THE CONSTRUCTION OF AN UPDATED ECONOMIC DATABASE FOR ENERGY STUDIES: AN APPLICATION TO THE BRAZILIAN SUGARCANE AGROINDUSTRY[1]

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ABSTRACT

The construction of an updated input-output (i-o) table for studying the Brazilian sugarcane agroindustry is discussed in detail. The database was built in two stages. Firstly, an i-o table containing 42 sector and 80 commodities for 2002 was estimated, using an updating method that uses preliminary national accounting data. Secondly, the sugarcane and ethanol industries were disaggregated from the sectors they appear in IBGE economic tables, based on detailed engineering information obtained from experts and specialized publications. The database thus obtained was used in an i-o model with mixed technologies to analyze the socioeconomic impacts of a large-scale expansion of bioethanol production in Brazil.

KEY WORDS

Input-output modeling, energy, bioethanol, Brazil.

INTRODUCTION

Constructing a database is frequently the most demanding task involved in input-output (i-o) modeling. As remarked by Leontief (1989):

> Theorizing requires inspiration and technical knowhow, while data gathering – particularly for practical implementation of large models – needs much sweat and tears, and always a large amount of time and money. No wonder we face overproduction of models and underinvestment – both intellectual and financial – into compilation of the data bases needed to implement them.

The mathematical structure of an i-o model is somewhat simple and its accuracy depends mainly on the correctness of the data used.

The development of an updated i-o table for studying the Brazilian sugarcane agroindustry followed two stages. Firstly, an i-o table containing 42 sectors and 80 commodities for 2002 was estimated, using an updating method that uses preliminary national accounting data published by IBGE (the official statistics bureau for Brazil). Secondly, the sugarcane and ethanol industries were disaggregated from the sectors they appear in IBGE economic tables, based on detailed engineering information obtained from experts and specialized publications. In Brazil, sugarcane can be collected manually or via harvesting machines and alcohol can be produced in plants appended to a sugar mill (appended distilleries) or in autonomous

[1] This work was carried out as part of the thematic project "Study on the possibilities of and impacts from large scale production of ethanol aiming at the partial substitution of gasoline in the world", funded by the Brazilian Center for Management and Strategic Studies (CGEE). It comprises only the socioeconomic impact analysis. The technological, transportation and environmental issues involved in the study were investigated by other research team members.

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distilleries (plants that produce ethanol only). All these different technologies were considered in the database.

UPDATING INPUT-OUTPUT TABLES

The most recent i-o table at basic prices made available by IBGE refers to the year of 1996. However, IBGE releases information on transactions evaluated at purchaser's prices for more recent years (currently up to 2002 in consolidate form) in its system of national accounts (IBGE, 2006). All these tables can be used to estimate an i-o table for 2002, as described below.

In Brazil, the i-o tables are compiled presently from 15 basic commodity-by-industry matrices, as shown in the table below.

The matrices of the Brazilian input-output tables

1	Supply (imports, make, taxes and margins) matrix
2	Use (absorption) matrix at purchaser's prices
3	Domestic use (absorption) matrix at basic prices
4	Imports matrix at basic prices
5	Matrix of import taxes
6	Matrix of ICMS[(a)] taxes on domestic commodities
7	Matrix of ICMS[(a)] taxes on imports
8	Matrix of IPI[(b)] and ISS[(c)] taxes on domestic commodities
9	Matrix of IPI[(b)] and ISS[(c)] taxes on imports
10	Matrix of trade margins on domestic commodities
11	Matrix of trade margins on imports
12	Matrix of transport margins on domestic commodities
13	Matrix of transport margins on imports
14	Table of other taxes and margins on domestic commodities
15	Table of other taxes and margins on imports

[(a)] ICMS: tax on the flow of commodities (a state sales tax)
[(b)] IPI: tax on industry product (a federal sales tax)
[(c)] ISS: tax on services (a municipal tax)

IBGE provides the complete set of matrices for the years 1985 and 1990–1996. However, only matrices 1 and 2 are available for the years of 1997–2002[3]. The updating exercise consists in obtaining estimates of the remaining matrices, using the complete i-o table of 1996 and the matrices 1 and 2 for 1997–2002.

