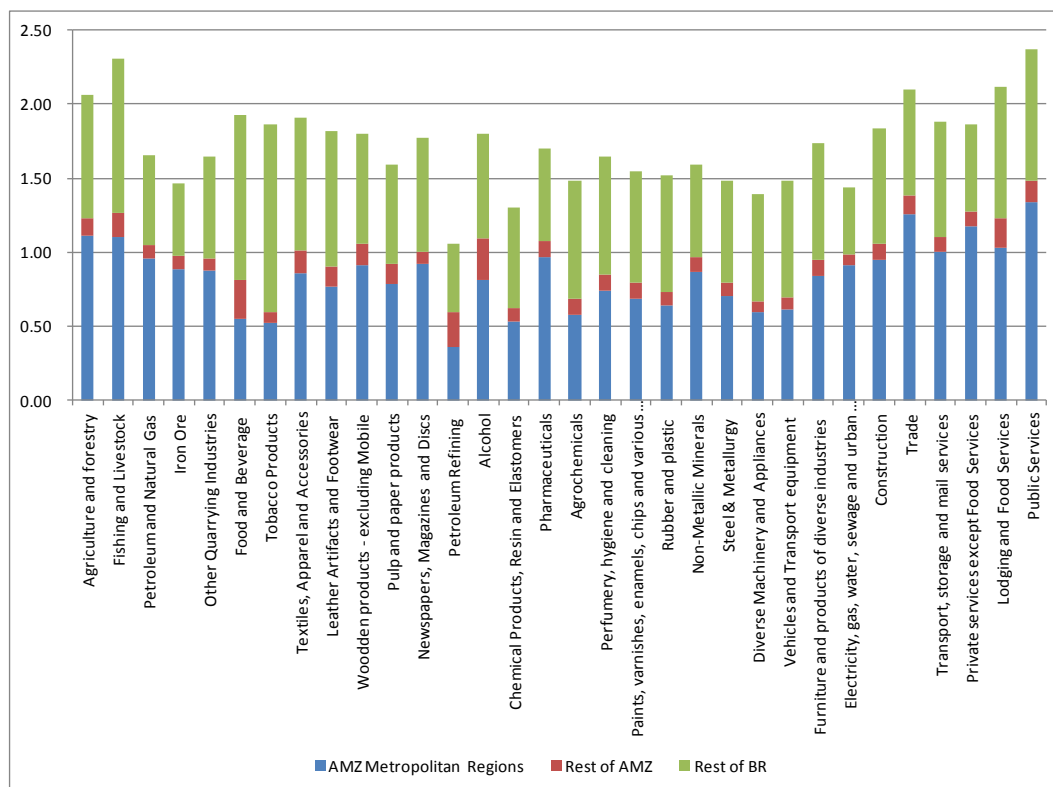
Source: Research Data

**Figure 7 - Employment Generator - Rest of Brazil**



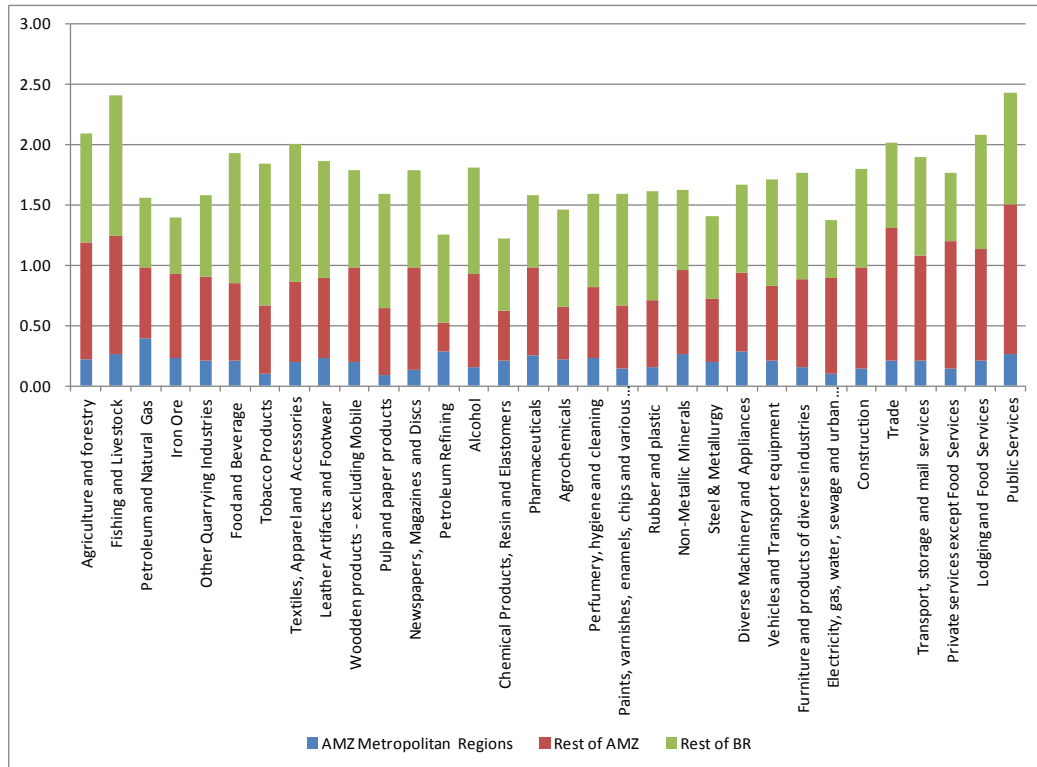
Source: Research Data

**Figure 8 - Value Added Generator - Metropolitan Regions of the Amazon**



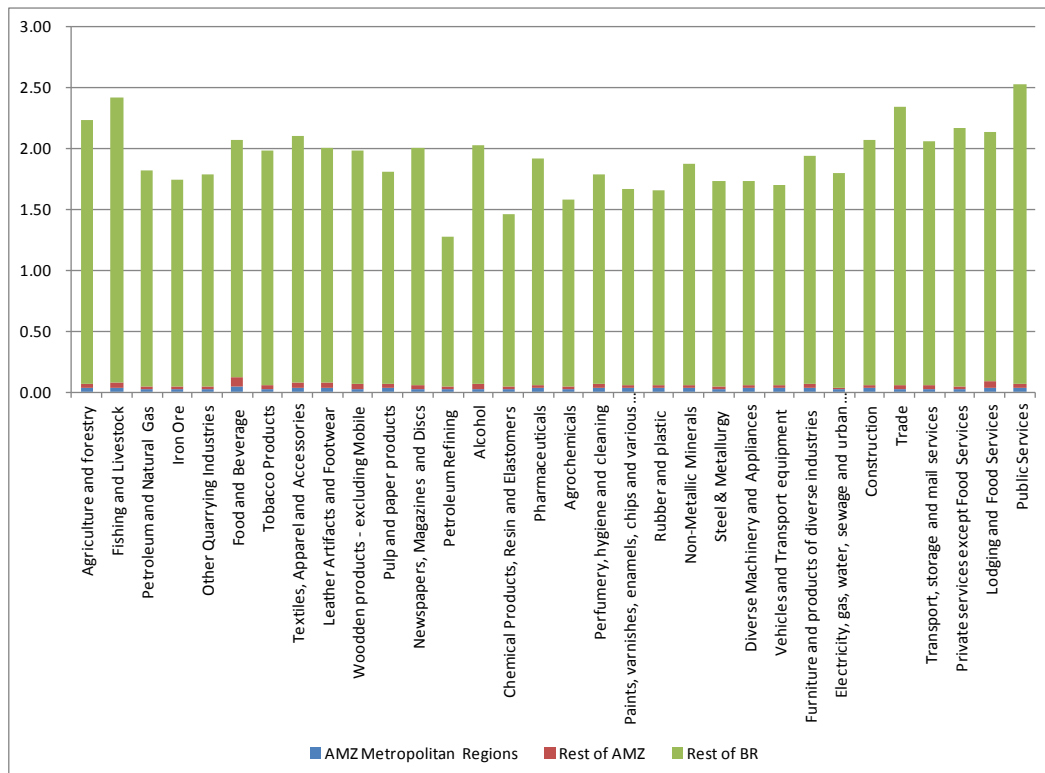
Source: Research Data

**Figure 9 - Value Added Generator - Rest of The Amazon**



Source: Research Data

**Figure 10 - Value Added Generator - Rest of Brazil**



Source: Research Data



## 5.2 Impacts from local demand on the Brazilian Amazon

### 5.2.1 Economic impacts

Given the description of the productive structures of the 3 Regions, we now consider the central question of this study, which what are the impacts, in economic and deforestation terms, of the local demand from consumers who live within the Amazon region, and also from the urbanization process represented by the Metropolitan regions of Brazilian Amazon (Region 1). In order to do so, we analyze the economic and sectoral impacts of this local demand, but always trying to focus on some “key” sectors that which are related to deforestation, through direct or indirect impacts.

Table 4 shows how the output produced in Region 2 (Amazon except for its Metropolitan regions) in these key sectors is distributed regionally through the 3 regions of Brazil. We analyze production from region one, because as we have seen in the previous sections this is the region where the forest is mostly concentrated, and thus, the results can be easily related to deforestation itself.

**Table 4: Output from the Rest of the Amazon (Region 2) by its destination**

	Household Consumption						Exportations		Intermediate consumption						
	Metropolitan Regions of Amazon		Rest of Amazon		Rest of Brazil				Metropolitan Regions of Amazon		Rest of Amazon		Rest of Brazil		
	Millions of R\$	% of Total Output in the Rest of the Amazon	Millions of R\$	% of Total Output in the Rest of the Amazon	Millions of R\$	% of Total Output in the Rest of the Amazon	Millions of R\$	% of Total Output in the Rest of the Amazon	Millions of R\$	% of Total Output in the Rest of the Amazon	Millions of R\$	% of Total Output in the Rest of the Amazon	Millions of R\$	% of Total Output in the Rest of the Amazon	
