

稅法改正效果 所得·消費 變化 稅負擔效果 分離推定 研究

成 明 宰*

要 約

20 가 .

가 ,

. 가 20

. 가 가

가 가 가 가 .

. 序

가 가 ,

가 가 .

*

가 .
 . 가
 가 가 ()
)
 . 가 가
 . ,
 (,) , .
 가 가 1).

가
 . (1979, 1982), . (1987), Leipziger(1992),
 (1992) , (1982),
 . (1996A), . (1996), . (1999),
 (2000) , . (1996B),
 (1996) , (1966), Heller(1981), Oh(1982), (1984),
 . (1986), (1987), . (1996C), (1996)
 / , (1988), (1992), (1996)

가

1) 가 가 가

1 , 2

3

가

가

20

가

1982 1999

가

2).

가

가

가

가

가

가

가

가

가

(

),

가가

,

,

2)

가

가

. 2000
2000

가

가

2000

. 分析方法

1. 所得推定 所得階層 區分

가. 就業勤勞者家口 家口 所得推定

가 가 가 가 가 .
 가 가 가 가 가
 가 . 가 가 가
 , 가 가 가
 가 , 가 가 가

3).

가 가 (consistency)
 가 . ,
 .
 .
 1 () 700
 , 700 (

3) (1999) (2000) .

) 1
700 1

가 ,
가
가 (reverse regression)
(orthogonality condition) ,
(joint normal distribution) 가 ,
(conditioning variable)
가
가
가
가
4),
가
(causality)

4) ‘ ’ ‘ ’

6 財政研究

< - 1> 勤勞者家口 所得函数(逆消費函数) 推定結果

가 . ,
 < -1> 5).

. 所得推定方法

< -1> 1999

가 .
 가 .

$$\ln(\quad) = 4.25264 + 0.74818\ln(\quad) + 0.02038(\text{가} \quad) \\
 + 0.23555 \times 1[\quad = \quad] + 0.18170 \times 1[\quad = \quad] \\
 + 0.29136 \times 1[\quad = \quad] + 0.35535 \times 1[\quad = \quad] \\
 + 0.38850 \times 1[\quad = \quad] + 0.52716 \times 1[\quad = \quad] +$$

, 1[·] (indicator function) [·] 1
 가 0 가 .
 가 0 0.04130

. 3,000 가 , 0.1 4
 가 4,431 . , 가 ,

1 0
 ln .

$$= \exp(4.25264 + 0.74818 \times \ln(30,000,000) + 0.02038 \times 4 \\
 + 0.23555 \times 0 + 0.18170 \times 0 + 0.29136 \times 1 + 0.35535 \times 0$$

5) 가 가

8 財政研究

$$+ 0.38850 \times 0 + 0.52716 \times 0 + 0.1)$$

44,309,805

가 0 가 가 4,009
, 0 .

. 所得階層 區分

가 가 가 가
가 가 0.1(, 10%) 가
. 가 가 가
10 1 .

2. 稅負擔 推定

가. 所得稅 推定⁶⁾

, , .
. ,

6) 가 가
가 가
가 가

가 가
가 가 (1998)

, 가 , ()

가

() , 0 1 가

()

10% 15% 15/ 116.57)

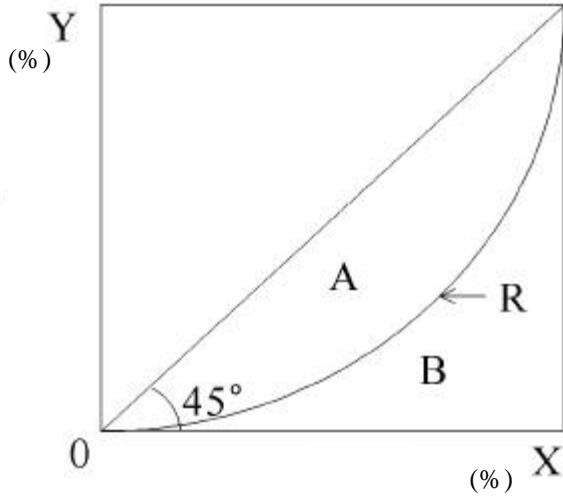
消費稅 推定

가가 10/ 110

가가 가

7) 15/ 100

[- 1] 租稅集中曲線



342 (=18 × 19)

