Should there be lower taxes on patent income?

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ONLINE APPENDIX

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Appendix A: Literature review tables

Table A1: Literature on corporate taxation and patent location

Paper	*Data*	*Level*	*#Obs*	*Years*	*Obs/year*	*Dependent variable(s)*	*Independent variables*	*Method*
Dischinger & Riedel (2011)	European MNEs with intang.	group member	6,223	1995-2005	566	intangible assets (D and log ratio to sales)	corp tax rate, tax diff btwn sub and parent, log sales, pop, R&D, GDP, growth in GDP per cap, corruption index, unemployment	logit FE; OLS FE; IV and GMM on first differences
Ernst & Spengel (2011)	EP apps; AMADEUS match	firm	80,484	1998-2007	8,048	EP patent filings	corp tax, EATR, B-index, GDP per cap, pubRD, Tertiary ed, GP index, Openness, Hi tech exports, Emply, assets	logit FE ; neg bin FE
Karkinsky & Riedel (2012)	EP apps; AMADEUS match; 18 EU countries	firm affiliate	64,061	1995-2003	7,118	EP patent filings	corp tax rate, tax diff btwn sub and parent, royalty rate, CFC rules, R&D, GDP,corruption index, IP strength	OLS FE
Griffith, Miller & O'Connell (2014)	EP apps; AMADEUS match; 18 EU countries	patent	379,849	1985-2005	18,088	filing country choice	GDP, RD/GDP, inventor presence, tax rate, patent box rate, IP strength, industry-location-firm size dummies	random coefficient mixed logit
Boehm, Karkinsky, Knoll, & Riedel (2015)	EP apps - corporate; match to AMADEUS	patent	530,805	1978-2006	18,304	applicant/invent or divergence at pat level	corp tax rate, pat quality, rule of law, corruption, GDP and GDP per cap; CFC; year country industry FE	probit FE
Dinkel & Schanz (2015)	worldwide patstat - MNEs matched to AMADEUS	group-country	62,717	2005-2012	7,840	D(pat abroad) D (country) N pats in country	Tax attractiveness (corp tax rate, royalty rate, witholding roy rate, all scaled); D(RD tax), D(transfer price), CFC, sales, GDP, RD per cap, distance, app-reg, emp-inventors	probit FE (ind & year) neg bin FE
Dudar, Spengel & Voget (2015)	royalty payments	country pairs	~20,000	1990-2012	~900 ~60 countries	royalty streams	royalty tax, tax difference, corporate tax, IP box dummies, CFC rules, TP rules, R&D, GDP, POP in recipient country, trade between	Poisson PML

Table A2: Literature on patent boxes

Paper	*data*	*level*	*#obs*	*years*	*obs/year*	*dependent variable(s)*	*independent variables*	*method*	*pat box result*
Alstadsaeter, Barrios, Nicodeme, Skonieczna and Vezzani (2018)	EP apps; ORBIS data for EU scoreboard firms in 33 countries	firm-technology-industry	~160,000	2000-2011	4444?	EP patent filings	GDP, inventor presence, tax rate, patent box rate, triadic pats, IP strength, country dummies	random effects neg binomial; R coeff mixed logit	filings wrt box: -5.0 (semi-elasticity)
Bösenberg & Egger (2017)	EP apps; 106 countries	country-technology	639; 9425	1996-2012	49; 2600	filings and transfers	B-index, EATR, pat box dummy; researchers per cap, GDP, avg pat characteristics	Poisson FE (year)	seller: 0.43*** buyer: 0.23***
Bradley, Duchy, and Robinson (2015)	worldwide patstat	countries	1,487	1990-2012	~70 countries	inventor patent apps; owner patent apps; pats with inv country not owner country, etc	Patent box, pat box rate, other tax vars, GDP, population, patent system quality	Panel OLS	domestic inventing increases if rate falls; no impact on mismatch owner-inventor
Dudar, Spengel & Voget (2015)	royalty payments	country pairs	~20,000	1990-2012	~900 ~60 countries	royalty streams	royalty tax, tax difference, corporate tax, IP box dummies, CFC rules, TP rules, R&D, GDP, POP in recipient country, trade between	Poisson PML	Royalties increase if IP box covering acquired and self-generated patents
Koethenbuerger, Liberini & Stimmelmayr (2016)	MNCs from Orbis	subsidiaries	85,944 (30,798 matched)	2007-2013	12,715 (4,498 matched, 2,942 patenters)	stated profit before tax	D(patent box),(new pat entrant), and interactions; assets, leverage	diff-in-diff; ind-year, ctry-year Fes	pat box used for profit shifting
Schwab & Todtenhaupt (2016)	MNCs from Orbis/AMADEUS with sub in patent box country match to PAtSTAT	firm	271,251	2000-2012	20,865	worldwide pat grants	patent box, R&D/GDP, GDP per cap, corp tax, GDP growth R&D user cost. Real interest rate, firm age, assets, work cap, capital intensity	Poisson FE (firm & year)	pat box in other countries has positive spillovers on domestic R&D
Ciaramella (2017)	EP apps	firm	329,398	1997-2015	~16,000	patent transfers during the exam phase at the EPO	pat box, corp tax rate, CFC; log GDP, distance, language, RD/GDP	Neg Bin FE (year)	buyer: 1.2*** seller: insig
Mohnen, Vankan & Verspagen (2017)	Dutch firm data	firm		2007-2013	~15,000	R&D person-hours	use of patent box	diff-in-diff	pat box positive for domestic R&D