Sectors in the Rest of the Amazon	Agriculture and forestry	1,033	4.1%	794	3.2%	999	4.0%	4,744	19.0%	1,481	5.9%	3,718	14.9%	7,596	30.3%
	Fishing and Livestock	587	4.8%	499	4.1%	682	5.6%	248	2.0%	969	8.0%	2,169	17.9%	3,084	25.4%
	Food and Beverage	2,047	14.2%	2,192	15.2%	2,914	20.2%	2,296	15.9%	430	3.0%	1,422	9.9%	1,609	11.2%
	Leather Artifacts and Footwear	6	2.0%	26	8.3%	17	5.6%	23	7.4%	3	0.8%	49	15.9%	34	11.0%
	Woodden products - excluding Mobile	13	0.4%	18	0.5%	31	0.9%	2,071	60.8%	221	6.5%	802	23.5%	712	20.9%
	Pulp and paper products	4	2.0%	3	1.5%	18	9.0%	162	80.0%	12	5.7%	25	12.4%	83	41.0%
	Newspapers, Magazines and Discs	5	9.3%	7	12.6%	6	11.4%	0	0.0%	9	17.8%	22	42.4%	11	20.9%
	Alcohol	20	2.9%	18	2.5%	94	13.2%	0	0.0%	72	10.1%	37	5.2%	184	26.0%
	Furniture and products of diverse industries	56	24.0%	121	51.3%	37	15.6%	64	27.1%	16	6.7%	25	10.4%	21	8.7%
	Construction	244	4.0%	2,330	38.1%	98	1.6%	580	9.5%	67	1.4%	353	7.7%	30	0.6%

Source: Research Data

In Table 4, we show that, when it comes to household consumption, the output produced to fulfill the direct final demand from families living within the Amazonian Metropolitan Regions is very similar to, or even greater than the output designated to fulfill the demand from households living in the Rest of Brazil. Of the total output produced in Region 2 (rest of the Amazon), from the Agriculture and Forestry sector, for example, 4.1% is produced to fulfill the consumption of the Amazon Metropolitan

Regions Families, while 4.0 % is designated to fulfill the direct consumption of households in the rest of Brazil. This result is very similar to the industries of Livestock and Fisheries, Leather Artifacts and Footwear, and also Newspapers and Magazines. For the sectors of Construction and Furniture and Product of diverse industries, this same relative effect is even greater. Moreover, if we add the output designated to fulfill consumption from families of both Metropolitan and Non Metropolitan Regions of the Amazon (Regions 1 and 2), and compare to the output directly designated to families from the Rest of Brazil, this direct local demand impact is even bigger.