. 가 , 18 × 19

()

()

() . (off-diagonal elements)

가 가

() ,

가

가

가 가

, 1982 2000

1982 1999

. 所得 · 消費 分配的 逆進度 指數 變化

1. 所得 · 消費

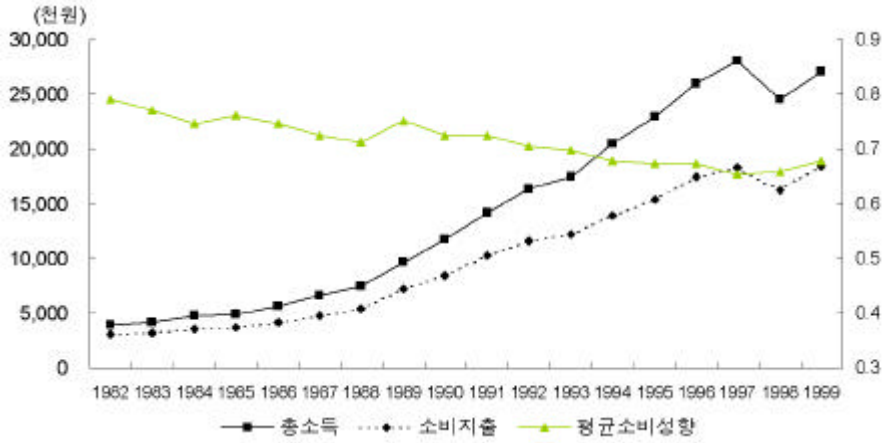
가 1982 1999 404 2,708
 11.85% 가 1997
 1998 2,452 가

< - 1> 總所得 分布

(:)

	1	2	3	4	5	6	7	8	9	10	
1982	1,516	2,108	2,489	2,884	3,236	3,667	4,235	4,992	6,038	9,228	4,037
1983	1,666	2,307	2,743	3,171	3,612	4,050	4,611	5,418	6,554	9,752	4,385
1984	1,833	2,581	3,099	3,559	4,021	4,562	5,126	5,951	7,255	10,887	4,882
1985	1,949	2,743	3,257	3,690	4,095	4,584	5,209	6,055	7,390	11,068	4,999
1986	2,200	3,160	3,754	4,245	4,818	5,423	6,112	7,102	8,629	12,675	5,809
1987	2,630	3,639	4,249	4,948	5,574	6,273	7,167	8,344	10,160	15,200	6,812
1988	3,091	4,302	5,123	5,819	6,535	7,287	8,240	9,498	11,513	17,235	7,860
1989	4,019	5,581	6,587	7,481	8,347	9,331	10,518	12,140	14,713	22,363	10,102
1990	5,118	6,974	8,115	9,119	10,183	11,392	12,721	14,550	17,225	24,848	12,025
1991	6,308	8,652	10,034	11,375	12,734	14,185	15,803	17,936	20,886	29,060	14,701
1992	7,181	10,005	11,672	13,152	14,610	16,305	18,089	20,298	24,186	33,615	16,906
1993	7,606	10,591	12,411	14,048	15,649	17,245	19,126	21,434	24,796	35,812	17,875
1994	8,637	12,167	14,239	16,066	17,964	20,074	22,433	25,304	29,738	40,851	20,745
1995	9,830	13,899	16,189	18,282	20,452	22,775	25,471	28,857	33,619	45,758	23,507
1996	10,632	15,135	17,773	20,322	22,951	25,585	28,634	32,299	37,490	52,046	26,283
1997	10,253	15,804	19,045	21,895	24,421	27,227	30,479	34,264	40,231	56,727	28,024
1998	6,635	12,316	15,574	18,432	21,007	23,793	26,830	30,828	36,707	53,119	24,520
1999	10,855	15,217	17,938	20,285	22,929	25,749	29,081	33,449	39,268	56,076	27,083

