Online Appendix A - Change in the timing of decisions

A.1. Stability condition of the equilibrium

As for the timing assumed in the main part of the article, the equilibrium has to be stable.

$$\begin{bmatrix} \dot{p_{11}} \\ \dot{p_{12}} \\ \dot{p_{21}} \\ \dot{p_{22}} \end{bmatrix} = \begin{bmatrix} \frac{\partial^2 \Pi_i}{\partial p_{11}^2} & \frac{\partial^2 \Pi_i}{\partial p_{11}\partial p_{12}} & \frac{\partial^2 \Pi_i}{\partial p_{11}\partial p_{21}} & \frac{\partial^2 \Pi_i}{\partial p_{11}\partial p_{22}} \\ \frac{\partial^2 \Pi_i}{\partial p_{12}\partial p_{11}} & \frac{\partial^2 \Pi_i}{\partial p_{12}^2} & \frac{\partial^2 \Pi_i}{\partial p_{12}\partial p_{21}} & \frac{\partial^2 \Pi_i}{\partial p_{12}\partial p_{22}} \\ \frac{\partial^2 \Pi_i}{\partial p_{21}\partial p_{11}} & \frac{\partial^2 \Pi_i}{\partial p_{21}\partial p_{12}} & \frac{\partial^2 \Pi_i}{\partial p_{21}^2} & \frac{\partial^2 \Pi_i}{\partial p_{21}\partial p_{22}} \\ \frac{\partial^2 \Pi_i}{\partial p_{22}\partial p_{11}} & \frac{\partial^2 \Pi_i}{\partial p_{22}\partial p_{12}} & \frac{\partial^2 \Pi_i}{\partial p_{22}\partial p_{21}} & \frac{\partial^2 \Pi_i}{\partial p_{22}^2} \end{bmatrix} \begin{bmatrix} p_{11} - p_{11}^{sep} \\ p_{12} - p_{12}^{sep} \\ p_{21} - p_{21}^{sep} \\ p_{22} - p_{22}^{sep} \end{bmatrix}$$

For stability, the coefficient matrix should have negative eigenvalues. This is the case if:

$$6kt > (d+e)^2.$$

Imposing this assumption ensures not only stability, but also the fulfillment of the second order conditions and the non-negativity of operators' profits.

A.2. Complete separation

The density choices follow from maximizing profits in the last stage. In the case of complete separation, density choices are given by

$$f_{ij} = \frac{dp_{ij} + ep_{i,-j}}{4kt} \quad \forall i, j.$$

Using the optimal densities, and maximizing profits with respect to the prices in the second stage yields equal sharing of the markets and the following equilibrium prices, and densities:

$$p_{ij}^{sep} = t \quad \forall i, j$$
$$f_{ij}^{sep} = \frac{d+e}{4k} \quad \forall i, j.$$

The profits, consumer surplus and welfare follow directly:

$$\begin{aligned}
\Pi_{ij}^{sep} &= \frac{8kt-(d+e)^2}{16k} \quad \forall i,j, \\
CS_j^{sep} &= \int_0^{x_{1j}} (v-p_{1j}+df_{1j}+ef_{1i}-tx)dx + \int_{x_{1j}}^1 (v-p_{2j}+df_{2j}+ef_{2i}-t(1-x))dx \\
&= \frac{4kv+(d+e)^2-5kt}{4k} \quad \forall j, \\
W_j^{sep} &= \frac{8kv+(d+e)^2-2kt}{8k} \quad \forall j.
\end{aligned}$$

A.3. Proof Lemma 1

AS in Country 1 increases the costs of network densities of Operator 2 in Country 1. This cost increase changes the density choice of Operator 2 in Country 1 to

$$f_{21} = \frac{dp_{22}+ep_{21}-2ty}{4kt}.$$

Table A.1 summarizes the resulting equilibrium network densities. For the sake of simplicity I define $M_3 = 6kt-(d+e)^2 > 0$, and $M_4 = 6kt-(d-e)^2 > 0$.