In terms of deforestation, the Food and Beverage sector is perhaps the most important example of this argument, due to its close relationship to deforestation through intermediate consumption of inputs from Livestock. Alone, families from the Metropolitan Regions of Amazon consume almost 15% of the total output of this sector produced in the Rest of the Amazon, and accounted together with consumption from families from Region 2, this percentage sums to 30%, while families from the rest of Brazil account for the consumption of only 20% of this same output. Even if we add exports to the consumption of families from the rest of Brazil, we would have 35% of Food and Beverage output being sold outside the Amazon region, against 30% being sold within it. Bearing in mind that population in the Brazilian Amazon accounts for only 13% of total Brazilian population, it seems clear that in terms of output directly (without taking intermediate consumption from other sectors into account) designated to families consumption, households living within the Amazon regions weigh much more than households from abroad or even from the rest of Brazil. Also, this percentage is even bigger in the highly urbanized metropolitan regions of Amazon, as theory would predict, due to the higher consumption patterns that people from urbanized areas tend to present. The only exceptions to this direct output destination argument are Pulp and Paper Products and Wooden Products sectors, whose production is mostly exported to other countries. In terms of deforestation, though, these sectors are not among the ones analysts indicate as being the most responsible for deforestation, and thus, in this sense, the argument stands.

Even though this is a first evidence supporting that local demand vectors, especially from the Metropolitan Regions of Amazon, seem to be relatively important as drivers of output and deforestation, we note that intermediate consumption is not been taking into account yet, and thus, we do not have the whole picture, even in economic terms. The reason for that is because it is easy to note from Table 4 that for most of the key sectors chosen, total output produced in the Rest of the Amazon region is rarely consumed directly by households, especially for the Agriculture and Forestry and Livestock and Fishing sectors, which are at the same time the ones directly connected to deforestation, in terms of competition for land use, and also at the base of the production chain, and thus, serving as suppliers of inputs for other industries. In other words: for sectors at the end of the production chain - Food, Furniture, and Construction – this first result can already be considered robust evidence, because most of the output of these sectors is intended for families. However, for sectors that are at the base of the production chain, intermediate consumption matters a lot and we still must consider them in the calculations, and the two sectors that drive deforestation directly are included in this latter group.

In order to incorporate these intermediate consumption effects, i.e., the indirect production of inputs needed to produce the output to fulfill the final demand, we used the input-output inter-regional Leontief inverse matrix of the 3 regions in a process that

allows us to compare the resulting output of each sector in each region induced by the consumption of families of each of the 3 different regions, also accounting for all production of inputs in all regions.

The procedure the following. First, we isolated the 4 regional final demand vectors of the system, which are: (1) The vector of consumption from the households of the Amazon Metropolitan Regions of each sector in each region, which shows how much the families from the Metropolitan Regions of Amazon consume directly (without taking intermediate consumption into account) from each sector of each region ( $CF^{RMAM}$ ); (2) The vector of consumption from the households of the Rest of the Amazon of each sector in each region, which shows how much the families from the Rest of The Amazon consume directly (without taking intermediate consumption into account) from each sector of each region ( $CF^{REAM}$ ); (3) The vector of consumption from the households of the Rest of Brazil of each sector in each region, which shows how much the families from the Rest of Brazil consume directly (without taking intermediate consumption into account) from each sector of each region ( $CF^{RBR}$ ); (4) The exports of each sector in each region, which shows how much the rest of the World consume directly from each sector of each region ( $EXP$ ). Each of these is of dimension (96 x 1), accounting for 32 sectors in each of the 3 regions.

Then, we pre-multiplied each of these four vectors by the the inverse Leontief matrix of the inter-regional system (of dimension 96 x 96), described as follow:

$$PTS^{RMAM} = L * CF^{RMAM} \quad (15)$$

$$PTS^{REAM} = L * CF^{REAM} \quad (16)$$

$$PTS^{RBR} = L * CF^{RBR} \quad (17)$$

$$PTS^{EXP} = L * EXP \quad (18)$$

where  $PTS^W$  is a 96 x 1 vector in which each element represents the total output that will be produced, in each sector of each region, in order to fulfill the final demand (i.e., the consumption) from families of region W, already taking into account all direct and indirect effects (i.e., all output fulfilling both final demand and intermediate consumption) involved in that production, and with  $W \in (RMAM; REAM; RBR; EXP)$ .

Each of these four  $PTS^W$  vectors can be split regionally into three vectors, as follows:

$$PTS^{RMAM} = \begin{bmatrix} PTS_{RMAM}^{RMAM} \\ PTS_{REAM}^{RMAM} \\ PTS_{RBR}^{RMAM} \end{bmatrix} \quad (19)$$

$$PTS^{REAM} = \begin{bmatrix} PTS_{RMAM}^{REAM} \\ PTS_{REAM}^{REAM} \\ PTS_{RBR}^{REAM} \end{bmatrix} \quad (20)$$

$$PTS^{RBR} = \begin{bmatrix} PTS_{RMAM}^{RBR} \\ PTS_{REAM}^{RBR} \\ PTS_{RBR}^{RBR} \end{bmatrix} \quad (21)$$

$$PTS^{EXP} = \begin{bmatrix} PTS_{RMAM}^{EXP} \\ PTS_{REAM}^{EXP} \\ PTS_{RBR}^{EXP} \end{bmatrix} \quad (22)$$

where each  $PTS_Z^Y$  is a (32 X 1) vector in which each element represents the output produced in each sector of region Z, in order to fulfill the final demand (i.e., the consumption) from families of region Y, already taking into account all direct and indirect effects throughout all the regions, with  $Y \in (RMAM; REAM; RBR; EXP)$  and  $Z \in (RMAM; REAM; RBR)$ .