Obviously, there may be various ways for obtaining such estimates. For instance, the *ad-hoc* method suggested by Guilhoto and Sesso (2005) distribute row-wise the total imports, taxes and margins on products (obtained from matrix 1) using as reference the transaction values at purchaser's prices observed in matrix 2. However, this simple method may produce unexpected values. The multiple proportion correction (MPC) method described here rests on the assumption that changes of the technical coefficients may be approximated by the corresponding alterations of the transaction values in matrix 2 (evaluated at purchaser's prices). This is explained in detail below.

Matrices 3–15 have 80 rows (products) and 48 columns (the 42 sectors classified by IBGE, the so-called financial dummy[4] and the five components of final demand – exports, government purchases, household consumption, investments and stock changes). The

[3] The input-output table corresponding to 2003 is still under revision.
[4] The financial dummy is used by IBGE for GDP correction.

standard IBGE classification of sectors and commodities are indicated in appendices A and B, respectively. The problem thus consists in estimating $80 \times 48 \times 13 = 49{,}920$ transaction values for a given year.

Let $M^{k,t}$ be the matrix *k* of the i-o table for year *t*, as defined in Table 1. Also, let $M_{i,j}^{k,t}$ be the transaction value in matrix *k* for commodity *i* in sector *j* observed or estimated in year *t*. For instance, $M_{2,3}^{10,1998}$ denotes the estimated trade margin associated with the purchase of domestic commodity 2 by sector 3 in the year of 1998.

It is important to notice that

$$M^{2,t} = \sum_{k=3}^{15} M^{k,t} \quad (t = 1985, 1990, .\mathbf{K}\, 2002) \tag{1}$$

i.e., the use matrix at purchaser's prices may be decomposed into transactions evaluated at basic prices ($M^{3,t}$), imports, taxes and margins.

Now let

$$A_{i,j}^{k,t} = \frac{M_{i,j}^{k,t}}{X_j^t} \quad (i = 1, \mathbf{K}, 80;\ j = 1, \mathbf{K}, 42;\ k = 2, \mathbf{K}, 15;\ t = 1985, 1990, \mathbf{K}, 2002) \tag{2}$$

where X_j^t is the total output of sector *j* in year *t*.[5] It should be pointed out that elements $A_{i,j}^{k,t}$ comprise only the rows and columns of $M_{i,j}^{k,t}$ corresponding to intermediate consumption.

It is convenient to define $A^{k,t}$ as the 80×42 matrix formed by $A_{i,j}^{k,t}$. In particular, $A_{i,j}^{2,t}$ and $A_{i,j}^{3,t}$ are the matrices of technical coefficients at purchaser's and basic prices, respectively.

It follows from (1) and (2) that

$$A_{i,j}^{2,t} = \frac{\sum_{k=3}^{15} M_{i,j}^{k,t}}{X_j^t} = \sum_{k=3}^{15} A_{i,j}^{k,t} \quad (i = 1, \mathbf{K}, 80;\ j = 1, \mathbf{K}, 42;\ t = 1985, 1990, \mathbf{K}, 2002)$$

so that

$$A^{2,t} = \sum_{k=3}^{15} A^{k,t} \quad (t = 1985, 1990, \mathbf{K}, 2002) \tag{3}$$

The matrices of transactions at purchaser's prices, $A^{2,t}$, $t = 1985, 1990, \mathbf{K}, 2002$, are known and may be used as a reference for estimating $A^{3,t}, \mathbf{K}, A^{15,t}$, $t = 1997, \mathbf{K}, 2002$. Accordingly, let

$$r_{i,j}^t = \frac{A_{i,j}^{2,t}}{A_{i,j}^{2,t-1}} \quad (i = 1, \mathbf{K}, 80;\ j = 1, \mathbf{K}, 42;\ t = 1997, \mathbf{K}, 2002)$$

The main assumption of the updating method described here is that

$$A_{i,j}^{k,t} \approx r_{i,j}^t\, A_{i,j}^{k,t-1} \quad (i = 1, \mathbf{K}, 80;\ j = 1, \mathbf{K}, 42;\ k = 3, \mathbf{K}, 15;\ t = 1997, \mathbf{K}, 2002) \tag{4}$$

The initial solution for recursive equations (4) are the known matrices $A^{3,1996}, \mathbf{K}, A^{15,1996}$.