Appendix B: Simple statistics and additional estimates for aggregate data

Table B1

Sample countries

Code	Country	R&E tax credit @	CFC rules^	Years with patent box	Gross or net income	Includes existing patents	Includes acquired patents	Develop-ment condition	Covers R&D done abroad	Patents transferred out 2000-2016	Patents transferred in 2000-2016	Diff-erence
AT	Austria	x								2765	1742	-1023
AU	Australia	x	x							1376	790	-586
AW*	Aruba										12	12
BB*	Barbados									292	2340	2048
BE	Belgium	x		2007-	gross	yes%	yes%	yes	yes*	1312	2836	1524
BM*	Bermuda									45	845	800
BS*	Bahamas									40	188	147
CA	Canada	x	x							4456	3095	-1361
CH	Switzerland			2011-	gross	yes	yes	no	no	7554	13991	6437
CL	Chile	x								16	50	34
CW*	Curacao									106	882	776
CY	Cyprus			2012-	net	yes	yes	no	yes$	160	287	127
CZ	Czech Republic	x								62	162	100
DE	Germany		x							16404	15675	-729
DK	Denmark	x	x							1280	1325	46
EE	Estonia		x							15	26	11
ES	Spain	x	x	2008-	net	yes	no%	yes	yes$	683	552	-131
FI	Finland		x							1656	3440	1784
FR	France	x	x	1971-	net	yes	yes#	no	yes$	5796	7508	1712
GB	UK	x	x	2013-	net	yes	yes%	yes	yes$	13892	9004	-4888
GG*	Guernsey									0	95	95
GI*	Gilbraltar									9	134	125
GR	Greece	x		2015-	net	no	yes	yes	yes	41	60	19
HK*	Hong Kong									22	570	548
HU	Hungary	x	x	2003-	gross	yes	yes	no	yes	112	317	205
IE	Ireland	x		1973-2010	net	yes	no%	yes	yes$	587	3020	2433
IE	Ireland	x		2016-	net	yes	no	yes	yes			
IL	Israel		x	2017-	gross	yes	yes	no	yes	1081	1415	334
IM*	Isle of Man									23	89	66
IS	Iceland	x	x							29	236	207
IT	Italy	x	x	2015-	net	yes	yes	yes	yes	2145	1805	-341
JE*	Jersey										83	83
JP	Japan	x	x							5378	4204	-1175
KR	South Korea	x	x	2014-	gross	yes	yes	yes	no	881	1180	299
KY*	Cayman Islands									82	2217	2134
LI**	Liechtenstein			2011-2015	net	yes	yes	no	yes	385	353	-32
LU	Luxembourg			2008-2015	gross	no	yes	no	yes	652	3849	3197
MC*	Monaco									76	73	-3
MT	Malta	x		2010-2015	gross	yes	yes	no	yes	42	170	128
MX	Mexico		x							81	297	216
NL	Netherlands	x		2007-	net	no	yes%	yes	yes$	8611	17101	8490
NO	Norway	x	x							518	1244	726
NZ	New Zealand	x	x							230	148	-82
PL	Poland	x		2019-						68	122	53
PT	Portugal	x	x	2014-	gross	no	no	yes	yes$	51	182	131
SE	Sweden	x	x							3749	4864	1115
SG*	Singapore									225	3104	2879
SI	Slovenia	x								57	50	-7
SK	Slovakia	x		2018-	net	yes	no	yes	yes	55	43	-12
TR	Turkey	x		2015-	net	no	yes	yes	no	19	60	41
US	US	x	x							34433	28441	-5991
VG*	Virgin Islands (British)									103	1904	1801
	Total									**117656**	**142178**	**24522**

* denotes countries that are tax havens; most do not have GDP data on the Penn World Tables either.

if held for at least 2 years. ^ CFC rules in 2014. % if further developed. $ with some restrictions on ownership.

** GDP data not available from the Penn World Tables for this country.

@Some kind of R&D tax credit (beyond expensing) available by 2016.

Sources: Tax info - Evers et al. (2013), Deloitte (2014), Alstadsæter et al. (2015), US congress JEC (2016).

Patent data - authors'computations from Patstat April 2018, with corrections for duplicate owners, and weighted for multiple sellers and/or buyers

Table B2

Effective average tax rates for countries with a Patent Box

Code	*Country*	*Years with IP box*	*Corp tax rate (statutory)**	*IP box rate (statutory)**	*Effective average tax rate ord. income#*	*Effective average tax rate IP box#*
BE	Belgium	2007-	34	4.4	21.11	-26.95
CY	Cyprus	2012-	12.5	2.5	11.69	2.34
FR	France	1971-	34.43	15	26.56	-6.41
GR	Greece	2015-	35	0	na	na
HU	Hungary	2003-	19	10.3	14.25	-2.54
IE	Ireland	1973-2010	19	0	12.50	0.00
	Ireland	2016-	12.5	6.25	na	na
IT	Italy	2015-	31.29	17.76	na	na
KR	South Korea	2014-	24.2	13.25	na	na
LI	Liechtenstein	2011-2015	12.5	2.5	6.92	1.39
LU	Luxembourg	2008-2015	29.22	5.84	21.92	5.47
MT	Malta	2010-2015	29	0	26.25	0.00
NL	Netherlands	2007-	25	5	18.75	3.75
PT	Portugal	2014-	29.5	15.75	31.50	15.00
ES	Spain	2008-	25	10	22.50	-2.95
CH	Switzerland	2011-	21.15	8.8	9.50	2.74
TR	Turkey	2015-	20	11	na	na
GB	UK	2013-	21	10	15.75	7.50

* in %, as of most recent date (2015 or 2016).

From Evers et al. (2015). Not available for the most recent patent box countries.