As we are interested in correlating our results with deforestation, and the Amazon rainforest is mainly concentrated in Region 2 (Rest of the Amazon), in Table 5 we show the vectors  $PTS_{REAM}^{RMAM}$ ,  $PTS_{REAM}^{REAM}$ ,  $PTS_{REAM}^{RBR}$ ,  $PTS_{REAM}^{EXP}$ , which are the output generated in each sector of the Rest of the Amazon, including direct and indirect production, produced to fulfill the consumption from, respectively, families of the Amazon Metropolitan Regions ( $CF^{RMAM}$ ), families from the Rest of the Amazon ( $CF^{REAM}$ ), families from the Rest of Brazil ( $CF^{RBR}$ ), and Exports (EXP).

It is important to make clear that, differently from the generators and multipliers from the previous section, we are not accounting for the induced effects of the income of the families in these simulations. The reason for this is that here we are treating the consumption from families of each region as exogenous, because we are determining the resulting output in each sector of the Rest of the Amazon region, which results from this consumption. Thus, this demand represents the shocks we are inputting into the input-output interregional system, and if we treated them as endogenous, as it is necessary to calculate the induced effects (Miller & Blair, 2009), we would be double-counting these shocks in our calculations.

The idea behind this strategy is straightforward: in the calculations of each of the four  $PTS_Z^Y$  we assume that the only source of final demand (i.e., consumption) in the Brazilian economy is the consumption of households in the region Y, and we calculate the resulting output in region Z. Then, we can compare each  $PTS_Z^Y$  in order to visualize how much the consumption of each region contributes to the production of each sector in all regions.

As we are particularly interested in what drives production in the Rest of the Amazon, where the rainforest is mainly concentrated geographically, and also in the deforestation process, in Table 5 we show the output in the sectors more directly connected to deforestation in the Rest of the Amazon, which results from direct and indirect production designated to fulfill the regional consumption from all regions, and also for export:

**Table 5: Output generated in each sector of the Rest of the Amazon, including direct and indirect production, produced to fulfill the consumption from, respectively, families of the Amazon Metropolitan Regions, families from the Rest of the Amazon, families from the Rest of Brazil and Exports.**

Sector in the Rest of Amazon	$PTS_{REAM}^{RMAM}$		$PTS_{REAM}^{REAM}$		$PTS_{REAM}^{RBR}$		$PTS_{REAM}^{EXP}$	
	Millions of R\$ (A)	% of total Demand driven Output [A/(A+B+C+D)]	Millions of R\$ (A)	% of total Demand driven Output [B/(A+B+C+D)]	Millions of R\$ (A)	% of total Demand driven Output [C/(A+B+C+D)]	Millions of R\$ (A)	% of total Demand driven Output [D/(A+B+C+D)]
Agriculture and forestry	2,056	10.88%	1,447	7.66%	7,542	39.90%	7,856	41.56%
Fishing and Livestock	1,251	16.53%	940	12.42%	3,770	49.83%	1,605	21.21%
Food and Beverage	2,457	19.86%	2,542	20.55%	4,381	35.42%	2,989	24.17%
Leather Artifacts and Footwear	9	6.95%	31	24.98%	42	33.66%	43	34.41%
Woodden products - excluding Mobile	49	1.52%	50	1.55%	367	11.34%	2,766	85.59%
Pulp and paper products	10	3.53%	8	2.56%	76	25.82%	200	68.08%
Newspapers, Magazines and Discs	11	19.23%	26	44.34%	15	25.87%	6	10.57%
Alcohol	48	13.84%	33	9.46%	209	59.77%	59	16.93%
Furniture and products of diverse industries	64	19.81%	137	42.40%	50	15.32%	73	22.48%
Construction	23	11.80%	85	43.18%	26	13.27%	63	31.76%

Source: Research Data

Interpretation of Table 5 is as follows: assuming that the only source of final demand in the Brazilian economy is the consumption from households who live within the Metropolitan areas of the Amazon from all sectors, then the resulting output produced in the Rest of the Amazon region, considering both direct and indirect production, would be R\$ 2,056 million in the Agriculture and Forestry sector; R\$ 1,251 million in the Livestock and Fisheries sector, R\$ 2,457 million in the Food and Beverage sector, and so on. Also, in the table, we show how much these values measured in Millions of R\$ represent in terms of the total output generated by the four demand vectors taken altogether, in order to compare how much each of these final vectors can be held “responsible” for the production of the each sector in the Rest of the Amazon.

Analyzing the results from Table 5, we find more evidence concerning the relatively high importance that local demand from the Amazon region has, in terms of the productive impacts exerted on the sector most closely connected to deforestation, in the regions in which the forest is mainly located. For the Agriculture and Forestry and Livestock and Fishing sectors of the Rest of the Amazon region, consumption from families living within the Brazilian Amazon can be held responsible for approximately 20% of the total output needed to fulfill all demand of the region. For the Food and Beverage sector, this percentage reaches an even higher value: approximately 40%. With exception of the sectors of Wooden products except Mobile and Pulp and Paper Products, which in turn are not very large in terms of size measured by Millions of R\$ generated, we observe percentages similar to or even higher than these. . In the Construction sector, for example, more than 50% of total production is due to the local demand within Amazon region.

When compared to how much the demand from the Rest of Brazil can be held responsible for production of these same sectors in the Rest of Amazon, these results again show clearly the high importance that local demand exerts on production in the Amazon rainforest area, and thus, on deforestation. This is because as we have previously seen, population of the Amazon region represents only 13.3% of total Brazilian population, and thus, the Amazon relative population proportion tends to be smaller than the output that this local population produces, for most sectors.

This, as we have justified in the previous section, is an expected result in theoretical terms, according to spatial economics and urban economics, due to the fact that the forest is located within the two Amazon regions, and thus, proximity to local markets makes this smaller population to weigh relatively more, when compared to population from the Rest of Brazil, in terms of causing the expansion of production within the Amazon region.