f_{ij}^1	**Country 1**	**Country 2**
Operator 1	$f_{ij}^{sep} + \frac{(d^2+e^2)(6kt-d^2+e^2)+2e^2(d^2-e^2)}{4kM_3M_4}y$	$f_{ij}^{sep} + \frac{3det}{M_3M_4}y$
Operator 2	$f_{ij}^{sep} - \frac{M_3M_4+6M_3kt+12dekt}{4kM_3M_4}y$	$f_{ij}^{sep} - \frac{3det}{M_3M_4}y$

Table A.1: Densities of Operator i in Country j with AS in Country 1

In the price setting stage, the operators anticipate this density difference. The difference in densities gives Operator 1 a competitive advantage who is, therefore, able to demand higher prices. The effects on prices and market shares are summarized in Table A.2.

		Country 1	**Country 2**
p_{ij}^1	**Operator 1**	$p_{11}^{sep}(1+d\frac{6kt-d^2-e^2}{M_3M_4}y)$	$p_{12}^{sep}(1+e\frac{6kt-d^2-e^2}{M_3M_4}y)$
	Operator 2	$p_{21}^{sep}(1-d\frac{6kt-d^2-e^2}{M_3M_4}y)$	$p_{22}^{sep}(1-e\frac{6kt-d^2-e^2}{M_3M_4}y)$
x_{ij}^1	**Operator 1**	$x_{11}^{sep}+d\frac{6kt-d^2-e^2}{2M_3M_4}y$	$x_{12}^{sep}+e\frac{6kt-d^2-e^2}{2M_3M_4}y$
	Operator 2	$x_{21}^{sep}-d\frac{6kt-d^2-e^2}{2M_3M_4}y$	$x_{22}^{sep}-e\frac{6kt-d^2-e^2}{2M_3M_4}y$

Table A.2: Prices and market shares of Operator i in Country j with AS in Country 1 only

These equilibrium prices and densities allow the derivation of the operators' profits, consumer surplus and welfare. Table A.3 shows that the change in timing does not change the sign of the operators' profit difference.

$\Gamma_{\Pi_{ij}^1-\Pi_{ij}^{sep}}$	**Country 1**	**Country 2**	**Sum**
Operator 1	$\frac{(6kt-d^2+e^2)[8dkt-(d-e)(d+e)^2]}{8kM_3M_4}>0$	$et\frac{2M_3+d(d+e)}{2M_3M_4}>0$	$\frac{(d+e)[8kt-(d+e)^2]}{8kM_3}>0$
Operator 2	$-\frac{(6kt-d^2+e^2)[8dkt-(d-e)(d+e)^2]}{8kM_3M_4}<0$	$-et\frac{2M_3+d(d+e)}{2M_3M_4}<0$	$-\frac{(d+e)[8kt-(d+e)^2]}{8kM_3}<0$

Table A.3: Evaluation of profit differences compared to complete separation

Similarly, the change of the timing has does not affect the sign of the consumer surplus difference.

$$\Gamma_{CS_1^1-CS_1^{sep}}=-\frac{d}{4k}<0$$
$$\Gamma_{CS_2^1-CS_2^{sep}}=-\frac{e}{4k}<0$$

Welfare in both countries can be derived as:

$$\Gamma_{W_1^1-W_1^{sep}}=\alpha\frac{(d+e)(8kt-(d+e)^2)}{8kM_3}-\frac{d}{4k}\gtreqless 0,$$
$$\Gamma_{W_2^1-W_2^{sep}}=-\alpha\frac{(d+e)(8kt-(d+e)^2)}{8kM_3}-\frac{e}{4k}<0.$$