Table B3

Inter-country patent transfer flows

Estimates including 14 tax haven countries

Dependent variable: Number of patents transferred from seller country to buyer country during the year

Variable	*All* *(1)*	*All* *(2)*	*All* *(3)*	*Within group* *(4)*
Buyer corporate tax rate	0.69	0.79	0.77	-0.93
	(1.33)	(1.30)	(1.30)	(1.87)
Dummy for buyer patent box	-0.04			
in all years after introduction	(0.14)			
Buyer patent tax rate wedge		0.03		
in all years after introduction		(0.71)		
Buyer patent tax rate wedge			-0.65	0.04
in year of introduction			(0.76)	(0.97)
Buyer patent tax rate wedge			1.38	-0.56
in year after introduction			(1.01)	(0.71)
Buyer patent tax rate wedge			-0.69	0.30
two years after introduction			(1.14)	(0.89)
Seller corporate tax rate	1.16	1.29	1.30	0.76
	(1.07)	(1.07)	(1.06)	(1.50)
Dummy for seller patent box	-0.34***			
in all years after introduction	(0.11)			
Seller patent tax rate wedge		-1.77***		
in all years after introduction		(0.61)		
Seller patent tax rate wedge			-1.18*	-0.74
in year of introduction			(0.65)	(0.80)
Seller patent tax rate wedge			-0.70	-1.12
in year after introduction			(0.72)	(1.08)
Seller patent tax rate wedge			0.01	-0.98
two years after introduction			(0.93)	(1.15)
Chi-squared	10545.1	10528.5	10583.4	10417.8
Chi-sq degrees of freedom	120	120	124	124

Poisson random effects panel regression with standard errors clustered on buyer-seller country pairs.

41,650 observations on 2,450 country pairs, 2000-2016

Coefficient significance is denoted by * p<0.1, ** p<0.05, *** p<0.01.

All regressions include complete sets of dummies for the 51 buyer and 49 seller countries and years.

Table B4

Inter-country patent transfer flows - exploring tax variables

Estimates including 14 tax haven countries

Dependent variable: Number of patents transferred from seller country to buyer country during the year

Variable	*All* *(1)*	*All* *(2)*	*All* *(3)*	*All* *(4)*	*All* *(5)*	*Within group* *(6)*	*Within group* *(7)*
Difference:	0.36	0.29	0.39	0.48	0.19	1.05	1.28
seller corp tax-buyer corp tax	(0.81)	(0.80)	(0.81)	(0.82)	(0.92)	(1.15)	(1.31)
Difference:	0.62	0.83	0.52	1.24*	0.29	1.54	0.29
buyer-seller patent tax wedge	(0.50)	(0.51)	(0.53)	(0.65)	(0.56)	(0.96)	(0.78)
D (existing patents) * buyer-		(0.75)					
seller patent tax wedge		(1.11)					
D (acqired patents) * buyer-			0.40				
seller patent tax wedge			(1.12)				
D (dev condition on use)*buyer-				-1.70		-2.38*	
seller patent tax wedge				(1.05)		(1.36)	
D (CFC rules apply to buyer)					-0.10		-0.11
					(0.22)		(0.28)
D (CFC) * seller-buyer corp					0.65		-1.05
tax difference					(1.50)		(1.73)
D (CFC) * buyer-seller patent					1.54		1.86
box difference					(1.09)		(1.53)
Chi-squared	10073.8	10077.7	10071.8	10051.4	10341.1	8146.2	14092.5
Degrees of freedom	120	121	121	121	123	121	123

Poisson random effects panel regression with standard errors clustered on buyer-seller country pairs.

41,650 observations on 2,450 country pairs, 2000-2016

Coefficient significance is denoted by * p<0.1, ** p<0.05, *** p<0.01.

All regressions include complete sets of dummies for the 51 buyer and 49 seller countries and years.

Table B5

Inter-country patent transfer flows - exploring tax variables

Dependent variable: Number of patents transferred from seller country to buyer country during the year

Variable	*All* *(1)*	*All* *(2)*	*All* *(3)*	*All* *(4)*	*All* *(5)*	*Within group* *(6)*	*Within group* *(7)*
Difference:	0.55	0.48	0.57	0.68	0.24	1.14	1.28
seller corp tax-buyer corp tax	(0.83)	(0.82)	(0.83)	(0.85)	(0.93)	(1.17)	(1.33)
Difference:	0.56	0.79	0.48	1.20*	0.22	1.45	0.19
buyer-seller patent tax wedge	(0.50)	(0.52)	(0.54)	(0.67)	(0.57)	(0.99)	(0.80)
D (existing patents) * buyer-		-0.81					
seller patent tax wedge		(1.11)					
D (acqired patents) * buyer-			0.33				
seller patent tax wedge			(1.12)				
D (dev condition on use)*buyer-				-1.70		-2.29	
seller patent tax wedge				(1.06)		(1.39)	
D (CFC rules apply to buyer)					-0.27		-0.19
					(0.21)		(0.30)
D (CFC) * seller-buyer corp					2.01		-0.45
tax difference					(1.44)		(2.10)
D (CFC) * buyer-seller patent					1.64		1.97
box difference					(1.09)		(1.57)
Chi-squared	4709.7	4751.1	4715.0	4780.1	4778.8	3129.8	3109.2
Degrees of freedom	92	93	93	93	95	93	95

Poisson random effects panel regression with standard errors clustered on buyer-seller country pairs.

22,644 observations on 1,332 country pairs, 2000-2016

Coefficient significance is denoted by * p<0.1, ** p<0.05, *** p<0.01.

All regressions include complete sets of dummies for the 37 buyer and seller countries and years.