These approximations respect (3) since

$$\sum_{k=3}^{15} r_{i,j}^t A_{i,j}^{k,t-1} = r_{i,j}^t \sum_{k=3}^{15} A_{i,j}^{k,t-1} = r_{i,j}^t\, A_{i,j}^{2,t-1} = A_{i,j}^{2,t} \quad (i = 1, \mathbf{K}, 80;\ j = 1, \mathbf{K}, 42;\ t = 1997, \mathbf{K}, 2002)$$

[5] The sectoral output are known for the years of 1985 and 1990–1996.

The financial dummy and the final demand components are estimated similarly. For the final demand components, for instance, (2) is redefined as

$$A_{i,j}^{k,t} = \frac{M_{i,j}^{k,t}}{\sum_{i=1}^{80} M_{i,j}^{k,t}} \quad (i = 1, \mathbf{K}, 80;\ j = 44, \mathbf{K}, 48;\ k = 2, \mathbf{K}, 15;\ t = 1985, 1990, \mathbf{K}, 2002) \qquad (5)$$

Next, each $M^{k,t}$ is obtained from the corresponding matrix $A^{k,t}$ using (2) and (5). Clearly, equations (1) are satisfied.

For a given *t*, the matrices $M^{3,t}, \mathbf{K}, M^{15,t}$ have to be consistent with the columns of imports, taxes and margins represented in matrix 1 (as indicated in Table 1). For example, it is necessary, for all *t*, that $\sum_{j=1}^{48} M_{i,j}^{4,t}$ be the total import of commodity *i* in matrix 1. However, this is not expected to occur.

A simple multiple proportion correction is then applied on matrices 3–15 so as to guarantee the consistency with matrix 1. Since this will eventually violate (1), in the following step matrices 3–15 are corrected once more, this time to make them consistent with matrix 2. This iterative process is repeated until consistency of matrices 3–15 with matrices 1 and 2 is simultaneously obtained within a given margin of tolerance. Up to now there is not any theoretical result assuring that the method will ultimately converge. Nevertheless, in the experiments conducted, the method was able to produce consistent matrices.

The method described above was numerically tested. It was applied to the 1990–1996 i-o tables released by IBGE to obtain an estimate of the 1996 transaction matrix at basic prices. The criterion was to compare the production multipliers calculated from two i-o tables: the first is the one estimated by the method; the other is that released by IBGE. The result is shown in appendix C. The average absolute deviation between the two series is about 1.14%. The values diverged by more than 1.5% for only seven sectors. This demonstration experiment suggests that tables updated by the proposed method may be reliable in i-o applications.

DISAGGREGATING SUGARCANE AGROINDUSTRY SECTORS

A one-to-one correspondence between producing sectors and commodities is commonly assumed in i-o models. However, the make matrix provided by IBGE shows sectors producing more than one commodity. Consequently, it was necessary to obtain first a normalized i-o table considering that each sector produces only one commodity. The industry-by-industry approach and the industry-based technology assumption were adopted (Miller and Blair, 1985). The industry-technology hypothesis considers that in each sector primary and secondary commodities are produced using the same inputs in the same proportion, but in quantities that are proportional to their output. The errors introduced by this normalization process are not significant since primary commodities constitute over 90% of total production in 40 of the 42 sectors detailed in the IBGE i-o tables.

The sugarcane and ethanol industries were then disaggregated from the sectors they appear in IBGE i-o tables. Sugarcane is in the primary sector of agriculture, forestry and fishing. Ethanol is included in the sector of chemicals (excluding pharmaceuticals).

Disaggregating a sector requires that some information be given about its intermediate consumption, imports, taxes and payments to the factors of production.

Sugarcane and ethanol are included in the *products* classified by IBGE, as indicated in appendix B, and so the corresponding rows in the commodity-by-industry use table were maintained in the normalized direct requirement matrix.

It is often necessary to gather engineering information about cost proportions for labor and the main products used in the sectors to be split. A preliminary cost description for the sugarcane and ethanol sectors were obtained by consulting experts and technical publications in the sugarcane agroindustry. The transaction values for these sectors were simply subtracted from the corresponding columns in the normalized use matrix, so that further numerical adjustments were not necessary.

