

Online appendix: information processing on equity prices and exchange rate for cross listed stocks

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1 Supplementary Results

This section complements the selected tables and figures reported in Section 4.2. Specifically, Table S.1 reports the cleaning details; Table S.2 shows the results for the maximum eigenvalue and trace tests; Table S.3 presents the estimates of the cointegrating vectors for the baseline sampling frequency; Table S.4 reports the results for the Lagrange multiplier (LM) test of no serial correlation; Figure S.1 depicts the price evolution for the baseline sampling frequency over the sample period; and Figures S.2-S.6 display the cumulative response of the price returns to an impulse in η_t^m and η_t^e .

Regarding figures S.2-S.6, the first column reports the cumulative response to an impulse in η_t^m , while the second and third columns present the cumulative response of the returns in different markets to an impulse in η_t^e . The empirical 95% confidence intervals are constructed using the bootstrap standard errors. Overall, the cumulative response functions indicate that markets impound most of the information within the first two minutes. This conclusion holds for all firms and impulses in both η_t^m and η_t^e . Considering the most liquid stocks in the sample (Bradesco, Gerdau, Petrobras and Vale), it is worth noting that a significant share of the total information is processed within the first minute, showing that there is little price discovery activity after this period. Figures S.2-S.6 reinforce the importance of using high-frequency data to identify the permanent innovations and their total effect on firm value and exchange rates.

Table S.1: Data Cleaning Details

Stock	Exchange	Raw obs (M)	outliers (K)	final obs (M)
	<i>ExRate</i>	4.088	0.600	4.087
Gerdau	<i>B3</i>	3.237	3.000	3.234
	<i>NYSE</i>	2.829	0.723	2.828
	<i>ARCA</i>	4.164	0.871	4.163
Petrobras	<i>B3</i>	9.071	7.353	9.063
	<i>NYSE</i>	5.021	4.485	5.017
	<i>ARCA</i>	4.873	2.501	4.870
Bradesco	<i>B3</i>	2.958	3.909	2.954
	<i>NYSE</i>	3.599	0.959	3.598
	<i>ARCA</i>	6.091	1.038	6.090
Ambev	<i>B3</i>	0.720	4.109	0.716
	<i>NYSE</i>	1.119	1.645	1.118
	<i>ARCA</i>	0.506	1.190	0.505
BR Telecom	<i>B3</i>	0.555	1.564	0.554
	<i>NYSE</i>	0.200	0.521	0.200
	<i>ARCA</i>	0.106	0.391	0.106
Vale	<i>B3</i>	6.385	5.236	6.380
	<i>NYSE</i>	3.577	1.823	3.575
Total		59.100	41.918	59.058

The first and second columns account for firm and exchange names, respectively. The third column gives the number of observations (in millions) before any cleaning process. Subsequent columns state the number of outliers (in thousands) detected by the [Brownlees and Gallo's 2006](#) cleaning filter and the final number of observations (in millions), respectively.

Table S.2: Cointegration tests

Max Eigenvalue test						
\mathcal{H}_0	Gerdau	Petrobras	Bradesco	Ambev	BR Telecom	Vale
$r = 0$	13,594.15	21,323.18	23571.04	5,650.48	2,960.57	1,050.73
$r = 1$	1319.79	37.74	2194.95	640.57	26.18	3.56
$r = 2$	1.13	1.53	1.54	2.03	1.40	‘-’

Trace test						
\mathcal{H}_0	Gerdau	Petrobras	Bradesco	Ambev	BR Telecom	Vale
$r = 0$	12,274.36	21,285.44	21,376.10	5,009.91	2,934.39	1,047.17
$r = 1$	1318.66	36.21	2193.41	638.54	24.78	3.45
$r = 2$	1.13	1.53	1.50	1.99	1.40	‘-’

The first column states the null hypothesis, while the subsequent columns report the test statistics for the different firms. The max eigenvalue test statistic values for 95% significance are 40.18, 24.28, and 12.32 for a null hypothesis of zero, one, and two cointegrating vectors, respectively. The alternative hypothesis is the null hypothesis number of cointegrating vectors plus one. The trace test statistic values for 95% significance are 24.16, 17.8 and 11.23 for the same null hypothesis as the max eigenvalue test, with alternative hypothesis of k cointegrating vectors, where k is the number of variables in the system. Vale does not trade at ARCA. Values in bold indicate that the null hypothesis is not rejected.