Figure B1

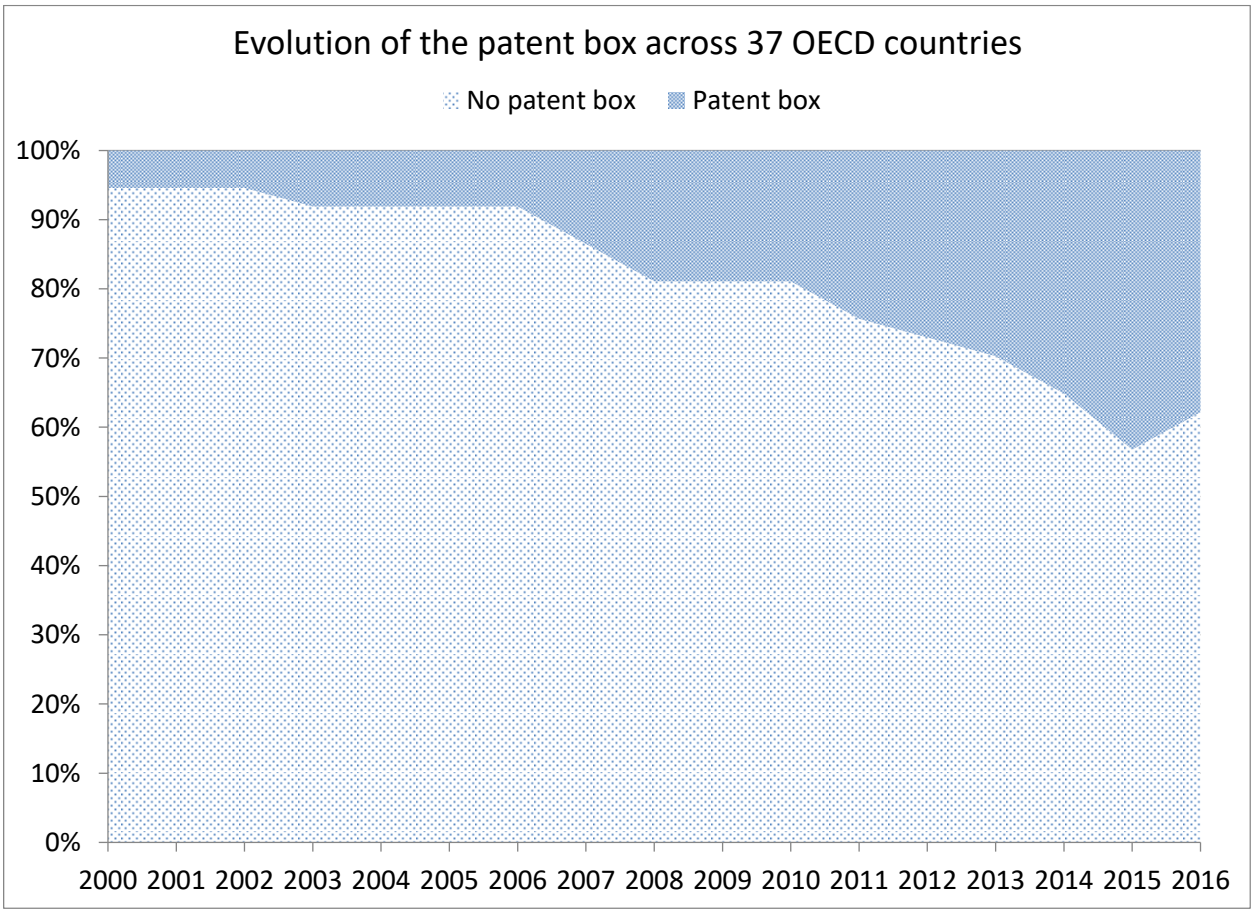
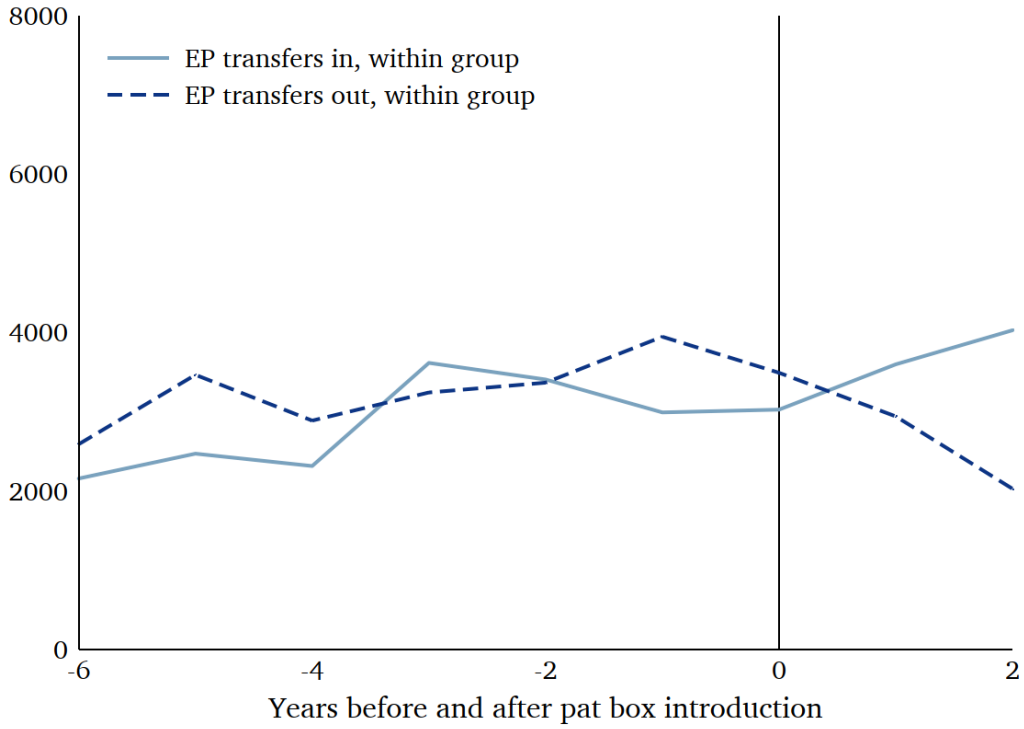