[- 1] 所得·消費支出 變化推移



가 1982 1997 306
 가 1982 1999 11.11%
 가 1999 1,836
 가 1982 0.76 1999 0.68
 가 1980 1990
 가 1997
 가 1998
 가 1982 1999 10) 0.24 0.29 1980
 가 0.29 1990
 가 0.24 1997

10) 가

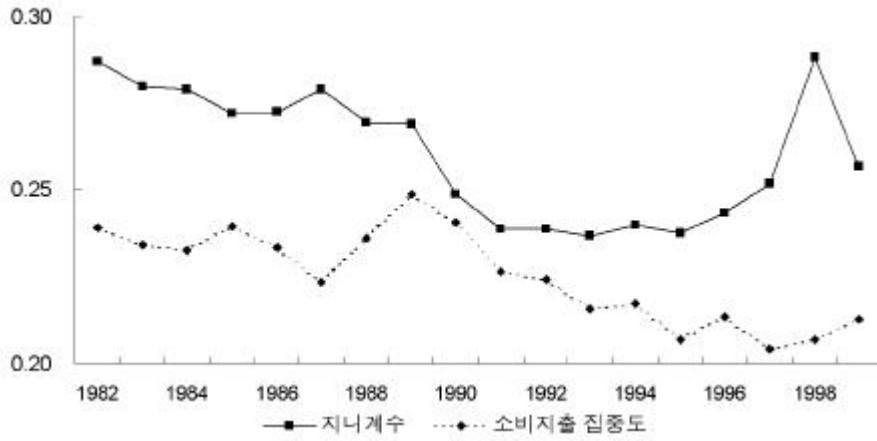
가

< -2> 消費支出 分布

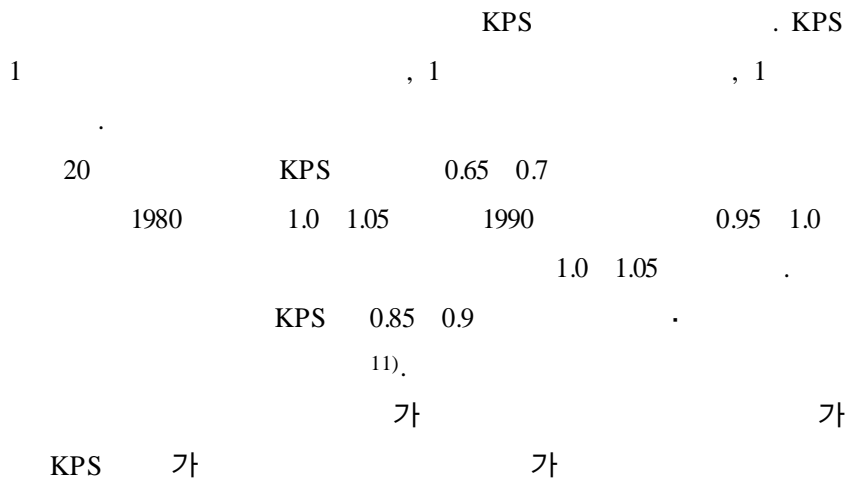
(:)