Table S.3: Cointegrating vector, β

	Gerdau		Petrobras		Bradesco		Ambev		BR Telecom		Vale
<i>B3</i>	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	1.00
<i>ExRate</i>	0.00	-0.98	0.00	-1.00	0.00	-1.00	0.00	-1.00	0.00	-0.99	-1.00
<i>NYSE</i>	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	-1.00
<i>ARCA</i>	-1.00	-0.99	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-0.99	-

The cointegrating vectors are estimated using [Johansen's 1991](#) full information maximum likelihood (FIML) estimator. Recall that estimates of β are $(k \times r)$ matrices, where k is the number of trading venues (4 markets for Gerdau, Petrobras, Bradesco, Ambev and BR Telecom; 3 markets for Vale) and r is the number of cointegrating vectors (2 cointegrating vector for Gerdau, Petrobras, Bradesco, Ambev and BR Telecom; 1 cointegrating vector for Vale). Lag length in the VEC model is determined through Schwarz criterion. Vale does not trade at ARCA.

Table S.4: Breusch Godfrey LM test: p-values

Gerdau						
lags	<i>ExRate</i>	<i>B3</i>	<i>NYSE</i>	<i>ARCA</i>	η_t^e	η_t^m
5	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00
15	1.00	1.00	1.00	1.00	1.00	1.00
50	0.37	0.74	1.00	0.99	0.37	0.97

Petrobras						
lags	<i>ExRate</i>	<i>B3</i>	<i>NYSE</i>	<i>ARCA</i>	η_t^e	η_t^m
5	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00
15	0.66	1.00	1.00	1.00	1.00	1.00
50	0.27	0.99	0.88	0.79	0.95	0.41

Bradesco						
lags	<i>ExRate</i>	<i>B3</i>	<i>NYSE</i>	<i>ARCA</i>	η_t^e	η_t^m
5	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00
15	0.91	0.98	1.00	1.00	0.99	1.00
50	0.05	0.83	0.96	0.90	0.08	0.75

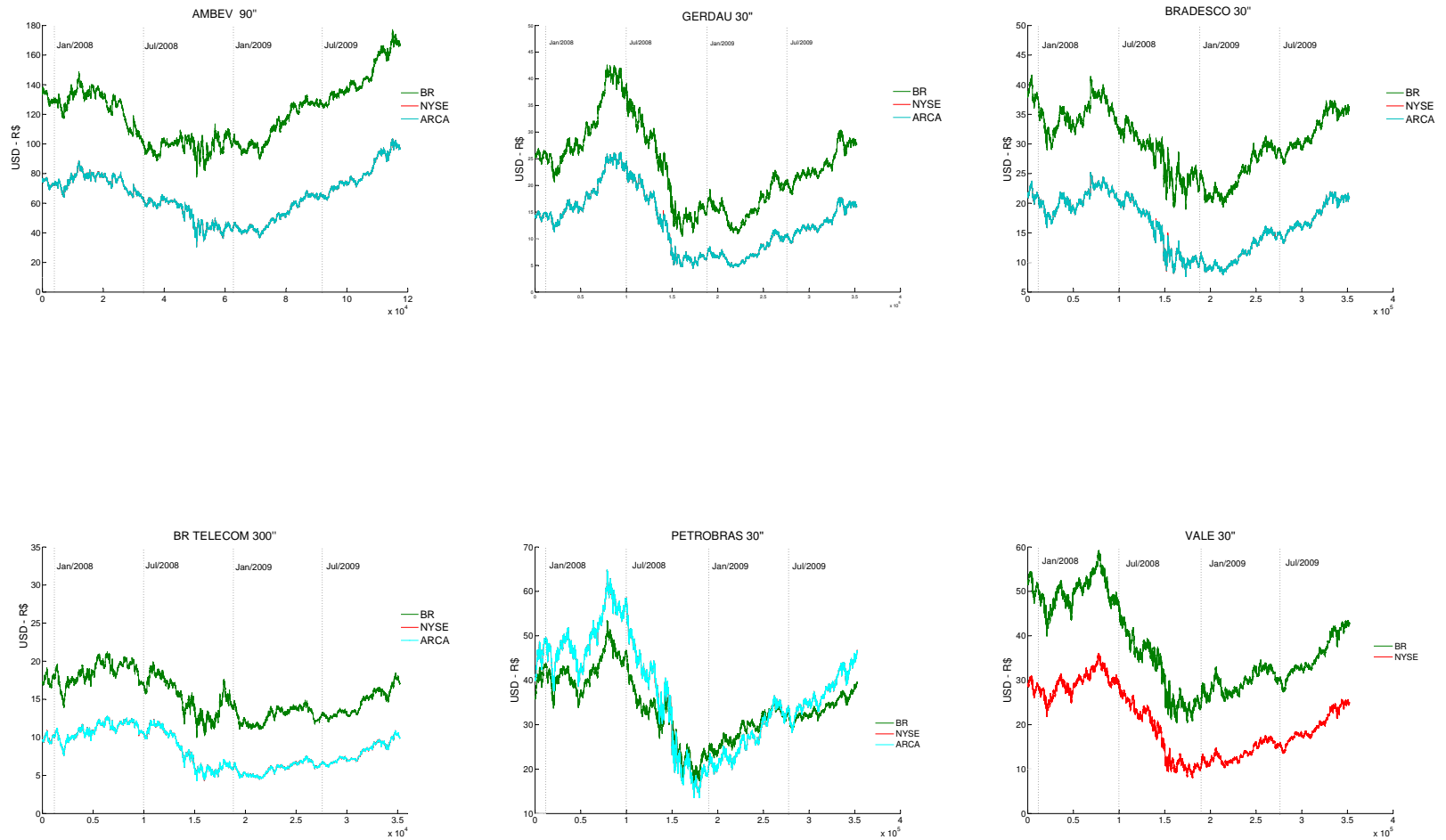
Ambev						
lags	<i>ExRate</i>	<i>B3</i>	<i>NYSE</i>	<i>ARCA</i>	η_t^e	η_t^m
5	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00
15	1.00	1.00	1.00	1.00	1.00	1.00
50	0.98	0.97	0.99	1.00	0.97	1.00