Evolution of the patent box across 37 OECD countries
No patent box
Patent box
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

Figure B2

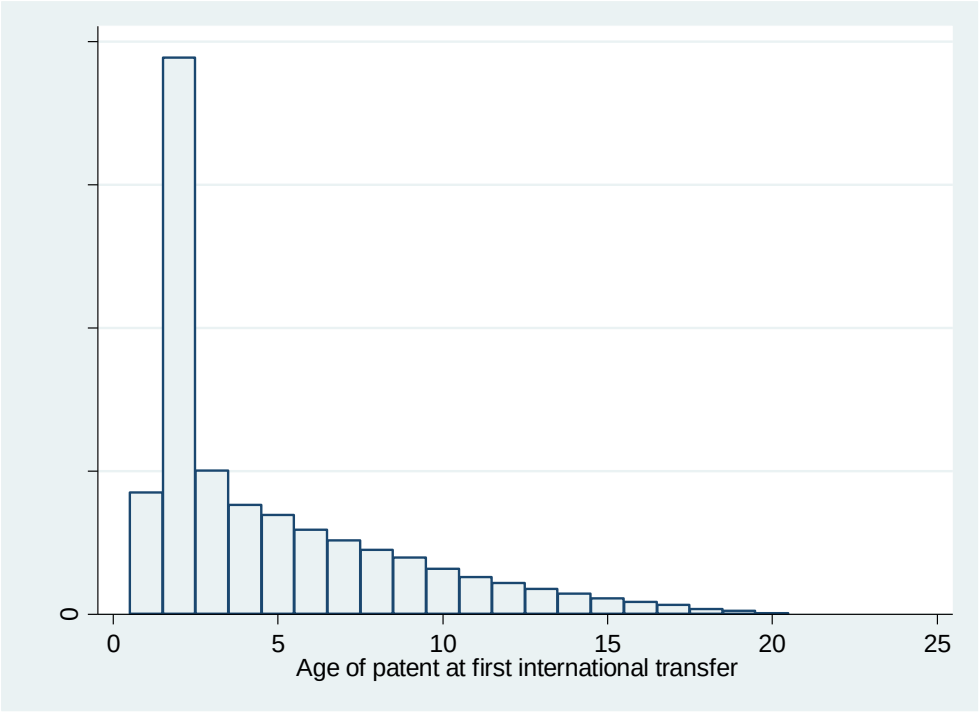
Patent transfers between countries around the time of patent box introduction, within group only



Appendix C: Patent level data on transfers

Our analysis sample of (first) international patent transfers consists of 91,617 patents applied for between 1991 and 2014, and transferred between 2000 and 2014. Patents are transferred internationally at all ages, but a large number are transferred two years after the year of application, which coincides with the most likely year of grant date (Figure C1).

Figure C1



This is confirmed by Figure C2, which shows the distribution of the age at transfer relative to the grant date for the 61% of the patents that have been granted, separately for arm's length transfers and those within group (i.e., within a multinational). For within group transfers, a large majority take place before the grant (78%). Although the majority of the other transfers also occur before grant (56%), they have a secondary peak two years after grant. In addition, all the transfers for the patents not yet granted take place before grant, perforce. We also examined the distribution of transfer age relative to grant for transfers to countries with and without a patent box at the time of transfer. These look very similar (not shown).

Figure C2

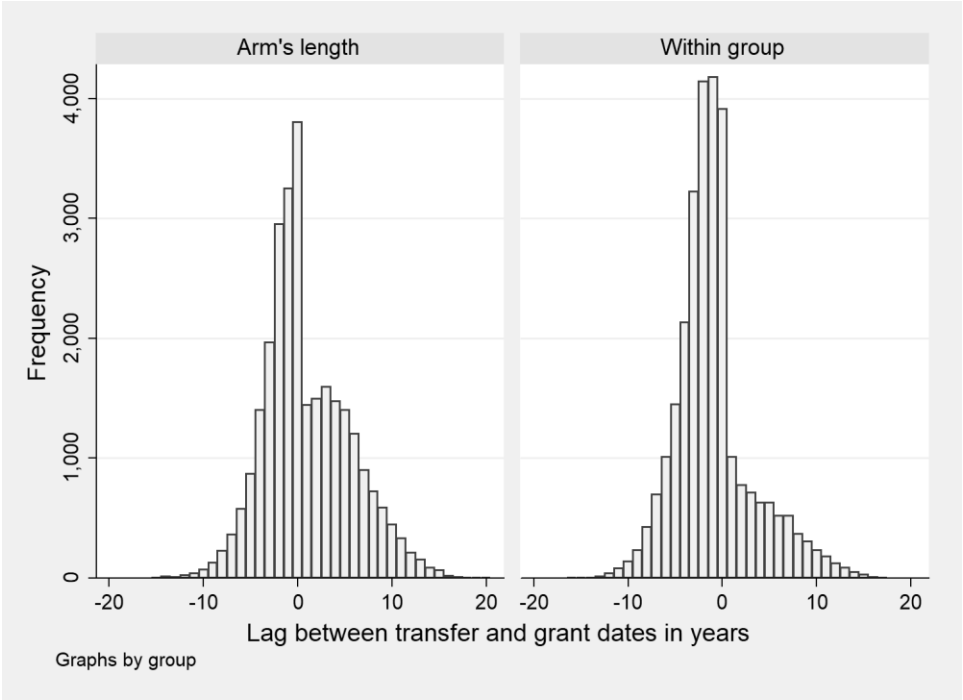

Arm's length
Within group
Frequency
0
1,000
2,000
3,000
4,000
-20
-10
0
10
20
Lag between transfer and grant dates in years
Graphs by group