	1	2	3	4	5	6	7	8	9	10	
1982	1,426	1,879	2,129	2,368	2,505	2,780	3,191	3,688	4,313	6,343	3,061
1983	1,561	1,924	2,205	2,516	2,789	2,992	3,294	3,847	4,682	6,494	3,229
1984	1,695	2,176	2,456	2,716	2,908	3,331	3,647	4,109	5,025	7,088	3,512
1985	1,751	2,303	2,497	2,759	3,016	3,356	3,896	4,406	5,153	7,660	3,677
1986	2,044	2,662	2,802	3,160	3,469	3,834	4,224	4,985	5,971	8,464	4,160
1987	2,403	3,025	3,216	3,732	3,969	4,395	4,981	5,474	6,723	9,344	4,723
1988	2,689	3,279	3,730	4,012	4,469	4,895	5,506	5,935	7,546	11,305	5,334
1989	3,368	4,237	4,890	5,449	5,992	6,604	7,547	8,491	10,161	15,539	7,224
1990	3,899	5,004	5,837	6,395	7,100	7,773	9,169	10,185	11,999	17,198	8,456
1991	4,825	6,505	7,080	8,107	8,681	9,977	10,842	12,248	14,384	20,090	10,276
1992	5,472	7,314	8,136	9,083	9,892	11,270	12,161	13,637	15,760	23,066	11,576
1993	5,929	7,491	8,969	9,970	10,661	11,723	13,082	14,359	16,523	23,357	12,209
1994	6,577	8,648	10,150	10,816	12,348	13,098	15,066	17,186	19,269	25,950	13,909
1995	7,180	10,044	11,237	12,956	13,718	14,697	16,298	18,884	21,110	27,921	15,401
1996	8,061	10,827	12,606	14,378	15,825	16,784	19,010	20,986	23,958	32,204	17,462
1997	9,384	12,376	13,045	14,968	15,988	17,366	19,718	21,484	24,671	34,476	18,341
1998	9,019	10,292	11,661	12,631	14,131	15,590	16,356	19,265	22,074	30,696	16,170
1999	8,732	11,776	13,224	15,046	16,180	17,511	19,523	22,286	25,059	34,266	18,359

[-2] 係數 消費支出 集中度 推移



2. KPS 指數 變遷



11))가 , , , , , ,) (가가 ,) 가

가

가

1980

1990

가

가

KPS 1
. 1990

가

12)

13)

KPS 가

KPS 가

가가

KPS 0.95 1.05

가

가가

가가

가

가

가가

1980

1980

1990

가

12)

가

가

13)

가

가

가

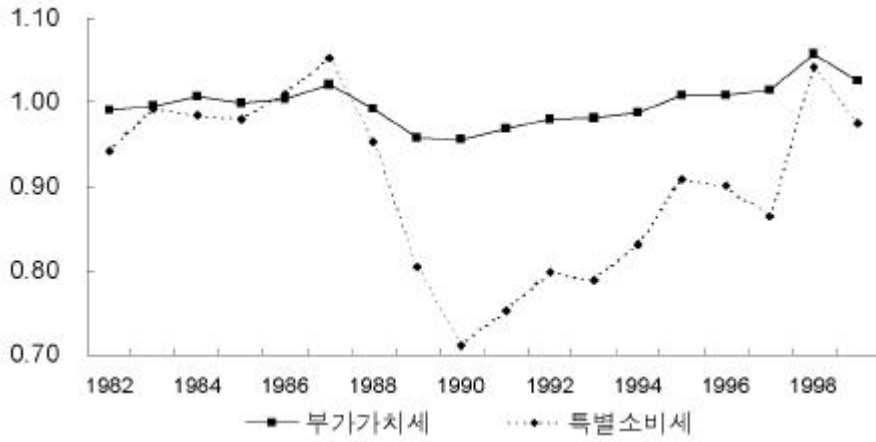
가 . 1990
 가
 . 가
 가
 .
 1980
 1980 . 가
 () . 1980
 가 , 가
 가 ,
 가
 KPS 14). . 가