BR Telecom						
lags	<i>ExRate</i>	<i>B3</i>	<i>NYSE</i>	<i>ARCA</i>	η_t^e	η_t^m
5	1.00	1.00	1.00	1.00	1.00	1.00
10	0.99	0.85	1.00	1.00	1.00	1.00
15	0.98	0.96	0.91	0.99	0.99	1.00
50	0.30	0.53	0.44	0.19	0.38	0.87

Vale						
lags	<i>ExRate</i>	<i>B3</i>	<i>NYSE</i>	<i>ARCA</i>	η_t^e	η_t^m
5	1.00	1.00	1.00		1.00	1.00
10	1.00	1.00	1.00		1.00	1.00
15	1.00	0.76	1.00		1.00	1.00
50	0.41	0.94	0.56		0.87	0.72

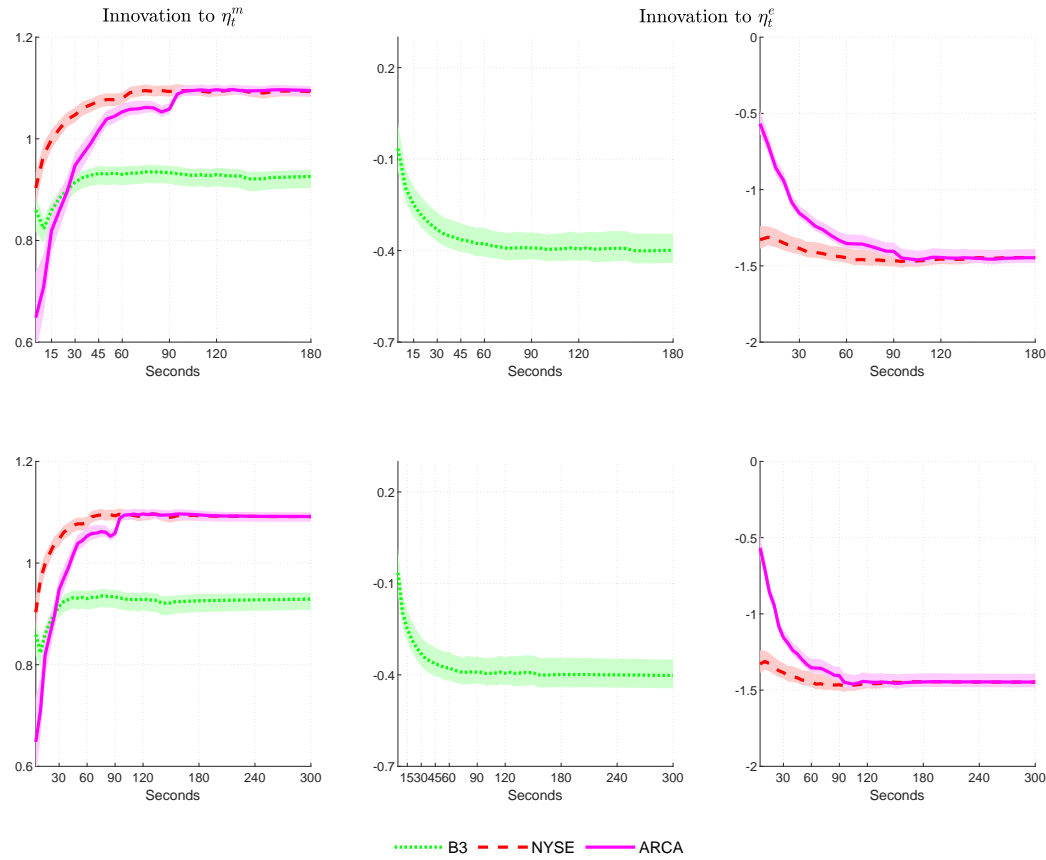
BreuschGodfrey Lagrange multiplier (LM) test for serial correlation at lags 5, 10, 15 and 50. I report the p-values for the residuals of the reduced form model (exchange