However, results also show that not only this proximity factor matters in this sense. Comparing demand within Brazilian Amazon, it is easy to note that the Metropolitan Regions demand, for most of the sectors, is more responsible for production in the Rest of the Amazon than the Rest of the Amazon itself. For the Livestock and Fishery, for example, Metropolitan Regions are responsible for 16.5% of the total production in the Rest of the Amazon designated to fulfill direct and indirect production for the final demand, while the households consumption from the Rest of the Amazon itself is responsible for only 12%. Similarly, we observe “within Amazon” results for the other selected sectors in Table 5. Bearing in mind that population living within the Metropolitan regions of Amazon represent only about 25% of total Amazonian population, this result suggest that the demand of each individual from the Amazon Metropolitan Regions weight more than the demand from an individual living within Amazon, but outside Metropolitan regions, in terms of the output this consumption generates, directly and indirectly.

In order to facilitate these comparisons between each region’s population and the output in the Rest of the Amazon (where the forest is mainly located) that results from this regional population consumption, we divided the results from Table 5 by each respective population whose demand originated the production in the Rest of the Amazon. Table 6 shows the results<sup>4</sup>.

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<sup>4</sup> We emphasize that we did not calculate this *per capita* indicator for exports, for that would imply to divide the output generated by the exports in the Rest of the Amazon by the whole population of the World, which would underestimate the results from this demand, because not all countries are consumers of goods and services produced within the Amazon Region, which means that we would have to trace to which countries exports from the rest of the Amazon were designated, which is not feasible with the database we used.

**Table 6: Output generated in each sector of the Rest of the Amazon, including direct and indirect production, produced to fulfill the consumption from, respectively, each individual of the Amazon Metropolitan Regions, each individual from the Rest of the Amazon, and each individual from the Rest of Brazil**

<b>Sector in the Rest of Amazon</b>	$PTS_{REAM}^{RMAM}$	$PTS_{REAM}^{REAM}$	$PTS_{REAM}^{RBR}$
	<i>R\$ per capita</i>	<i>R\$ per capita</i>	<i>R\$ per capita</i>
Agriculture and forestry	326.6	76.8	45.9
Fishing and Livestock	198.7	49.8	23.0
Food and Beverage	390.3	134.8	26.7
Leather Artifacts and Footwear	1.4	1.7	0.3
Woodden products - excluding Mobile	7.8	2.7	2.2
Pulp and paper products	1.6	0.4	0.5
Newspapers, Magazines and Discs	1.8	1.4	0.1
Alcohol	7.7	1.8	1.3
Furniture and products of diverse industries	10.2	7.3	0.3
Construction	3.7	4.5	0.2

Source: Research Data

As Table 6 shows, consumption from each individual living in different regions of Brazil and Amazon result in different scales of production in the Rest of the Amazon, where the forest is mainly located. It is clear that consumption from each individual living within Amazon Region results in more production from sectors more directly related to deforestation, than consumption from each individual living in the Rest of Brazil. Moreover, consumption from individuals who live within the Metropolitan regions of Amazon determines even a greater output in these same sectors from the Rest of the Amazon than consumption from individuals who live in the Rest of Amazon itself, who are even closer to the forest. As an example, the table shows that demand from each individual living within the Metropolitan regions of Amazon results in a total output of R\$198.70 in the Livestock sector of the Rest of the Amazon, while the consumption from each individual within the Rest of the Amazon results in R\$49.80, and consumption from each individual living in the Rest of Brazil results in only R\$23.00 of output in the same region (Rest of the Amazon) and in the same sector (Livestock and Fishery).

This result, as previously justified, is exactly the one that spatial economics theorists would predict: consumption from population located closer to the forest tend to weigh more, in terms of the production it generates where the forest is located, than consumption from each individual living in farther regions, due to lower transportation costs. But not only distance matters in this sense: even though the metropolitan regions from Amazon are located farther from the forest than the Rest of the Amazon, the output generated by each the family living within these huge urban conglomerates is greater, because urbanization is accompanied by development and economic growth, which in turn results in higher consumption patterns in more densely urbanized areas.

### 5.2.2 Deforestation Impacts from local demand in the Amazon

We now turn to the main result of this study, which is to measure how much local demand of the Brazilian Amazon can be held responsible for deforestation of the Amazon rainforest, in terms of the land-use changes they cause in previously covered by forest areas, in order to make it possible for sectors such as Livestock and Agriculture to supply these demands. In order to do so, we adopted the following procedure.

Using the data from the Second Brazilian Inventory of Emissions and Anthropogenic Removals of Greenhouse Gases, as described in the previous sections, we were able to estimate the area, measured in hectares in the year 2004, of forest-covered land which has been turned into pastures for Livestock or Agriculture. Also, we had the total output in the Amazon region (for both Metropolitan and non-Metropolitan areas) from these two sectors, from the 2004 input-output tables. Using these data, we were able to estimate the deforestation coefficient of these two sectors for the Amazon regions, in a similar manner used to calculate the employment and value added coefficients:

$$DC^{AGR} = \frac{A_{FOR}^{AGR}}{X^{AGR}} \quad (23)$$

$$DC^{LIV} = \frac{A_{FOR}^{LIV}}{X^{LIV}} \quad (24)$$

Where  $DC^{AGR}$  is the deforestation coefficient of the Agriculture sector in both Amazon regions;  $A_{FOR}^{AGR}$  is the area of original forest cover that has turned its land use into Agriculture in the Amazon region in 2004;  $X^{AGR}$  is total Output, measured in millions of reais, of the Agriculture sector in Amazon in 2004;  $DC^{LIV}$  is the deforestation coefficient of the Livestock sector in both Amazon regions;  $A_{FOR}^{LIV}$  is the area of original forest cover that has turned its land use into pastures for Livestock production in the Amazon region in 2004;  $X^{LIV}$  is total 2004 Output, measured in millions of reais, of the Livestock sector in the Amazon. Thus, the deforestation coefficient of the Livestock sector measures how much one additional real of production in the Livestock sector in the Amazon results, on average, in deforestation in the Amazon region for the creation of new pastures, with a similar interpretation for the deforestation coefficient of Agriculture.

The resulting  $DC^{AGR}$  and  $DC^{LIV}$  calculated through our method assume the values of 8.45 and 127.25 hectares by one million Reais. This means that for each unit of output from the Livestock sector in within the Amazon region, 127.25 hectares are deforested in the region, yearly, for the year of 2004. This first result complies with analysts who point out that, in terms of land use, Livestock is the most responsible for deforestation in the Amazon region.