In order to show that $\Gamma_{W_1^1-W_1^{sep}}$ becomes positive with increasing e, one can plug in the lowest and the largest possible e to $\Gamma_{W_1^1-W_1^{sep}}$ and then check the derivative for monotonicity:

$$\Gamma_{W_1^1-W_1^{sep}}(e=0) = d\frac{2kt\alpha-(2-\alpha)(6kt-d^2)}{8kM_3} \gtreqless 0 \tag{A.1}$$

$$\lim_{e\to\sqrt{9kt}-d} \Gamma_{W_1^1-W_1^{sep}} \to +\infty \tag{A.2}$$

$$\frac{\partial\Gamma_{W_1^1-W_j^{sep}}(e)}{\partial e} = \alpha\frac{M_3[8kt-(d+e)^2]+4kt(d+e)^2}{8kM_3^2} > 0 \tag{A.3}$$

Notice that even though (A.1) may be either positive or negative (depending on d and α) (A.2) increases to infinity as long as $\alpha > 0$. Given monotonicity of $\Gamma_{W_1^1-W_j^{sep}}$ with respect to e, there exists an unique e^0 for which $\Gamma_{W_1^1-W_j^{sep}} = 0$ whenever $\Gamma_{W_1^1-W_j^{sep}}(e = 0) < 0$ as long as α is strictly positive.

Additionally, because $\frac{\partial\Gamma_{W_1^1-W_j^{sep}}(e)}{\partial e}$ increases in α, e^0 decreases in α.

A.4. Proof Lemma 2

Accounting separation in both countries is the last setting which I need to consider. In this case, the density choices of both operators abroad change to:

$$f_{ij} = \frac{dp_{ij}+ep_{i,-j}-2ty}{4kt}. \quad \forall i \neq j.$$

Again, all second order conditions are fulfilled under Assumption A.1.

		Country 1	**Country 2**
f_{ij}^b	**Operator 1**	$f_{11}^{sep} + \frac{(d-e)^2}{4kM_4}y =$ $f_{11}^1 - 3\frac{det}{M_3M_4}y$	$f_{12}^{sep} - \frac{12kt-(d-e)^2}{4kM_4}y =$ $f_{12}^1 - \frac{M_3M_4+6M_3kt+12dekt}{4kM_3M_4}y$
	Operator 2	$f_{21}^{sep} - \frac{12kt-(d-e)^2}{4kM_4}y =$ $f_{21}^1 + 3\frac{det}{M_3M_4}y$	$f_{22}^{sep} + \frac{(d-e)^2}{4kM_4}y =$ $f_{22}^1 + \frac{(d^2+e^2)(6kt-d^2+e^2)+2e^2(d^2-e^2)}{4kM_3M_4}y$
p_{ij}^b	**Operator 1**	$p_{11}^{sep}[1 + \frac{d-e}{M_4}y] =$ $p_{11}^1[1 - e\frac{6kt+(d^2-e^2)}{M_3M_4}y]$	$p_{12}^{sep}[1 - \frac{d-e}{M_4}y] =$ $p_{12}^1[1 - d\frac{6kt-(d^2-e^2)}{M_3M_4}y]$
	Operator 2	$p_{21}^{sep}[1 - \frac{d-e}{M_4}y] =$ $p_{21}^1[1 + e\frac{6kt+(d^2-e^2)}{M_3M_4}y]$	$p_{22}^{sep}[1 + \frac{d-e}{M_4}y] =$ $p_{22}^1[1 + d\frac{6kt-(d^2-e^2)}{M_3M_4}y]$
x_{ij}^b	**Operator 1**	$x_{11}^{sep} + \frac{d-e}{M_4}y =$ $x_{11}^1 - e\frac{6kt+(d^2-e^2)}{2M_3M_4}y$	$x_{12}^{sep} - \frac{d-e}{M_4}y =$ $x_{12}^1 - d\frac{6kt-(d^2-e^2)}{2M_3M_4}y$
	Operator 2	$x_{21}^{sep} - \frac{d-e}{M_4}y =$ $x_{21}^1 + e\frac{6kt+(d^2-e^2)}{2M_3M_4}y$	$x_{22}^{sep} + \frac{d-e}{M_4}y =$ $x_{22}^1 + d\frac{6kt-(d^2-e^2)}{2M_3M_4}y$

Table A.4: Densities, prices and market shares of Operator i in Country j with AS in both countries

Whereas Table A.4 shows the differences in prices, densities and market shares, Table A.5 presents the relevant terms for the profits of the operators.