rate, B3, NYSE and ARCA) and for the structural residuals, efficient exchange rate (η_t^e) and efficient price (η_t^m). Under the null hypothesis, there is no serial correlation. Vale does not trade at ARCA.

Figure S.1: Price Evolution



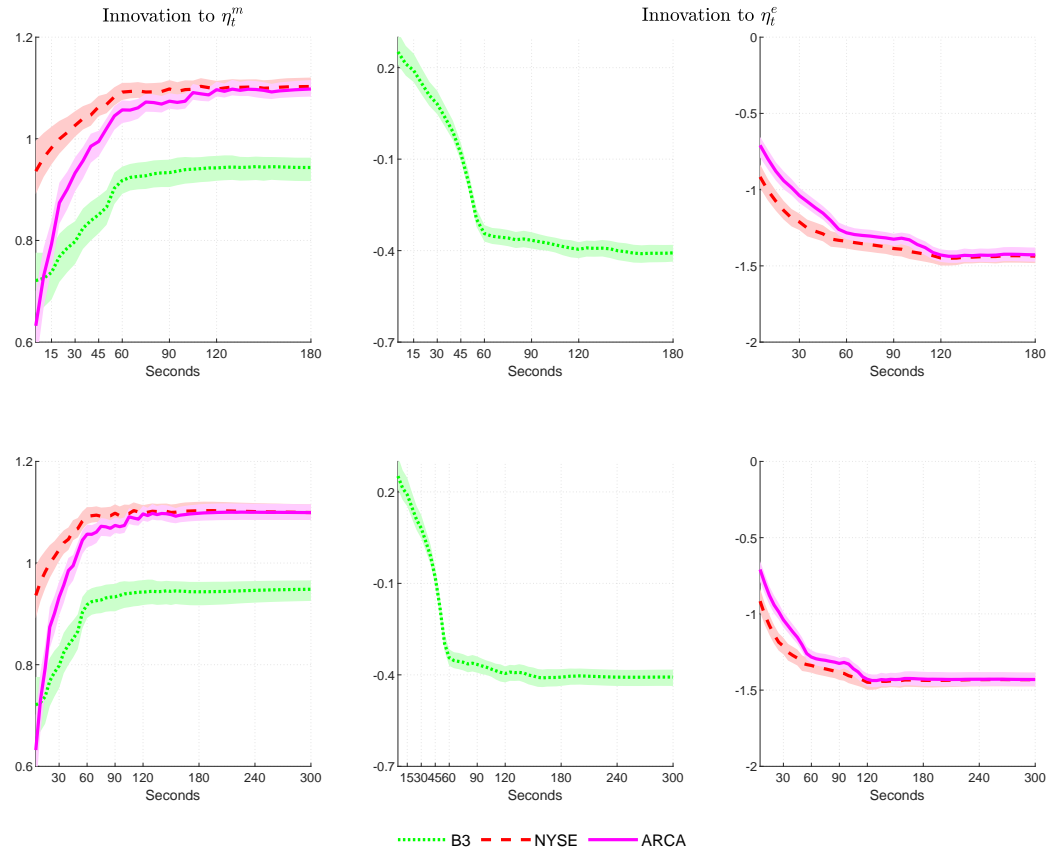
Displays price evolution of Ambev, Gerdau, Bradesco, Br Telecom, Petrobras and Vale stocks traded at B3, NYSE and Arca. Sampling frequency are fixed as follows: Ambev, 90"; Gerdau, 30"; Bradesco, 30"; Br Telecom, 300"; Petrobras 30"; and Vale 30". Prices are aggregated following [Harris et al. \(1995\)](#) and free of non plausible values.