Given these coefficients, in order to find how much deforestation is due to the households demand of the Region  $i$ , first we multiply the output in the Agriculture and Livestock sectors produced in the two regions of the Amazon (Regions 1 and 2) to fulfill the households consumption for those living within region  $i$  by the Agriculture



and the Livestock deforestation coefficients of Amazon, respectively. With this, we obtain the deforestation which results from the demand of region  $i$  in the Agriculture sector, and in the Livestock sector, separately. Thus, the final step is to add these , to obtain the total deforestation driven by the demand from Region  $i$ .

As an example, using our notation, if we want to measure the deforestation driven by households consumption from the Amazon Metropolitan Regions, we must multiply the Livestock deforestation coefficient in the Amazon region, as calculated by (Equation 24), by the elements in  $PTS_{RMAM}^{RMAM}$  and  $PTS_{REAM}^{RMAM}$  that represent the output of the Livestock sector in the two regions of the Amazon (Regions 1 and 2) produced to fulfill the households consumption of the Amazon Metropolitan regions of all sectors, considering both direct production of this output and the indirect production of the inputs needed to produce this output. This will give us the deforestation caused by the Livestock sector to fulfill the households consumption from Amazon Metropolitan Regions. Then, we repeat this procedure for the Agriculture sector: we multiply the Agriculture deforestation coefficient in the Amazon region, as calculated by (X), by the elements in  $PTS_{RMAM}^{RMAM}$  and  $PTS_{REAM}^{RMAM}$  that represent the output of the Agriculture sector in the two regions of Amazon (Regions 1 and 2) produced to fulfill the consumption from households of the Amazon Metropolitan regions of all sectors, considering both direct production of this output and the indirect production of the inputs needed to produce this output. This will give us the deforestation caused by the Agriculture sector to fulfill the households consumption from the Amazon Metropolitan Regions. Finally, we add the deforestation caused by the Livestock production to attend the consumption of households from Amazon Metropolitan Regions with deforestation caused by the Agriculture production to fulfill household consumption in the Amazon Metropolitan Regions, and obtain the total deforestation caused by the production to fulfill the demand of all sectors from households of the Amazon Metropolitan Regions.

Reproducing this procedure for all 4 regional demand vectors (Consumption of households from the Amazon Metropolitan Regions; Consumption of households from the Rest of the Amazon; Consumption of households from the Rest of Brazil; and Exportations), we obtained the results shown Table 7.

**Table 7: Deforestation on Brazilian Amazon caused by families consumption from each region in Brazil**

Regional Demand Vectors	Deforestation (ha)	Population (inhabitants)	Deforestation per capita (ha / 100 inhabitants)	Relative per capita Deforestation
Household consumption from families within Metropolitan Regions in Amazon (A)	191,513(16%)	6,747,872	2.8	7.7
Household consumption from families in the Rest of the Amazon (B)	134,110(11%)	16,729,306	0.8	2.2
Household consumption from families within Amazon (Total: A + B)	325624.155152292 (27%)	23,477,178	1.4	3.7
Household consumption from Families in the Rest of Brazil	590,451 (49%)	159,442,364	0.4	1.0
Exportations	283335 (24%)	NA	NA	NA
<b>Total</b>	<b>1,199,411</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>

Source: Research Data

As we can see, in absolute terms, about 73% of Brazilian Amazon deforestation is due to the demand vectors from regions outside Brazilian Amazon (49%) and exportations (24%). Thus, household consumption from within Amazon is responsible for the other 27%. At a first glance, this latter may seem small in an absolute

comparison with the Rest of Brazil. However, keeping in mind that Amazon population represents only 12% of total Brazilian population, it becomes clear that each individual within the Amazon region weights more, in terms of deforestation, than individuals from outside this area. Again, this is an expected result in theoretical terms, since there are lower transportation costs for producers within the Amazon region to sell their products within the region. Still, we remind that even though this result may seem obvious for some, for some unknown reason it is still being overlooked by empirical literature on Amazon, in terms of policy prescription for forest preservation.

Moreover, another clear message from Table 7 is regards the weight of urbanization over deforestation. Household consumption from the Metropolitan Regions is responsible for a larger share of the Amazon deforestation (16%) than families living in the Rest of the Amazon regions itself. Bearing in mind that families in the rest of the Amazon are closer to the forest, as the forest is mainly located at this region, and also population from the Metropolitan regions represents only 25% of the total Amazonian population, this evidence thus suggests that consumption from individuals living in the highest urban conglomerates of Brazilian Amazon weigh even more than individuals living in smaller cities or rural areas. Also, this is expected from a theoretical perspective, because Spatial Economists state that urbanization is often accompanied by an increase in consumption patterns due to the development and growth it brings by its agglomeration externalities and increasing returns to scale (see Fujita & Thisse, 1999).

All these results are confirmed, and more easily checked, when we measure them in per capita terms (see Table 7. We did not calculate the per capita results for the export vector, because we would be underestimating this result, and we would have to divide the resulting deforestation caused by exports by the population of all countries, however, not every country consumes products from the Amazon region. For the within Brazil vectors, however, as it is the same national economy, this calculation can be done without major problems. Analyzing the results, it is easy to note that one individual from within the Amazon region (Metropolitan regions or the Rest of Amazon) is weighted 3.7 times more, on average, than one individual from the Rest of Brazil, in terms of the deforestation which results from the consumption of all goods and services (1.4 hectares per one hundred inhabitants within the Amazon region vs. 0.4 hectares per one hundred inhabitants in the Rest of Brazil). Moreover, if this individual lives within the Metropolitan regions of the Amazon, this weight is 7.7 times higher than the weight of an individual living in the Rest of Brazil, or even 2 times higher than the weight from the consumption of one individual living within the Amazon region, but outside the Metropolitan areas. These per capita results confirm that local demand vectors, especially in the most urbanized largest cities of Brazilian Amazon, exert a considerable relative pressure over deforestation, as predicted by Spatial Economista, when compared to the pressure exerted by individuals in farther areas, or even closer but less urbanized areas.