가 가
 . KPS 1980 0.4 가
 , KPS 1 15).
 가 가
 .
 KPS가 1 . KPS가

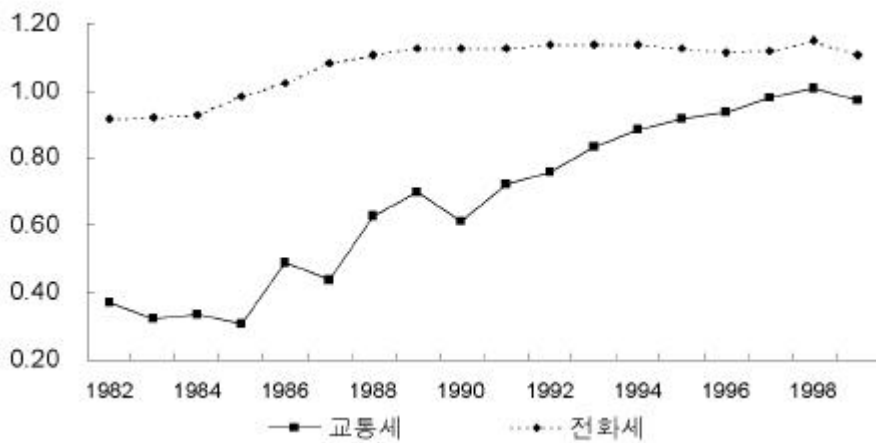
14) 1999 가 ,
 KPS 가
 15) 1993 KPS

IT 가

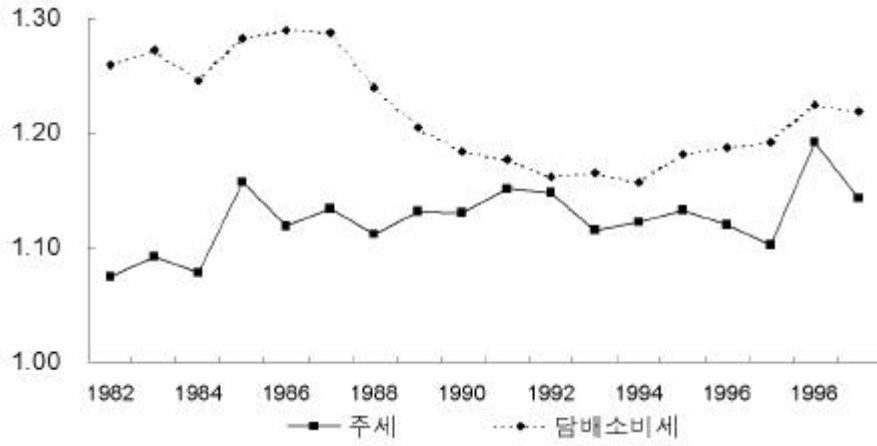
[-5] KPS 指數 : 附加價值稅 特別消費稅



[-6] KPS 指數 : 交通稅 電話稅



[-7] KPS 指數 : 酒稅 消費稅



. 所得 · 消費 變化 稅法改正 再分配 效果

1. 所得稅 · 消費稅 計

[-1] .
 , KPS 0.85 0.9
 .
 < -1>
 .
 가 . 1980 1990
 KPS 0.9
 가 . 가
 가 , 1990 가
 KPS , 1990
 가 . 1980

< - 1> KPS : 所得稅・消費稅 計(1982 1999)

1990 . 가

KPS 가 가 가
KPS . 가
가 가 가
가 가 가
가 . 가

()
가 .
(causality)
() ,
가 .

2. 所得稅 計

()
KPS가 가 가
가 가
가 가 . ,
가 .

< -2> KPS : 所得稅 計(1982 1999)

가

가

,
가

가

가

가

< -2>

< -3>

1988 1989

KPS

1988

KPS

0.69625

0.67191

가

가

KPS가 9.3%

1989

55%

50%

(4 가) 244

403.52

1988

1989

KPS

0.63136

0.06489p

가

가

가

1989

KPS

0.67191

0.04055p

가

가

가

< -2>

가
가 .
가
가
가 ,
가 ,
< -3>
가
가
가
가
가
가
< -2>
< -3> 가

3. 消費稅 計

가
가
가 , KPS 가 가 1990

< -3> KPS : 勤勞 綜合所得稅(1982 1999)

< -4> KPS :消費稅 計(1982 1999)

1982 1999 KPS 1980
 1.0 1.05 1990 0.95 1.0
 KPS가
 1.0 1.05
 KPS,

가

1982 1999

가

가

4. 特別消費稅 交通稅

1980 1980 KPS가 1990 가
 . ,
 가 .
 .
 1980 , 1980 1990 KPS
 KPS가 가 1990 KPS
 가 . 1980
 () 가
 , 1980 가