In Brazil, sugarcane can be collected manually or via harvesting machines and alcohol can be produced in plants appended to a sugar mill (appended distilleries) or in autonomous distilleries (plants that produce ethanol only). All these different production technologies were inserted in the database in a bottom-up manner, as described above.

Finally, the database was calibrated to be consistent with the main socioeconomic indicators observed in 2002, such as employment and average wage. The following parameters were considered valid for 2002:

- Sugarcane harvest: 73% manual, 27% mechanized;
- Sugarcane production: 320.65 million tonnes (84.3% and 15.7% for the center-south and north-northeast regions, respectively);
- Jobs in the sugarcane sector: 41.3% and 58.7% for the center-south and north-northeast regions, respectively;
- Average wage in the sugarcane sector: in the north-northeast states, it is 41.7% of the one observed in the center-south region;
- Ethanol distilleries: 85% appended, 15% autonomous (in volume produced).

The derived i-o coefficients are shown in appendix D. It can be observed that the ratio between employment coefficients for the manual and mechanical harvest is about 6. The sugarcane output of R$ 100.000[6] requires six jobs in the manual mode or just one if harvest is mechanized.

CONCLUSIONS

The experience of constructing a database for energy studies was described.

A novel method for updating i-o tables was detailed. In the experiments conducted, the method was able to produce consistent matrices. As a suggestion for further work, it would be interesting to study the algorithm to verify its convergence properties. The results of numerical tests suggest that tables estimated by the proposed method may be reliable in i-o applications.

It was necessary to combine economic and engineering information to produce an i-o table having a detailed description for the energy sectors. General guidelines for disaggregating sectors in i-o tables were advanced.

The database was used in an extended i-o model with mixed technologies to analyze the socioeconomic impacts of a large-scale expansion of bioethanol production in Brazil (Scaramucci and Cunha, 2006).

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[6] R$ (real) is the Brazilian currency.

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APPENDIX A
STANDARD IBGE SECTOR CLASSIFICATION

Code	*Description*
1	Agriculture, forestry and fishing
2	Mining and quarrying
3	Petroleum and gas extraction
4	Non-metallic mineral products
5	Iron and steel
6	Non-ferrous metals
7	Fabricated metal products, except machinery and equipment
8	Machinery, tractors and equipment nec
10 (*)	Electrical machinery and apparatus, nec
11	Office, accounting and computing machinery
12	Motor vehicles (automobiles, trucks and buses)
13	Other vehicles and automotive parts
14	Wood and products of wood and cork
15	Pulp, paper, paper products, printing and publishing
16	Rubber products
17	Chemicals excluding pharmaceuticals
18	Coke, refined petroleum products and nuclear fuel
19	Fertilizers and others chemicals
20	Pharmaceuticals
21	Plastics products
22	Textiles
23	Clothing products
24	Footwear products
25	Coffee products
26	Other vegetables processing
27	Meat
28	Dairy products
29	Sugar
30	Vegetable oil mills
31	Other food products
32	Miscellaneous manufacturing
33	Electricity, gas and water supply
34	Construction
35	Wholesale and retail trade
36	Transport
37	Post and telecommunications
38	Finance and insurance
39	Personal services
40	Business services
41	Real state activities
42	Public administration
43	Private households with employed persons

(*) Sector 9 is nonexistent.