Moreover, considering that the urbanization process is still increasing within the Amazon region, and also that these results refer to the year of 2004, which means we are not considering the last 8 years in our calculation, and in these 8 years a rapid expansion of cities is being observed in Brazilian Amazon, then our results are probably underestimating the impacts of local demand vectors and local urbanization on deforestation. This also means that even the results in absolute terms from Table 7 are underestimated; thus, it is reasonable to assume that local demand vectors are,

nowadays, responsible for more than 27% of the total deforestation in Brazilian Amazon.

## 6 FINAL REMARKS

The Brazilian Amazon is going through an important process of population augmentation and growing urbanization in the last decades. Spatial Economics models point out clearly that such a process may bring relevant impacts on local land use and deforestation, due to development and growth which are caused by urbanization, and also because of lower transportation costs to sell locally the output produced in previously forest-covered areas. However, somehow this process is still being overlooked by analysts who examine the causes of deforestation of the Amazon rainforest.

In this study, we fill this gap by trying to measure how much of this deforestation is due to the consumption of goods and services from households who live within the Amazon region itself, comparing it to deforestation driven by consumers who live outside the Amazon. As the Brazilian Amazon contains 5 big Metropolitan Regions, and in order to take into account this referred urbanization process in our calculations, we not only compared the effects of demand vectors from within and outside Brazilian Amazon, but we also isolated the effects from consumption of households who live within the Metropolitan Areas of Brazilian Amazon from the consumption vector of families who live within Amazon, but outside those Metropolitan regions.

Using an Inter-regional Input-Output model with socioeconomic data, and combining this database with information on land-use transition from forest areas to agricultural and livestock land use, we found robust evidence that these local demand vectors play an important role in terms of the deforestation they drive. Results show that even though the local population from the Amazon region represents only 13% of total Brazilian population, it drives around 30% of the total deforestation taking place within the region, through its direct and indirect consumption of the output produced in forest areas. The demand vector from families who live within the Amazonian Metropolitan Regions is responsible for more than a half of this 30%, even though only 25% of Amazon population live in these areas. In per capita terms, results also show that the demand vector from one individual living within the Amazon region, but outside the Metropolitan areas, generates 2.2 more deforestation than the consumption vector of one individual living outside Amazon, but within Brazil. For the consumption vector of one individual living within the Amazonian Metropolitan Regions, the deforestation impact is even higher: it is 7.7 times the impact of the demand vector from one individual living outside Brazilian Amazon. The results concerning the economic multipliers, as well as the ones focusing only on the output per sector driven by each regional demand vector also point in this same direction.

Therefore, these results bring support the theoretical expectations from Spatial Economics that local demand vectors and the urbanization process taking place within Brazilian Amazon play an important role in terms of the deforestation it might cause.

Bearing in mind that these results refer to the year 2004, and both local population growth and urbanization have been growing rapidly since then in the

Amazon region, these local demand effects on deforestation cannot continue to be overlooked, if one wants to choose the correct policies of deforestation prevention in the future.

### ***Appendix A – Data and definitions issues regarding the geographic division of region 1: The metropolitan regions of the Amazon***

The five Metropolitan Regions we selected to define Region 1 are the ones officially defined by IBGE, the Brazilian government official geography institute, as belonging within the Brazilian Amazon. However, two important issues arise with regard to the choice of these five areas to compose Region 1.

First, many researchers argue that there are more urban conglomerations within the Brazilian Amazon that could be considered metropolitan regions. However, as those are not officially declared by IBGE as Metropolitan Regions, we did not include them in Region 1, and therefore, they belong to Region 2 in our analysis. This choice, in fact, can be considered a conservative strategy, in terms of measuring the impacts of urbanization over deforestation. Because we diminish the number of possible urban conglomerates in our analysis, our results tend to underestimate the impacts of urbanization, as the demand vector representing urbanizations also is also smaller. As this is a conservative criteria, we chose to adopt it instead of trying to define which are the possible “real” Metropolitan Regions Brazilian Amazon, for this second strategy would need several other controversial hypotheses, which we want to avoid, for this is not the main goal of this paper.

Second, due to database issues, we were not able to build Region 1 considering only the municipalities within each of the 5 Metropolitan Regions. The reason for that is because our inter-regional Input Output tables can only be built at the level of IBGE “Micro regions”, and sometimes these Micro regions correspond not only to the municipalities within Amazonian Metropolitan Regions, but also contain a few other municipalities that do not belong to the Metropolitan Areas. Table 8 shows the relationship between those the municipalities from the Micro Regions that compose Region 1 in our analysis, indicating whether or not they belong to the Metropolitan Regions defined by IBGE, and also including the share of urban population each city holds.