Table C1

EPO patents applied for 2000-2016: Simple statistics

Variable	*Mean#*	*St.dev.*	*Median*	*IQ range*	*Min*	*Max*
Internationally transferred patents (N=106,471)						
Family size	7.198	0.573	7	0.83	1	235
Number of claims	13.453	0.551	14	0.73	1	592
5-year forward cites	1.212	0.822	1	3.00	0	206
Number of inventors	2.375	0.438	2	1.50	0	62
Value index	0.180	0.663	0.10	0.87	-1.74	4.31
Value index (dummies removed)%	0.136	0.613	0.07	0.80	-2.14	4.11
Number of applicants	1.017	0.066	1	0.00	1	10
Cumulative applicant patents*	10.12	2.072	2.0	30.00	1	953
MNC (multi-country research)	0.675	0.468	1	1	0	1
Corporation, not MNC	0.242	0.428	0	0	0	1
Individual	0.068	0.252	0	0	0	1
Government or non-profit	0.015	0.121	0	0	0	1
Patents that are not internationally transferred (N=270,538)@						
Family size	5.721	0.565	5	0.80	1	427
Number of claims	12.380	0.540	13	0.80	1	481
5-year forward cites	0.946	0.713	1	2.00	0	187
Number of inventors	2.269	0.444	2	1.00	0	53
Value index	-0.023	0.651	-0.10	0.84	-1.87	4.47
Value index (dummies removed)%	-0.008	0.592	-0.07	0.76	-2.17	4.34
Number of applicants	1.022	0.073	1	0	1	18
Cumulative applicant patents*	10.01	1.930	3	22	1	953
MNC (multi-country research)	0.628	0.483	1	1	0	1
Corporation, not MNC	0.284	0.451	0	1	0	1
Individual	0.048	0.214	0	0	0	1
Government or non-profit	0.040	0.195	0	0	0	1

	Difference in means#			
	Diff	*s.e.*	*T-stat*	*Ranksum test - chisq(1)*
Family size	0.100	0.002	44.9	98.2
Number of claims	0.036	0.002	16.9	38.7
5-year forward cites	0.107	0.003	34.8	47.9
Number of inventors	0.020	0.002	11.6	22.3
Value index	0.203	0.003	79.2	86.8
Value index (dummies removed)%	0.145	0.002	61.3	66.3
Number of applicants	-0.002	0.000	-8.7	-11.5
Cumulative applicant patents	0.005	0.008	0.6	-9.4
MNC (multi-country research)	0.047	0.002	25.8	32.7
Corporation, not MNC	-0.042	0.002	-25.1	-27.2
Individual	0.020	0.001	21.0	19.5
Government or non-profit	-0.025	0.001	-43.8	-40.3

The geometric mean is shown for all variables except the four sector dummies and the value index; the t-test is conducted on the log means for these variables.

* Cumulative patent applications by patent owner in year 2000 or year of patent filing, whichever is later.

@ 10 per cent sample of non-transferred patents.

% This index is based on the first 4 variables with year, country, and technology class means removed.

The ranksum tests whether the distribution of the variable for the transferred patents is to the right of that for non-transferred patents.

Table C2

All EPO patents applied for 2000-2016: 361,131 observations#

Correlation matrix										
Family size	1.000									
Number of claims	0.088	1.000								
5-year forward cites	0.345	0.162	1.000							
Number of inventors	0.181	0.108	0.183	1.000						
Number of applicants	0.005	0.011	0.010	0.110	1.000					
Cumulative applicant patents	-0.022	-0.072	0.014	0.091	-0.047	1.000				
MNC (multi-country researcher)	0.053	-0.029	0.057	0.148	-0.096	0.498	1.000			
Corporation, not MNC	-0.036	0.013	-0.039	-0.107	-0.036	-0.415	-0.802	1.000		
Individual	-0.042	-0.006	-0.053	-0.152	0.178	-0.202	-0.334	-0.153	1.000	
Government or non-profit	0.002	0.051	0.013	0.068	0.110	-0.042	-0.251	-0.115	-0.048	1.000
Correlation matrix with year, tech, country dummies removed										
Family size	1.000									
Number of claims	0.024	1.000								
5-year forward cites	0.299	0.117	1.000							
Number of inventors	0.122	0.078	0.139	1.000						
Number of applicants	-0.007	0.012	0.008	0.106	1.000					
Cumulative applicant patents	-0.007	-0.048	0.009	0.076	-0.035	1.000				
MNC (multi-country researcher)	0.058	-0.033	0.039	0.121	-0.081	0.450	1.000			
Corporation, not MNC	-0.023	0.024	-0.016	-0.074	-0.047	-0.383	-0.794	1.000		
Individual	-0.038	-0.001	-0.038	-0.125	0.175	-0.153	-0.289	-0.211	1.000	
Government or non-profit	-0.044	0.027	-0.012	0.034	0.092	-0.019	-0.250	-0.123	-0.055	1.000

All variables are in logs except the four sector dummies

Sample is based on a 10 per cent sample of the non-transferred patents and all of the transferred patents.