Figure S.2: Petrobras: IRF



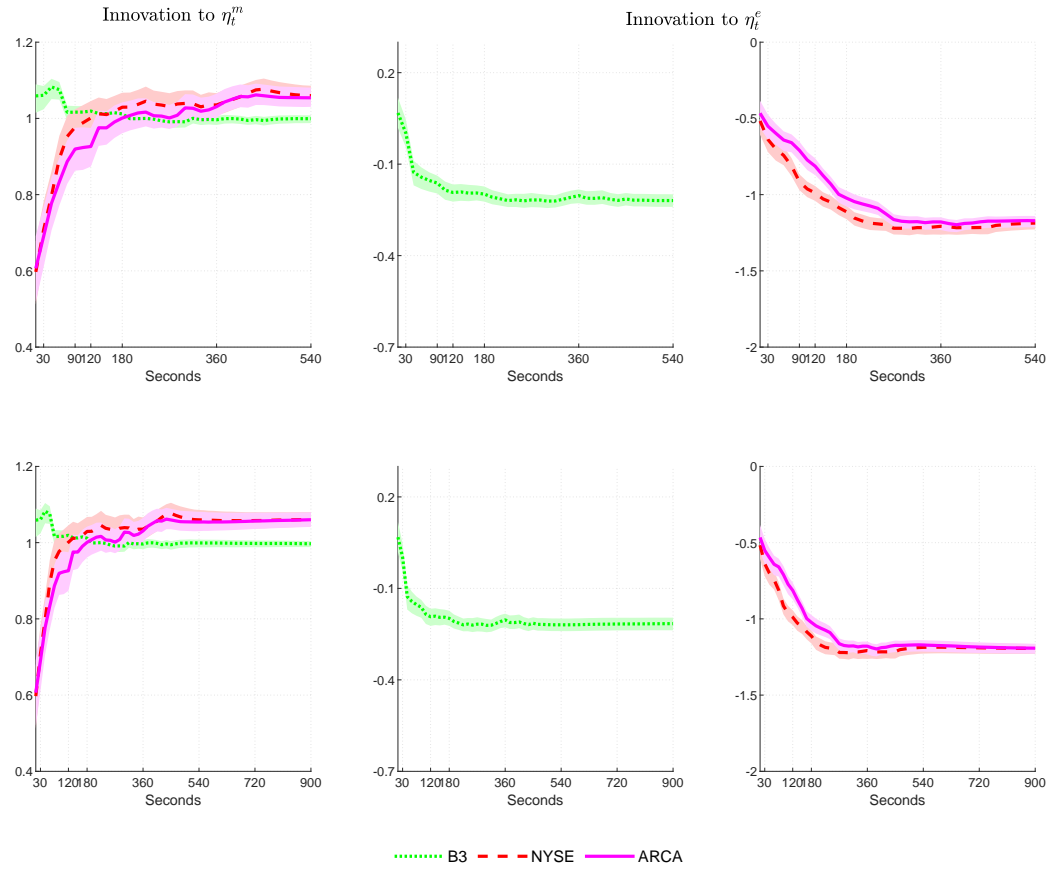
The dotted line denotes B3, the dashed line denotes NYSE, and the solid line denotes ARCA. First column displays the cumulative impulse response functions showing the effect at B3, ARCA and NYSE of an innovation on the firm efficient price over 180 and 300 seconds (upper and lower graph, respectively). Second and third column displays cumulative impulse response functions showing the effect of an innovation on the efficient exchange rate over 180 (upper graphes) and 300 (lower graphes) seconds at B3 (left graph) and at ARCA and NYSE (right graph). The empirical 95% confidence intervals are obtained using the bootstrap standard errors.