**Table 8 – IBGE Micro Regions and Metropolitan Regions.**

City	Metropolitan Region (MR)	Micro Region	Population in 2010	Urban Population in 2010	Share of Urban Population in 2010
Barcelos	-	13001	25,718	11,157	43.38%
Novo Airão	MR Manaus	13001	14,723	9,499	64.52%
Santa Isabel do Rio Negro	-	13001	18,146	6,856	37.78%
São Gabriel da Cachoeira	-	13001	37,896	19,054	50.28%
Autazes	-	13007	32,135	13,893	43.23%
Careiro	MR Manaus	13007	32,734	9,437	28.83%
Careiro da Várzea	-	13007	23,930	1,000	4.18%
Iranduba	MR Manaus	13007	40,781	28,979	71.06%
Manacapuru	MR Manaus	13007	85,141	60,174	70.68%
Manaquiri	-	13007	22,801	7,062	30.97%
Manaus	MR Manaus	13007	1,802,014	1,792,881	99.49%
Presidente Figueiredo	MR Manaus	13008	27,175	13,001	47.84%
Rio Preto da Eva	MR Manaus	13008	25,719	12,205	47.46%
Itacoatiara	MR Manaus	13009	86,839	58,157	66.97%
Itapiranga	-	13009	8,211	6,451	78.57%
Nova Olinda do Norte	-	13009	30,696	13,626	44.39%
Silves	-	13009	8,444	4,029	47.71%
Urucurituba	-	13009	17,837	10,448	58.57%
Ananindeua	MR Belém	15007	471,980	470,819	99.75%
Barcarena	-	15007	99,859	36,297	36.35%
Belém	MR Belém	15007	1,393,399	1,381,475	99.14%
Benevides	MR Belém	15007	51,651	28,912	55.98%
Marituba	MR Belém	15007	108,246	107,123	98.96%
Santa Bárbara do Pará	MR Belém	15007	17,141	5,458	31.84%
Serra do Navio	-	16003	4,380	2,575	58.79%
Pedra Branca do Amapari	-	16003	10,772	5,963	55.36%
Cutias	-	16003	4,696	2,442	52.00%
Ferreira Gomes	-	16003	5,802	4,175	71.96%
Itaubal	-	16003	4,265	1,754	41.13%
Macapá	MR Macapá	16003	398,204	381,214	95.73%
Porto Grande	-	16003	16,809	10,809	64.30%
Santana	MR Macapá	16003	101,262	99,111	97.88%
Paço do Lumiar	MR Grande São Luís	21002	105,121	78,811	74.97%
Raposa	MR Grande São Luís	21002	26,327	16,675	63.34%
São José de Ribamar	MR Grande São Luís	21002	163,045	37,709	23.13%
São Luís	MR Grande São Luís	21002	1,014,837	958,522	94.45%
Chapada dos Guimarães	-	51017	17,821	11,037	61.93%
Cuiabá	Cuiabá-Várzea Grande	51017	551,098	540,814	98.13%
Nossa Senhora do Livramento	-	51017	11,609	4,242	36.54%
Santo Antônio do Leverger	-	51017	18,463	7,160	38.78%
			<b>6,937,727</b>	<b>6,271,006</b>	<b>90.39%</b>

Source: IBGE Brazilian Census data.

As Table 8 shows, the municipalities that do not belong to Metropolitan Regions, but integer Region 1 are usually less urbanized, in terms of share of urban population, than the ones that constitute the Metropolitan Regions. Thus, this means that our results can be considered conservative, for we are underestimating the rate of urbanization of Region 1, and therefore, we are also underestimating the impacts of such urbanization over deforestation. Moreover, the total rate of urban population of Region 1, even with this underestimation issue, is still 90.4%, which can be considered big for any city in the world.

Besides, population living within the municipalities that comprise the 5 Metropolitan Regions of Amazon hold 94.7% of the total population from Region 1 as defined in our estimations. Thus, in terms of overestimating the total population living in the Metropolitan Region, the bias we may commit represents about 5%.

Still, even with these two urbanization underestimation problems, and this population overestimation issue, our results show robust evidence that urbanization seems to be exerting a great impact on deforestation in the Brazilian Amazon, and as these impacts are relevant, our main message does not change substantially; on the

contrary, the robustness of our evidence might be considered even stronger given such considerations.

## Appendix B – Sectoral aggregation map

**Table 9 – Sectoral Aggregation Map.**

Original Industry Number	Original Industry	New Aggregated Industry Number	New Aggregated Industry Name
1	Agricultura, silvicultura, exploração florestal	1	Agricultura, silvicultura, exploração florestal
2	Pecuária e pesca	2	Pecuária e pesca
3	Petróleo e gás natural	3	Petróleo e gás natural
4	Minério de ferro	4	Minério de ferro
5	Outros da indústria extrativa	5	Outros da indústria extrativa
6	Alimentos e Bebidas	6	Alimentos e Bebidas
7	Produtos do fumo	7	Produtos do Fumo
8	Têxteis	8	Têxteis, Vestuário e Calçados
9	Artigos do vestuário e acessórios		
10	Artefatos de couro e calçados		
11	Produtos de madeira - exclusive móveis	9	Produtos de madeira - exclusive móveis
12	Celulose e produtos de papel	10	Celulose e papel, Jornais, revistas e discos
13	Jornais, revistas, discos		
14	Refino de petróleo e coque	11	Refino de petróleo e álcool
15	Álcool		
16	Produtos químicos	12	Indústria Química
17	Fabricação de resina e elastômeros		
18	Produtos farmacêuticos		
19	Defensivos agrícolas		
20	Perfumaria, higiene e limpeza		
21	Tintas, vernizes, esmaltes e lacas		
22	Produtos e preparados químicos diversos		
23	Artigos de borracha e plástico		
24	Cimento	13	Minerais não metálicos
25	Outros produtos de minerais não-metálicos		
26	Fabricação de aço e derivados	14	Siderurgia e Metalurgia
27	Metalurgia de metais não-ferrosos		
28	Produtos de metal - exclusive máquinas e equipamentos		
29	Máquinas e equipamentos, inclusive manutenção e reparos	15	Máquinas e equipamentos em geral
30	Eletrodomésticos		
31	Máquinas para escritório e equipamentos de informática		
32	Máquinas, aparelhos e materiais elétricos		
33	Material eletrônico e equipamentos de comunicações		
34	Aparelhos/instrumentos médico-hospitalar, medida e óptico		
35	Automóveis, camionetas e utilitários	16	Veículos e fabricação de equipamentos de transporte transportes
36	Caminhões e ônibus		
37	Peças e acessórios para veículos automotores		
38	Outros equipamentos de transporte		
39	Móveis e produtos das indústrias diversas	17	Industria Moveleira
40	Eletricidade e gás, água, esgoto e limpeza urbana	18	Eletricidade e gás, água, esgoto e limpeza urbana
41	Construção	19	Construção
42	Comércio	20	Comércio
43	Transporte, armazenagem e correio	21	Transporte, armazenagem e correio
44	Serviços de informação	22	Serviços privados e mercantis
45	Intermediação financeira e seguros		
46	Serviços imobiliários e aluguel		
47	Serviços de manutenção e reparação		
48	Serviços de alojamento e alimentação		
49	Serviços prestados às empresas		
50	Educação mercantil		
51	Saúde mercantil		
52	Outros serviços		
53	Educação pública	23	Serviços e Administração Pública
54	Saúde pública		
55	Administração pública e seguridade social		

Source: Research Data

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