APPENDIX B
STANDARD IBGE PRODUCT CLASSIFICATION

Code	*Description*	*Code*	*Description*
0101	Coffee, raw	2001	Pharmaceuticals
0102	Sugarcane	2101	Plastic products
0103	Rice, raw	2201	Natural textile fibers
0104	Wheat, unmilled	2202	Natural fabrics
0105	Soya, unmilled	2203	Artificial textile fibers
0106	Cotton	2204	Artificial fabrics
0107	Corn	2205	Other textiles
0108	Cattle and swine	2301	Clothing
0109	Milk, unprocessed	2401	Leather and footwear
0110	Poultry	2501	Coffee products
0199	Other agricultural products	2601	Rice, processed
0201	Iron ores	2602	Wheat flour
0202	Other minerals	2603	Other food products
0301	Petroleum and gas	2701	Meat
0302	Coal	2702	Poultry products
0401	Non-metallic products	2801	Processed milk
0501	Basic steel products	2802	Other dairy products
0502	Rolled steel	2901	Sugar
0601	Non-ferrous products	3001	Vegetable oil, raw
0701	Other metallurgic products	3002	Vegetable oil, processed
0801	Machinery and equipment	3101	Other food and feed
0802	Tractors	3102	Beverages
1001	Electrical equipment	3201	Miscellaneous products
1101	Electronic equipment	3301	Electricity, gas and water supply
1201	Automobiles, trucks and buses	3401	Construction products
1301	Other vehicles and parts	3501	Trade margin
1401	Wood and furniture industries	3601	Transport margin
1501	Pulp and paper	3701	Post and telecommunications
1601	Rubber products	3801	Insurance
1701	Non-petrochemical chemical products	3802	Financial services
1702	Ethanol	3901	Accommodation and food services
1801	Gasoline	3902	Other services
1802	Fuel oil	3903	Private education and health services
1803	Other refined products	4001	Business services
1804	Basic petrochemical products	4101	Real estate
1805	Resins	4102	Imputed rent
1806	Gasohol	4201	Public administration
1901	Chemical fertilizers	4202	Public health services
1902	Paints, varnishes and lacquers	4203	Public education services
1903	Other chemicals	4301	Private households with employed persons

APPENDIX C
PRODUCTION MULTIPLIER COMPARISON (1996)

Code	*Description*	*IBGE*	*Estimated*	*Deviation*
1	Agriculture, hunting and fishing	1,669	1,670	0,08%
2	Mining and quarrying	2,042	2,020	-1,07%
3	Petroleum and gas extraction	1,599	1,589	-0,62%
4	Non-metallic mineral products	2,079	2,070	-0,41%
5	Iron and steel	2,598	2,595	-0,10%
6	Non-ferrous metals	2,229	2,256	1,20%
7	Fabricated metal products, except machinery and equipment	2,330	2,321	-0,40%
8	Machinery, tractors and equipment nec	1,804	1,821	0,98%
10 (*)	Electrical machinery and apparatus, nec	2,271	2,286	0,65%
11	Office, accounting and computing machinery	1,664	1,735	4,23%
12	Motor vehicles (automobiles, trucks and buses)	2,184	2,375	8,78%
13	Other vehicles and automotive parts	2,334	2,237	-4,17%
14	Wood and products of wood and cork	2,057	2,035	-1,06%
15	Pulp, paper, paper products, printing and publishing	2,208	2,179	-1,32%
16	Rubber products	2,171	2,096	-3,43%
17	Chemicals excluding pharmaceuticals	2,035	2,013	-1,09%
18	Coke, refined petroleum products and nuclear fuel	1,894	1,939	2,37%
19	Fertilizers and others chemicals	2,077	2,058	-0,93%
20	Pharmaceuticals	1,842	1,835	-0,38%
21	Plastics products	1,934	1,943	0,50%
22	Textiles	2,234	2,229	-0,20%
23	Clothing products	2,219	2,210	-0,41%
24	Footwear products	2,206	2,123	-3,74%
25	Coffee products	2,492	2,492	-0,02%
26	Other vegetables processing	2,244	2,225	-0,82%
27	Meat and meat products	2,369	2,366	-0,14%
28	Dairy products	2,440	2,437	-0,12%
29	Sugar	2,533	2,520	-0,50%
30	Vegetable oil mills	2,604	2,594	-0,37%
31	Other food products	2,343	2,325	-0,76%
32	Miscellaneous manufacturing	1,911	1,908	-0,19%
33	Electricity, gas and water supply	1,570	1,564	-0,36%
34	Construction	1,610	1,602	-0,52%
35	Wholesale and retail trade	1,642	1,641	-0,04%
36	Transport	1,760	1,698	-3,52%
37	Post and telecommunications	1,264	1,259	-0,47%
38	Finance and insurance	1,400	1,397	-0,20%
39	Personal services	1,597	1,581	-1,03%
40	Business services	1,412	1,409	-0,28%
41	Real state activities	1,064	1,064	-0,05%
42	Public administration	1,416	1,415	-0,09%
43	Private households with employed persons	1,119	1,118	-0,13%

(*) Sector 9 is nonexistent.