Figure S.3: Bradesco: IRF



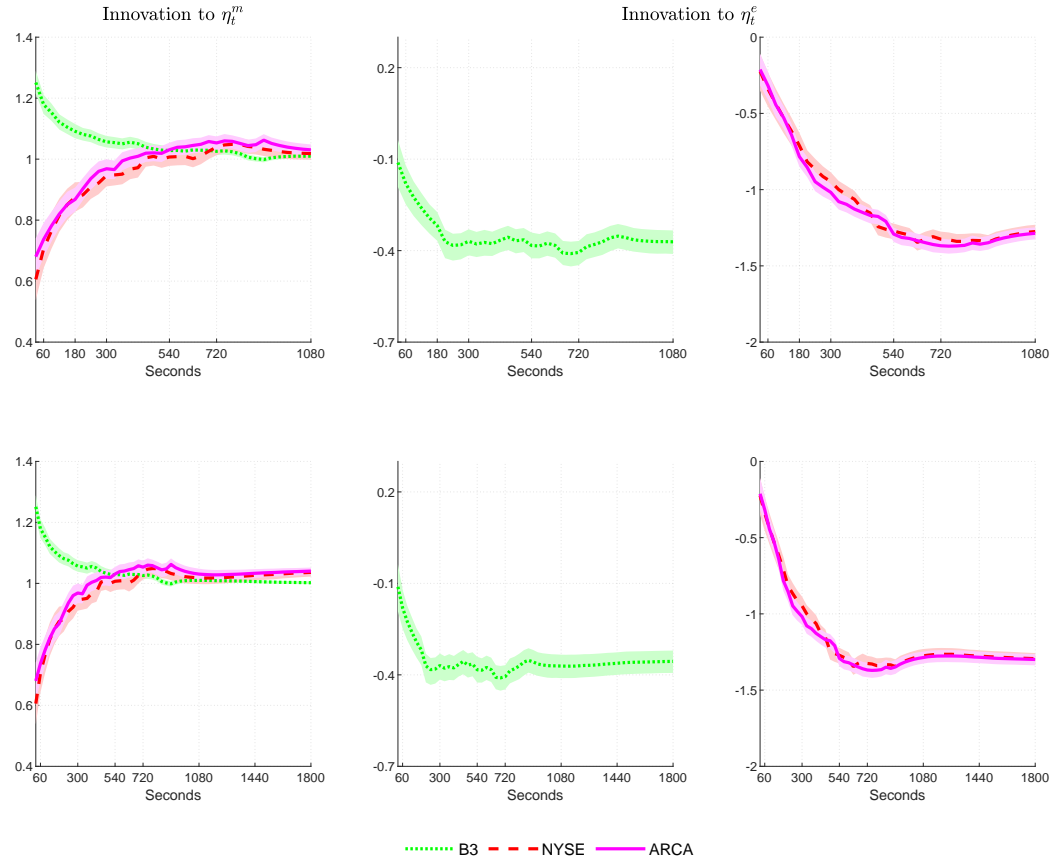
The dotted line denotes B3, the dashed line denotes NYSE, and the solid line denotes ARCA. First column displays the cumulative impulse response functions showing the effect at B3, ARCA and NYSE of an innovation on the firm efficient price over 180 and 300 seconds (upper and lower graph, respectively). Second and third column displays cumulative impulse response functions showing the effect of an innovation on the efficient exchange rate over 180 (upper graphs) and 300 (lower graphs) seconds at B3 (left graph) and at ARCA and NYSE (right graph). The empirical 95% confidence intervals are obtained using the bootstrap standard errors.

