

Toward an Agent-Based Model for the Brazilian Economy

Data Initialization

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Number of Agents

The number of agents of each type in relation to other types will be based on the real proportions we observe in Brazilian time series and official records. The number of consumers, from now on E , is fixed in 2000 and the quantity of other agents is calculated from this number. We begin by reading data on Brazilian firms and employees¹. Some registers of this database are shown below (Table 1).

Table 1: Twenty first records of IBGE's Central Registry of Enterprises, 2015. First column represents the specialization according to CNAE 2.0. Bracket is in number of employees. Wage volume is in thousands of R\$.

	Bracket	Units	Employees	Salaried	Wage Volume	Avg. Min. Wages
01.1 Produção de lavouras temporárias	Total	25785	153479	122971	3296382	2.5
	0 a 4	24011	27076	2246	63192	1.6
	5 a 9	782	5000	2851	52334	1.8
	10 a 19	504	6449	4429	101708	2.1
	20 a 29	128	2988	2580	66161	2.2
	30 a 49	92	3605	3361	91794	2.5
	50 a 99	102	6895	6619	158734	2.4
	100 a 249	75	11709	11464	323595	2.5
	250 a 499	36	11773	11659	316903	2.5
	500 ou mais	55	77984	77762	2121961	2.6
01.2 Horticultura e floricultura	Total	5830	18770	12260	230209	1.8
	0 a 4	5265	6315	924	14540	1.3
	5 a 9	306	2000	1528	22525	1.4
	10 a 19	149	1947	1580	23315	1.5
	20 a 29	46	0	0	0	0.0
	30 a 49	28	1041	973	14707	1.4
	50 a 99	14	0	0	0	0.0
	100 a 249	15	2373	2323	46847	2.0
	250 a 499	5	1723	1714	46716	2.9
	500 ou mais	2	0	0	0	0.0

According to this dataset, in 2015 Brazil had approximately 4.7 million non-financial private firms, which employed around 43.2 million workers, and there were about 88.96 thousand private banks and other financial firms. The number of consumption goods firms was approximately 4.3 million, whereas the number of capital goods firms was around 0.4 million.

We need to consult the unemployment rate series to calculate the total number of workers available in 2015. That year, the unemployment rate was 8.3% in 2015, as disclosed by IBGE's *Monthly National Household Survey*, so the total number of workers can be approximated to 47.14 million.

Let F_1 be the number of consumption goods firms, F_2 the number of capital goods firms, and B the number of banks within the model. Then:

¹Brazilian Institute for Statistics and Geography, Central Registry of Enterprises (2015)

Table 2: Number of agents of each type.

Description	Unit	Value
Number of Consumers	consumers	2000
Number of Unemployed Consumers	consumers	166
Number of Consumption Goods Firms	firms	184
Number of Capital Goods Firms	firms	16
Number of Banks	banks	4

Table 3: GDP and its components.

Description	Unit	Value
Real GDP	goods	77094000
Real GDP per employed worker (last 12 months)	goods	42036
Percentage of salaries in GDP	percentage	44
Profit per employed worker (last 12 months)	goods	23540

$$F_1 \approx E \cdot \left(\frac{4.3}{47.1} \right) \approx 2000 \cdot 0.092 \approx 184 \quad (1)$$

$$F_2 \approx E \cdot \left(\frac{0.4}{47.1} \right) \approx 2000 \cdot 0.008 \approx 16 \quad (2)$$

$$B \approx E \cdot \left(\frac{0.1}{47.1} \right) \approx 2000 \cdot 0.002 \approx 4 \quad (3)$$

Table 2 shows a list of the parameters already discussed.

Gross Domestic Product

The initial Gross Domestic Product (GDP) of the model was defined in terms of the population of consumers, just as every other model parameter. First, we collect the values of the real² and the nominal³ GDP. In 2015, real GDP was around R\$ 1.8 trillion. Nominal GDP, provided by the Department of Economics of the Central Bank of Brasil (BCB/Depec), was about R\$ 6 trillion in 2015.

If y is the real GDP per worker in 2015, then the model's initial GDP, Y , can be written as

$$Y = y \cdot E \approx \left(\frac{1.8e + 06}{47.1} \right) \cdot 2000 \approx (3.9e + 04) \cdot 2000 \approx 7.7e + 07 \quad (4)$$

At this point we also need to obtain the percentage of salaries in GDP⁴. The most recently published data on detailed composition of Brazilian GDP are from 2014's *National Accounts System* (IBGE), but these are surely good approximations for 2015's values. In 2014, wages accounted for 44% of the GDP. Hence, profits were 56% of the GPD that same year. These figures allowed us to set some other parameters, as shown in table 3.