< -5> KPS :特別消費稅(1982 1999)

. 1990 가 , 가
가 . 1980
1990
1980 1990
KPS 가

1990

KPS 가 . 1980 , 1990
KPS가 . 1990 ,
1990 가

가

KPS

1990

1990

가

1990

1980

KPS 가 , 1990

가

1999

2000 KPS가

가

가 () KPS 가)

가 ()

가

1980 KPS 가 1

1990 1 1980

1990 가 ()

(1993, 1996, 2000) 1990 가 (: 1990)

가 (: 1990)

가

. 1990

가

가

1994

가

1982 1993

.

.

< -6> KPS : 交通稅(1982 1999)

가

KPS

KPS ()

가

가 2

가

()

5. 酒 稅

, KPS

20

KPS 가 가

1991

KPS

1994

1996

KPS

가

. 1997

150%

130%

가

가

KPS

가

, 2000

WTO

가

KPS

< -7> KPS : 酒稅(1982 1999)

가 .
 , 1990 KPS 가
 가 가
 1990 가 , 1998
 KPS 가 가 . 1990
 가
 . 1990 . 가 . 가
 가 가 ,
 가 가 가
 KPS가 가 16).

6. 其 他

. (), 가가 , ,
 가 17).
 .

16) 1996 가 28,479k1 26.3% 가
 16.7% , 1997 24,560k1 13.9% .
 1997 3.4% 가 .

17) 가 가
 가
 , KPS 가
 KPS .

가
 , 1980 1990 KPS 가
 가
 가
 KPS
 가가 1980 1990
 KPS 가 1
 가

< -8> KPS : 利子 · 配當所得稅, 附加價値稅, 交通稅, 電話稅, 消費稅, 教育稅

		가가				
1982	0.86237	0.99099	0.36905	0.91570	1.25967	0.97482
1983	0.80423	0.99504	0.32337	0.94113	1.27165	1.02336
1984	0.75433	1.00644	0.33358	0.97224	1.24500	1.01276
1985	0.78313	0.99926	0.30798	0.98093	1.28269	1.03371
1986	0.75747	1.00415	0.49000	1.02348	1.28990	1.03144
1987	0.75868	1.02050	0.43588	1.08072	1.28671	1.06632
1988	0.76230	0.99208	0.62565	1.10383	1.23985	0.98260
1989	0.86478	0.95798	0.69634	1.12345	1.20468	0.87807
1990	0.86562	0.95614	0.61180	1.12462	1.18331	0.82020
1991	0.78980	0.96887	0.72044	1.12540	1.17652	0.81969
1992	0.76872	0.97957	0.75791	1.13630	1.16188	0.88261
1993	0.84499	0.98134	0.83365	1.13775	1.16537	0.76601
1994	0.86920	0.98739	0.88547	1.13803	1.15647	0.81206
1995	0.81195	1.00806	0.91548	1.12569	1.18086	0.88606
1996	0.85947	1.00778	0.93612	1.11107	1.18719	0.96109
1997	0.84806	1.01590	0.97990	1.11742	1.19180	0.99654
1998	0.87841	1.05702	1.00579	1.14940	1.22406	1.05628
1999	0.81865	1.02925	0.97153	1.10628	1.21904	1.00953

: 1994

1980

가
가

KPS가 1.15 1.25

1980

1980

가 가
1996

가
가

KPS

가 1

가

KPS가

가
가

2 3

, 가

가

(chronical changes in tax burden)

가

가

1982 1999 18

1982 2000 19

參 考 文 獻

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가가 가
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93-02,
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가
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1
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99-03,
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가
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『 』, 5, 1982.

『 』, 『 』, 『 』, 1996(A).

『 가가 : 가 가 『 』, 1996(A).