Figure S.4: Ambev: IRF



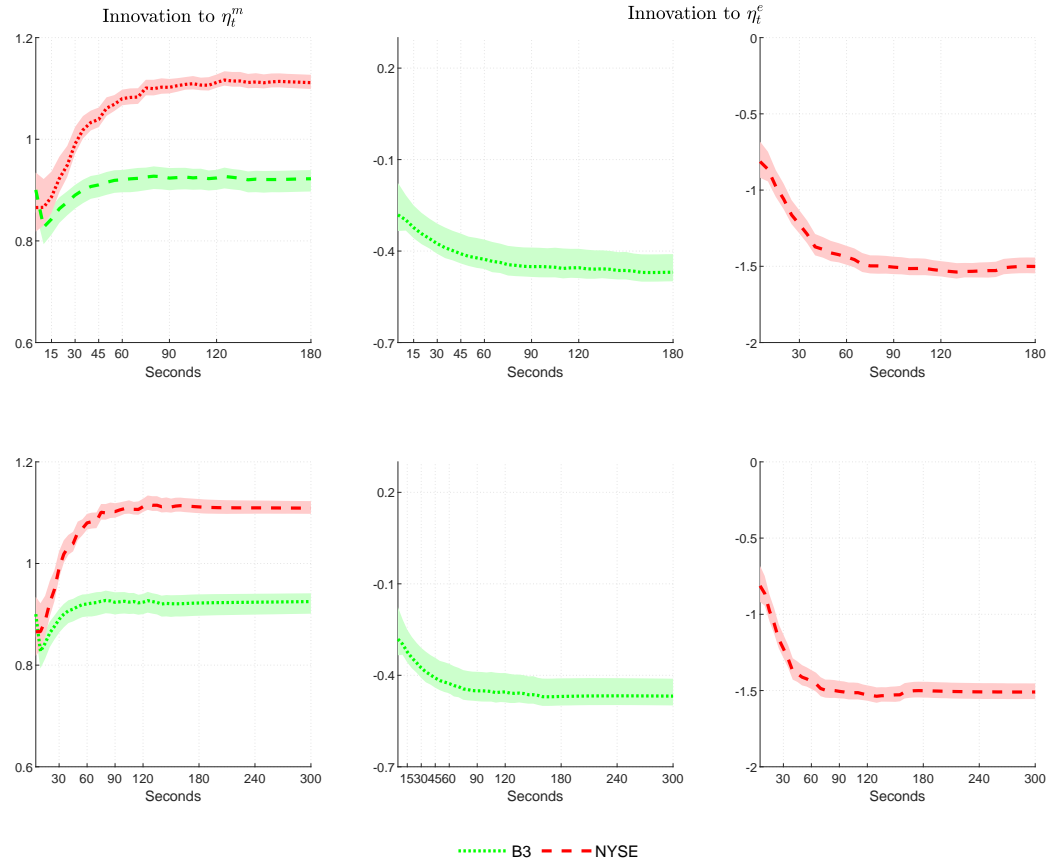
The dotted line denotes B3, the dashed line denotes NYSE, and the solid line denotes ARCA. First column displays the cumulative impulse response functions showing the effect at B3, ARCA and NYSE of an innovation on the firm efficient price over 540 and 900 seconds (upper and lower graph, respectively). Second and third column displays cumulative impulse response functions showing the effect of an innovation on the efficient exchange rate over 540 (upper graphs) and 900 (lower graphs) minutes at B3 (left graph) and at ARCA and NYSE (right graph). The empirical 95% confidence intervals are obtained using the bootstrap standard errors.

Figure S.5: BR Telecom: IRF



The dotted line denotes B3, the dashed line denotes NYSE, and the solid line denotes ARCA. First column displays the cumulative impulse response functions showing the effect at B3, ARCA and NYSE of an innovation on the firm efficient price over 1080 and 1800 minutes (upper and lower graph, respectively). Second and third column displays cumulative impulse response functions showing the effect of an innovation on the efficient exchange rate over 1080 (upper graphes) and 1800 (lower graphes) minutes at B3 (left graph) and at ARCA and NYSE (right graph). The empirical 95% confidence intervals are obtained using the bootstrap standard errors.

Figure S.6: Vale: IRF



The dotted line denotes B3 and the dashed line denotes NYSE. First column displays the cumulative impulse response functions showing the effect at B3 and NYSE of an innovation on the firm efficient price over 180 and 300 seconds (upper and lower graph, respectively). Second and third column displays cumulative impulse response functions showing the effect of an innovation on the efficient exchange rate over 180 (upper graphs) and 300 (lower graphs) seconds at B3 (left graph) and at NYSE (right graph). The empirical 95% confidence intervals are obtained using the bootstrap standard errors.

References

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