$\Gamma_{\Pi_{ij}^b - \Pi_{ij}^{sep}}$	**Country 1**	**Country 2**	**Sum**
Operator 1	$\frac{(d-e)[8kt-(d^2-e^2)]}{8kM_4}$	$-\frac{(d-e)[8kt-(d^2-e^2)]}{8kM_4}$	0
Operator 2	$-\frac{(d-e)[8kt-(d^2-e^2)]}{8kM_4}$	$\frac{(d-e)[8kt-(d^2-e^2)]}{8kM_4}$	0

Table A.5: Evaluation of profit differences compared to complete separation

As a consequence of the operators' density and price choices, the consumer surplus and welfare are given by:

$$\Gamma_{CS_j^b - CS_j^{sep}} = \Gamma_{W_j^b - W_j^{sep}} = -\frac{d+e}{4k} < 0 \quad \forall j.$$

Online Appendix B - LIB index comparison for IS and AS countries

In this chapter I compare the average values of the Rail Liberalization index (LIB), and it's two parts the LEX and ACCESS index, for the groups of countries that have either decided to choose AS or IS. The LIB index can be separated in two parts, the LEX index and the ACCESS index. The LIB index is the weighted sum of the two (20% LEX, 80% ACCESS). Whereas the LEX index summarizes the legal barriers for entrants (”law in the books”), the ACCESS index captures the additional practical barriers (”law in action”).

Note that one important component of the LEX index is the degree of separation itself. In order to avoid a mechanical relation, I corrected the LEX index and subtracted the separation score for all countries (The relevant data can be found in Annex VI of IBM (2011)).

Furthermore, I also compare the level of competition, measured by the COM index, across the two groups. The COM index reflects the different levels of competition by analyzing the number and market shares of the competing companies.

Table B.1 shows that countries that have chosen IS score on average higher than countries with AS. Note that I use the information provided by the authors of the LIB index (IBM, 2011, p. 53) to characterize IS and AS countries. The ACCESS index is of special importance because it captures the ”de facto” barriers to competition, excluding restriction by law, i.e. barriers that may be implemented by the firms on the market. For the ACCESS index the t-test shows a p-value of 0.127. This is a respectable number given the low number of observations, supporting the assumption that AS allows discrimination of (potential) competitors.

index	IS		AS		p-value
	Obs.	Mean	Obs.	Mean	
LIB	12	699.500	15	661.600	0.156
		(27.294)		(24.542)	
LEX	12	647.833	15	640.800	0.421
		(24.542)		(24.172)	
ACCESS	12	712.400	15	666.800	0.127
		(29.349)		(25.869)	
COM	12	467.333	15	407.333	0.213
		(60.770)		(45.145)	

Standard errors in parentheses.

IS countries: Bulgaria, Denmark, Spain, Finland, Greece, Great Britain, the Netherlands, Norway, Portugal, Romania, Sweden and Slovakia.

AS countries: All countries that have not fully institutionally separated, i.e., Austria, Belgium, Czech Republic, Estonia, France, Germany, Hungary, Italy, Ireland, Latvia, Lithuania, Luxembourg, Poland, Slovenia and Switzerland.

Table B.1: Index comparison for AS and IS countries

The COM index turns out to be higher for IS countries but the difference is also not statistically significant. However, this measure for competition is difficult to interpret because efficiency gains within the integrated firm would have also an anti-competitive effect. A more efficient firm is in a better position to compete with entrants. Hence, a lower level of competition in AS countries may be due to welfare decreasing discrimination or due to (potentially) welfare increasing efficiency gains.

References

IBM, 2011. Rail liberalisation index 2011. Tech. rep., IBM Global Business Services.