Table C3

Variable means by type of transfer#

	no transfer@	*non-group, non-tax*	*group, non-tax*	*non-group, tax-related*	*group, tax-related*
Observations	272,305	39,772	39,166	11,942	13,924
Family size	5.72	7.02	7.41	7.13	7.18
Number of claims	12.38	13.53	13.68	13.19	12.83
5-year forward cites	0.95	1.17	1.26	1.21	1.21
Number of inventors	2.27	2.22	2.50	2.37	2.49
Value index	-0.02	0.14	0.23	0.17	0.18
Value index (dummies removed)%	-0.01	0.12	0.16	0.11	0.14
Number of applicants	1.02	1.01	1.01	1.01	1.04
Cumulative applicant patents*	10.0	5.9	14.0	7.8	22.0
MNC (multi-country researcher)	0.63	0.56	0.76	0.60	0.84
Corporation, not MNC	0.28	0.34	0.16	0.33	0.12
Individual	0.05	0.08	0.07	0.06	0.03
Government or non-profit	0.04	0.02	0.01	0.02	0.01

The geometric mean is shown for all variables except the four sector dummies later.

@ 10 per cent sample of non-transferred patents.

% This index is based on the first four variables with applicant year and country, and technology class means removed.

Appendix D: Modelling international patent transfer

Overview

Estimation of a model of international patent transfer as a function of the characteristics of the patent (X), the current country (Z), and the potential countries to which the patent might be transferred (W) proved difficult, probably because we have limited variability in the tax variables, especially those for the patent box. The body of the paper presents simple logit and multinomial logit estimates, with standard errors clustered at patent owner level. This approach allows correlation across time and patents owned by a single entity, but it does not identify effects associated with the characteristics W of the countries to which a patent might be transferred, with the exception of identifying those with a patent box.

We attempted to estimate a number of other econometric models as described in the following:

1. A hazard rate model of transfer as a function of the patent characteristics X, seller characteristics Z, and possibly interactions of X with W. This kind of model allows for the absorbing nature of the first transfer. In principle, transfer to a patent box country versus a non-patent box country could be explored using a competing risks hazard model, but this proved impossible due to lack of convergence.
2. A multinomial probit model similar to the multinomial logit models in the text, which would allow for correlation among the alternatives.
3. A multinomial logit model of choice with random coefficients on the case variables.[4]

With a suitable assumption on the distribution of ε, the model in the text will generate a hazard function for the transfer from country s to country b. Alternatively, given its equivalence to a random utility model, it will generate a multinomial logit or nested logit model under the extreme value assumption. Transfer is more likely under the following conditions:

1. The difference between the tax rates applying to patent income in the two countries is larger. For most countries and years, this is the corporate tax rate, while for countries that have introduced a patent box, it will be the patent box rate. For the government/non-profit sector, the rate will be zero.
2. The value of the patent in generating tax-relevant income is higher. That is, the value indicators X are larger.
3. The cost of making the transfer is lower, which we proxy using the dummies for the type of patenting entity and its cumulative patent holdings.

All of these are measurable for the patents that are actually transferred.

However, a major problem for hazard rate or simple logit estimation is that the potential tax rates in the buyer country are unobserved if we do not observe a transfer. To ameliorate rather than actually solve this problem, we computed average tax rates of patent income in each year across the countries, excluding the country in which the patent is resident. The difference in tax rates in the equation above was then the difference between the tax rate faced by patent income in the potential selling country

[4] Fixed coefficients would result in as many coefficients as choices for each case variable, and is unlikely to be identified.

less the average tax rates across the potential buying countries. In the case of an actual transfer, we used the observed tax rate in the buying country instead, so as not to lose too much precision in our estimates. This estimation strategy was unsuccessful, as one might have expected.

If we believe that the country of patent ownership affects the profits available from a patent in ways other than the tax rate faced by those profits, we can complicate the model as follows:

$$\pi_{its} = (1-\tau_{ts})(X_i\beta + Z_s\delta + \varepsilon_{it})$$

From this equation it is worth observing that case variables (those that are associated with the patent and its original location/owner) are those indexed by *i*, *j*, and *s*. Such variables are identified in the simple logit or hazard rate models. Alternative-specific variables are those indexed by *b*, possibly in product with case variables. These are not identified unless multinomial logit (possibly nested) or multinomial probit with many alternatives are used.

The following case variables are suggested by the model:

- Patent quality measures, interacted with the patent tax rate of the seller.
- Characteristics of the selling country, interacted with the patent tax rate of the seller.
- Characteristics of the patent owner.

It is possible that one also might want to add the non-interacted variables, and the interaction of taxes with the patent owner characteristics. It is also possible to include dummies for the selling country, and for the transfer years. For the tax rate, the sensible variable to use is the nominal tax rate faced by patent income (which may be nothing like the actual tax rate faced by an individual entity, but we do not have the information to compute that). The tax rate we use is the corporate tax rate in the case of no patent box, or the patent box rate.

The alternative-specific variables are the following:

- Patent quality measures, interacted with the patent tax rate of the buyer.
- Characteristics of the buying country, interacted with the patent tax rate of the buyer.

Again, it might be useful to add the non-interacted variables. And note that these variables are not available in the case of no transfer. It is also possible to include dummies for the buying country, although identification may be difficult.

In what follows we present a set of hazard estimates corresponding to the logit estimates in the body of the paper.[5] For simplicity, we measure patent value as the first principal component of the set of 4 value indicator variables (forward cites, claims, family size, and number of inventors). All these variables have positive loadings on the first component, and we know that they measure slightly different things, so it makes sense to use some kind of common aggregate.