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附錄 . 所得稅 消費稅 負擔 分布

< - 1> 所得稅 負擔 分布

(:)

	1	2	3	4	5	6	7	8	9	10	
1982	7	16	27	41	57	77	97	143	224	574	126
1983	7	12	27	36	47	66	89	125	229	502	114
1984	6	17	28	44	63	73	116	166	281	580	137
1985	9	22	40	52	64	92	127	201	297	670	157
1986	14	31	53	63	84	122	160	259	336	809	193
1987	15	40	58	80	103	138	213	308	468	1,003	242
1988	24	59	88	119	162	210	299	384	586	1,285	321
1989	18	59	93	125	163	237	301	429	658	1,498	358
1990	32	73	124	179	199	277	382	502	735	1,490	399
1991	34	86	110	148	217	291	404	575	795	1,627	429
1992	49	103	161	231	347	443	593	801	1,147	2,170	604
1993	53	127	185	228	300	388	533	655	957	2,067	550
1994	55	150	209	283	344	453	699	862	1,268	2,261	658
1995	79	180	247	331	461	615	817	1,058	1,493	2,674	795
1996	54	162	249	341	469	629	821	1,081	1,476	2,948	823
1997	58	190	289	404	542	683	906	1,220	1,694	3,343	932
1998	6	67	172	251	387	505	671	962	1,451	2,933	740
1999	45	143	246	337	447	548	738	1,048	1,608	3,291	845

< -2> 消費稅 負擔 分布

(:)

	1	2	3	4	5	6	7	8	9	10	
1982	58	79	91	104	119	124	149	171	200	303	140
1983	68	81	101	121	125	137	147	178	223	308	149
1984	70	100	102	125	127	147	181	187	220	330	159
1985	68	98	122	120	136	149	168	191	217	335	160
1986	87	122	131	136	154	175	188	221	260	382	185
1987	109	145	158	180	198	200	242	267	308	439	224
1988	129	158	170	194	214	236	256	282	363	556	256
1989	158	208	240	256	292	325	366	418	500	895	366
1990	181	246	296	319	343	397	481	545	692	1,085	458
1991	226	323	345	429	444	533	602	682	870	1,317	577
1992	255	371	397	466	530	602	658	755	948	1,391	637
1993	276	387	500	538	593	713	795	882	1,119	1,657	746
1994	325	506	605	649	752	835	975	1,114	1,331	1,912	900
1995	386	554	679	791	828	903	1,026	1,214	1,336	1,848	956
1996	440	616	774	907	1,014	1,069	1,238	1,318	1,573	2,248	1,120
1997	568	830	851	1,071	1,172	1,228	1,412	1,675	1,824	2,726	1,335
1998	605	774	935	1,012	1,185	1,327	1,377	1,622	1,745	2,653	1,323
1999	617	966	1,088	1,285	1,341	1,530	1,708	1,979	2,152	3,139	1,580

附錄 . 主要 稅法改正 內容

1. 所得稅

가
 , 가
 ()
 가
 가

< - 1> 所得稅 免稅點 變遷(4 가) (:)

Year	Exemption Point (KRW)	Exemption Point (USD)
1982	2,380.0	1,200
1983 - 1988	2,440.0	
1989 - 1990	4,035.2	1,980
1991 - 1992	5,128.5	
1993	5,500.0	2,100
1994	5,871.4	2,220
1995	6,271.4	
1996	10,571.4	4,600
1997 - 1999	11,571.4	

20

< - 1> . 4 가
 1982 238 1999 1,157.1

1982 120 1999 460

19).
 1982 6 60%, 1980 6 55%, 1990
 5 50% , 1996 10 40% . 1980
 16 17 1996 4 . 20

15%

가 22% .

< -2> 所得稅率 變遷

(: %)

1982	6	60	17
1983 1988	6	55	16
1989 1990	5	50	8
1991 1992	5	50	5
1993	5	50	6
1994 1995	5	45	6
1996 1999	10	40	4

19) 가 40% 가 1982 1999 가

2. 消費稅

가가 1977 10%

1999 가 가

가 .