²World Bank, World Development Indicators (2017)

³Central Bank of Brasil (BCB), Department of Economics

⁴The GDP can be defined as the total sum of salaries and profits in an economy

Table 4: Aggregated data for capital goods firms, by brackets. Some columns are not shown, because they are not going to be useful in the following calculations.

Bracket	Units	Employees
0 a 4	277072	500346
10 a 19	26293	347908
100 a 249	1871	263939
20 a 29	7308	166033
250 a 499	629	180062
30 a 49	5229	179502
5 a 9	56226	349936
50 a 99	3641	250889
500 ou mais	616	1189663

Table 5: Number of firms and employees per bracket.

Bracket	Units	Employees	units	employees
0 a 4	277072	500346	12	22
10 a 19	26293	347908	2	15
100 a 249	1871	263939	1	12
20 a 29	7308	166033	1	8
250 a 499	629	180062	1	8
30 a 49	5229	179502	1	8
5 a 9	56226	349936	3	15
50 a 99	3641	250889	1	11
500 ou mais	616	1189663	1	51

Initial profits were assigned to each firm according to its number of workers. The unit of profit, π_u , is shown in the table above (*Profit per employed worker*). If a firm has N employees, its starting profit is $N \cdot \pi_u \cdot x$, where $x \sim U(0, 2)$. This way, we introduce more heterogeneity into the system, by allowing some firms to begin with littler or no profits and other with outstanding past results. Given that the mean of x is 1, the average initial profit per worker matches real data.

Number of Employees Per Firm

The *Central Register of Enterprises* also serves the purpose of calculating how many employees each firm must have. Before all else, we extract two groups from the dataset: consumption goods firms and capital goods firms. Then, we aggregate data by brackets, adding grouped columns for each subset. For instance, capital goods subset would look like the table shown below (table 4).

The next step is to divide each element from the column *units* by the sum of all elements, so as to find the percentages they represent. On the other hand, elements of *employees* are divided by 43230386, which is the total number of workers registered in the original dataset (the sum of employees from capital and consumption goods firms). This way, this column will represent percentages of the total number of workers. Having these columns of percentages, we multiply the first by the number of the associated type of firm within the model (16 capital goods firms and 184 consumption goods firms) and the second by the number of employed consumers (1834). The results are presented in table 5.

Note that the second column, *employees* represent the total number of employees in all units. Therefore, we find the average number of employees per firm and round it down to the nearest integer. Some firms will have this number of employees, while others will have one more, in order to absorb the remainder. For instance, if *employees* is 535 and *units* is 100, 65 firms will have 5 employees and 35 firms, 6 employees, since

Table 6: Distribution of employees per firm. The first table presents results for capital goods firms. The second, for consumption goods firms.

N. Firms	N. Employees	Tot. Employees	N. Firms	N. Employees	Tot. Employees
3	1	3	34	1	34
9	2	18	99	2	198
1	4	4	22	6	132
2	5	10	7	7	49
5	28	35	11	12	132
1	10	10	4	13	52
1	11	11	2	19	38
1	50	50	2	20	40
			3	31	93
			1	54	54
			1	55	55
			1	82	82
			1	121	121
			1	507	507

$\lceil 535/100 \rceil = 5$ and the remainder is 35, which imposes that 35 firms have $5 + 1 = 6$ employees. We now have the initial distribution of employees per firm. The result of such calculations are shown in table 6.

Distribution of Wealth and Income

Workers belong to social classes that are defined by income brackets. Each of these brackets concentrates a certain amount of wealth and is delimited by monthly earnings in terms of minimum wages. In this session we show how we attributed a social class to every worker and set his income and wealth accordingly. Data on the distribution of wealth and income are yearly disclosed by the Federal Revenue Office. The dataset is presented below (table 7).

Wealth is on the last column of this dataset, and totals on the last row. Hence, total wealth is element (18, 6) of table 7 multiplied by 1 million (data are in R\$ millions). To find the model's total wealth proportional to its GDP, we have to divide it by the nominal GDP, since income and wealth are in nominal values, and then multiply it by the model's initial GDP. By doing so, we find that the model initial total wealth is 92.4 million.

Given that the table separates income that is exempt from taxes (column 5) from income that is not exempt (column 3), we collapse the two values by adding them. Column 4 is removed because it contains income from investments and real-state, but the current version of the model does not incorporate these.

IBGE divides the population in social classes according to the number of minimum salaries workers earn each month. So we aggregate the lines of table 7 following this classification.