[5] The multinomial probit models and random coefficient logit models did not converge, which is most likely due to insufficient variation in the data on patent boxes.

Hazard rate estimation

The natural way to model the decision to transfer a patent internationally is with a survival or hazard rate model.[6] Because the regressors we will use in our initial analysis are constant over time, the results from a hazard rate model will be similar to those from a logit probability model with standard errors clustered across time, as was presented in the text. In the case of the Weibull model with covariates that do not vary over time, the estimates will be identical (Lancaster 1990, p. 104). We present estimates based on a proportional hazard model here; the equivalent logit estimates from the body of the paper are shown for comparison.

We model the decision to transfer a patent using proportional hazard rate models, where the hazard of patent *i*'s transfer at time *t* is given by the following:

$$\begin{aligned} h(X_i,t) &\equiv \Pr(i \text{ transferred at } t \mid i \text{ not yet transferred}, X_i) \\ &= h(t)\exp(X_i b) \end{aligned},$$

where *i* denotes a patent and *t* denotes the time since the patent's application date. *h(t)* is the baseline hazard, which is either a non-parametric or a parametric function of time since entry into the sample. The impact of any characteristic *x* on the hazard can be computed as follows:

$$\frac{\partial h(X_i,t)}{\partial x_i} = h(t)\exp(X_i b)b \quad \text{or} \quad \frac{\partial h(X_i,t)}{\partial x_i}\frac{1}{h(X_i,t)} = b$$

Thus if *x* is measured in logs, β measures the elasticity of the hazard rate with respect to *x*. Note that this quantity does not depend on the baseline hazard *h(t)*, but is the same for any *t*.

Figure D1 shows the Kaplan-Meier estimate of the cumulative hazard of an international transfer as a function of patent age. The curve is smooth and shows the large jump between ages 1 and 2 that we also observed in Figure C1. We estimated a number of proportional hazard models, all of which were able to reproduce this curve easily (not shown). We use the Cox proportional hazard model here, as it is the most flexible, and best accommodates the jump in the data at age 1 to 2.

[6] As indicated above, ideally one would model the decision to transfer a patent to a particular country as a function of that country's characteristics as well as the patent characteristics, using a random coefficients logit model as in Griffith et al. (2004), or perhaps a competing risks model. However, we found that there was insufficient variability across countries in the patent box to obtain meaningful estimates using these methods.

Figure D1

Cumulative hazard of an international transfer for EP patents

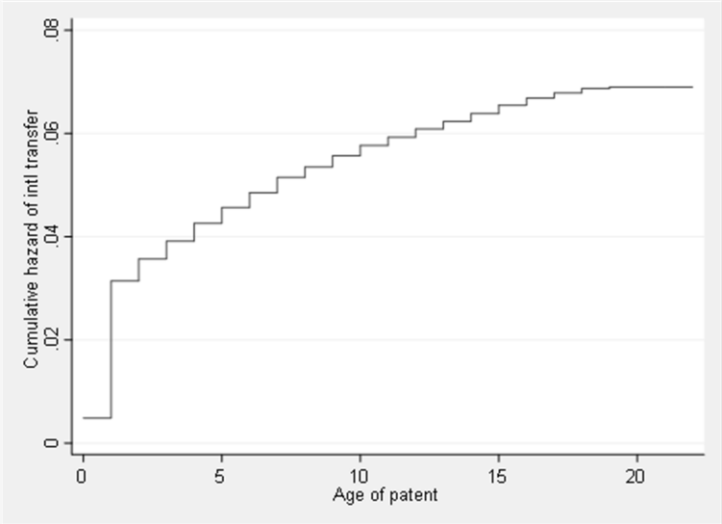


Table D1 presents the results of Cox proportional hazard estimation of the same model as the logit estimation, which is shown for comparison. Note that because hazard rate estimation requires that all observations begin at least with the period before the transfer, the sample sizes are slightly different from the logit model in the text (where a transfer is allowed in the first period). The estimates are still very similar to the logit estimates, as they should be.

Table D1

Cox PH and Logit models of the probability of an international transfer

	Cox PH		*Logit*	
Variable	*(1)*	*(2)*	*(3)*	*(4)*
Selling country tax rate *	-0.328*	-0.403**	-0.282	-0.402**
patent value index	(0.183)	(0.180)	(0.198)	(0.198)
Patent value index	0.327***	0.350***	0.352***	0.388***
	(0.051)	(0.052)	(0.055)	(0.056)
Selling country tax rate		1.125***		2.093***
		(0.352)		(0.389)
Log (cumulative patents)	-0.003	-0.003	-0.007	-0.007
for patent owner	(0.036)	(0.036)	(0.042)	(0.042)
Patent owner a multinational	0.206**	0.207**	0.274**	0.275**
research firm	(0.097)	(0.098)	(0.113)	(0.113)
Patent owner a corporation,	-0.040	-0.038	-0.037	-0.035
not multinational	(0.052)	(0.052)	(0.059)	(0.059)
Log likelihood	-1,270,943.0	-1,270,765.8	-436,075.7	-435,531.0
Chi-squared	1,841.1	1,865.2	1,794.1	1,823.1
Degrees of freedom	88	89	88	89
R-squared	0.015	0.015	0.052	0.053

3,186,962 patent-year observations; 104,565 transfers

Heteroskedastic standard errors clustered on 74,513 patent owners.

All equations include seller country, year, and tech dummies.

Method of estimation is Cox proportional hazard in columns 1 and 2 and Logit in columns 3 and 4.

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