APPENDIX D
TECHNICAL COEFFICIENTS (2002)

Description	*HH*(*)	*MH*(*)	*SD*(*)	*AD*(*)
Sugarcane	0,0665	0,0695	0,3975	0,4608
Ethanol	0,0000	0,0000	0,0000	0,0000
Gasohol	0,0062	0,0062	0,0003	0,0003
Chemicals excluding pharmaceuticals	0,0020	0,0020	0,0000	0,0000
Rest of agriculture, hunting and fishing	0,0142	0,0124	0,0000	0,0000
Sugar	0,0000	0,0000	0,0700	0,0000
Mining and quarrying	0,0000	0,0000	0,0000	0,0000
Petroleum and gas extraction	0,0000	0,0000	0,0000	0,0000
Non-metallic mineral products	0,0042	0,0037	0,0000	0,0000
Iron and steel	0,0000	0,0000	0,0000	0,0000
Non-ferrous metals	0,0000	0,0000	0,0000	0,0000
Fabricated metal products, except machinery and equipment	0,0014	0,0014	0,0000	0,0000
Machinery, tractors and equipment nec	0,0133	0,0327	0,0258	0,0248
Electrical machinery and apparatus, nec	0,0001	0,0001	0,0018	0,0018
Office, accounting and computing machinery	0,0001	0,0001	0,0006	0,0006
Motor vehicles (automobiles, trucks and buses)	0,0001	0,0001	0,0005	0,0005
Other vehicles and automotive parts	0,0000	0,0000	0,0008	0,0008
Wood and products of wood and cork	0,0011	0,0011	0,0002	0,0002
Pulp, paper, paper products, printing and publishing	0,0005	0,0005	0,0025	0,0025
Rubber products	0,0000	0,0000	0,0000	0,0000
Coke, refined petroleum products and nuclear fuel	0,1581	0,1880	0,0036	0,0040
Fertilizers and others chemicals	0,1080	0,0941	0,0174	0,0255
Pharmaceuticals	0,0000	0,0000	0,0000	0,0000
Plastics products	0,0022	0,0022	0,0012	0,0012
Textiles	0,0014	0,0014	0,0004	0,0004
Clothing products	0,0000	0,0000	0,0001	0,0001
Footwear products	0,0002	0,0002	0,0000	0,0000
Coffee products	0,0000	0,0000	0,0000	0,0000
Other vegetables processing	0,0000	0,0000	0,0000	0,0000
Meat	0,0000	0,0000	0,0000	0,0000
Dairy products	0,0000	0,0000	0,0000	0,0000
Vegetable oil mills	0,0000	0,0000	0,0000	0,0000
Other food products	0,0000	0,0000	0,0000	0,0000
Miscellaneous manufacturing	0,0006	0,0006	0,0034	0,0034
Electricity, gas and water supply	0,0000	0,0000	0,0000	0,0000
Construction	0,0000	0,0000	0,0023	0,0023
Wholesale and retail trade	0,0250	0,0250	0,0154	0,0154
Transport	0,0179	0,0179	0,0285	0,0285
Post and telecommunications	0,0005	0,0005	0,0062	0,0062
Finance and insurance	0,0043	0,0043	0,0112	0,0112
Personal services	0,0001	0,0001	0,0002	0,0002
Business services	0,0412	0,1015	0,0070	0,0070
Real state activities	0,0001	0,0001	0,0009	0,0009
Public administration	0,0035	0,0035	0,0010	0,0010
Private households with employed persons	0,0000	0,0000	0,0000	0,0000

(*) HH: manual harvest; MH: mechanical harvest; SD: appended distillery; AD: autonomous distillery.

COEFFICIENTS FOR IMPORTS, TAXES, PRIMARY FACTORS AND JOBS (2002)

Description	*HH*(*)	*MH*(*)	*SD*(*)	*AD*(*)
Imports	0,0261	0,0228	0,0038	0,0038
Net taxes on products	0,0239	0,0239	0,0043	0,0043
Labor	0,2905	0,0835	0,0462	0,0462
Capital services	0,1866	0,3005	0,3069	0,3060
Net taxes on production	0,0000	0,0000	0,0400	0,0400
Number of formal and informal jobs	0,0622	0,0103	0,0030	0,0021

(*) HH: manual harvest; MH: mechanical harvest; SD: appended distillery; AD: autonomous distillery.