First, we found the percentage of people in each class in the Brazilian population. Then, we applied those percentages to the model and, using the unemployment rate, calculated the numbers of employed and unemployed workers within a class. For instance, 8.45% of the Brazilian population belongs to class A. Hence, 169 ($= 2000 \cdot 0.845$) workers in our model must belong to this class, 14 ($= 169 \cdot 0.83$) being initially unemployed and 155 ($= 169 - 14$), employed. Results of these computations are exhibited above (table 8).

Debt

Non-corporate debt is expressed as a percentage of household income⁵. Since families in our model are composed of one member only, this percentage represents approximately how much debt each worker has in relation to his income, in the first run. Actually, non-corporate debt rate was assigned to consumers following

⁵BCB, Household Debt without Mortgage Loans (Series 20400)

Table 7: Income and wealth distribution.

Bracket	Population	Income	Not Exempt	Exempt	Wealth
Até 1/2	1301366	254	46	113	136273
Mais de 1/2 a 1	573674	4487	92	341	38903
Mais de 1 a 2	1227268	14525	599	2553	135712
Mais de 2 a 3	3278035	73567	2159	6323	268682
Mais de 3 a 5	7403868	228922	16832	29606	526420
Mais de 5 a 7	4339708	192783	16498	32910	443328
Mais de 7 a 10	3352450	202073	18801	42627	496954
Mais de 10 a 15	2536352	211127	21922	58535	604905
Mais de 15 a 20	1180520	130938	15647	45710	445973
Mais de 20 a 30	1086611	157914	21739	69414	622922
Mais de 30 a 40	489421	92454	14777	51599	426299
Mais de 40 a 60	389811	89905	18318	69382	524434
Mais de 60 a 80	142916	37610	10550	44527	303922
Mais de 80 a 160	141451	40987	18427	84343	533681
Mais de 160 a 240	32329	11540	8269	39315	245037
Mais de 240 a 320	13753	6063	5447	24337	151526
Mais de 320	29311	27541	62826	207572	1288419
Total	27518844	1522690	252949	809206	7193391

Table 8: Wealth and income of our model's consumers.

	Employed	Unemployed	Monthly Wage	Wealth
A	155	14	8571	311371
B	248	22	2134	49981
C	513	46	1078	21609
D	712	64	549	13158
E	207	19	122	17715

a $U(0, 54.34)$ distribution, whose mean is exactly the percentage found in Brazilian data (27.17, as shown in the table below). We did so because some individuals might not hold debt at all, but others may be severely indebted.

Corporate debt⁶ is split among firms roughly in proportion to the their number of employees. It means that the whole amount of debt is divided into the total number of workers, and the result of this division is the unit of debt, which is then multiplied by a uniform random variable between 0 and 2 (such that the mean is exactly the unit of debt). For instance, a firm with 5 workers has an initial debt of 5 times this randomized unit. Again, the idea of using a random element is to introduce heterogeneity and account for different levels of indebtedness. This level, however, refer only to the long-term debt. We will talk about short-term debt later.

⁶BCB, Credit operations outstanding by type of borrower - Private sector (Series 22047)

Table 9: Debt parameters

Description	Unit	Value
Mean household debt (% last 12 months earnings)	goods	27.17
Mean firms debt (% GDP)	goods	23.00
Firms debt per employee	goods	9668.28

Table 10: Interest rates

Description	Unit	Value
Mean interest rate on loans - workers	monthly yield	3.95
Mean interest rate on loans - firms	monthly yield	2.08
Mean interest rate on savings	monthly yield	0.65
Bankruptcy rate	yearly %	3.10

As usual, real values were those of 2015 and compatibilization with model units was achieved through simple proportions.

Interest Rates

Interest rates charged on loans are different across types of agents. The risk of a worker defaulting on his debt is greater than the risk of a firm going bankrupt. Therefore, a worker must pay higher interests on loans. The same logic applies to firms of different sizes. Smaller firms offers more risk, so they must be charged higher interests.

In view of the lack of data on the dimensions of the differences among these charges, interest rates will be calibrated along with several other parameters in the second model. However, in the first model, banks choose initial values for each type of borrower obeying a very simple rule. A mean rate, which is the interest demanded from medium firms, is attributed to each bank according to a normal distribution, whose mean is the real mean of interest rates on new credit operations⁷ in 2015. Banks add or subtract a uniformly random value between 0 and 0.5 to set other interest rates. For example, if the interest charged to medium firms is 2.08, then to small firms it could be 2.29 ($= 2.08 + 0.21$), to micro firms, 2.43 ($= 2.29 + 0.14$), and to large firms, 1.65 ($= 2.08 - 0.43$).

⁷BCB-Dstat, Monthly average interest rate of nonfinancial new credit operations - Non-financial corporations (Series 25437) and Households (Series 25462)