20 1989 , 1994 ,

1999 가 . 1989

14 28% 10 20% , 가 19.6 28%

15 25%, 10.5 28% 10 25% 10%, 15%, 20%,

25% . 1994 10%, 15%,

20% 가 가

. 1994 10

. 1999 12

가 .

1991 7

200% 120% 150% 70% . 1994 1996

120% 100% . 1997

150% 130% .

1989 15% 10%

< -3> 石油類 關聯 消費稅 稅率變遷

(: %, / , /kg(LPG, LNG))

	1980.11.14	83.3.26	87. 6.9	89.3.27	91. 7. 1	92.1. 1
	160(130)	100	100	100(85)	100(120)	-
	-	-	100(85)	100(70)	100(100)	100(109)
	10(7)			10(9)		
가		10		10(8)		
가						
	1994.1.1	94.2.15	94.7.15	95.8.12	96.1.1	96.12.14
()	150	150(190)	150(170)	150(195)	345	345(414)
	20	20(25)	20		40	
	10	10(13)	10		17	
가		10			18	
가		10			14	
	1997.1.1	98.1.8	98.5.3	98.9.16	99.5.6	99.12.3
()	345(414)	455	591	691	651	630
	40(48)	85	110	160	160	155
	17(25)			60		
가	18			40		
가	14			40		
	2000. 3. 2	00. 5. 1	01. 7. 1	02. 7. 1	03. 7. 1	04. 7. 1
()	600			630		
	137	155	199	244	288	332
	43	60	84	107	131	154
가				40		
가		40	152	263	376	488
가				40		
			3	7	10	13
	2005. 7. 1			06. 7. 1		
()				630		
	377			421		
	178			201		
가				40		
가	599			711		
가				40		
	17			20		

- 1. 1993 1 1
- 2. ()
- 3. 1996 1 1 가
- 4. 1996 7 1 , , 15%
- 5. 1 20
- 6. 2001 7 1

自由貿易協定 締結 誘因

- Grossman & Helpman

鄭 在 皓*

要 約

(small country) (Free Trade Agreement)

가 Grossman and Helpman

(1995b) . Grossman and Helpman(G&H)

FTA 가 가 FTA 가 FTA 가

FTA 가 가

(Customs Union) FTA 가 FTA

G&H FTA 가

가 FTA 가 가

, G&H 가 가

FTA 가 가

*

. 序 論

1990 1999 10 100 가
 (preferential trading agreement) GATT (General Agreement on Tariffs and
 Trade,) WTO(World Trade Organization,
)¹⁾ , , ,
 (small country)
 . , , , , , ,
 가 Andean Common Market(ANCOM) . , , , ,
 , 가 Central African Customs and Economic Union
 (UDEAC) . , , , , ,
 가 , ASEAN Free Trade Agreement(AFTA)
 .
 GATT/WTO 가
 . 가
 가 . GATT 24
 가 . GATT 24 GATT
 MFN(Most Favored Nation) ²⁾
 , 가
 가 . GATT
 (Customs Union) (Free Trade Agreement),

1) WTO (Uruguay Round negotiations) 1995
 , (2000 9) 138 .
 2) GATT 1 MFN 가
 가 . GATT
 (the principle of non-discrimination) Bagwell and Staiger(1999)가
 (the principle of reciprocity) GATT
 .

가 . (common
tariffs) . , 가
. (FTA) 가
. FTA가 ,
. ,
FTA
FTA
FTA 가
3). FTA FTA
FTA 가 FTA 가
FTA 가 가
가
가
가
가
Grossman and Helpman(1995b) 가
FTA “ FTA
3) FTA GATT 24 가

가 (politically viable) 가?”

가

가가

가

Grossman and Helpman(G&H)

가 가 . 가 FTA

FTA FTA

가 . , FTA 가

가 .

가 FTA 가

가

. FTA G&H

FTA 가 FTA 가

, G&H 가 가

FTA 가 가 .

G&H FTA 가 가

G&H가 FTA 가

가 . G&H

가 FTA 가 가가

가

. 基本 模型

A B, G&H . G&H
 가 (rest of the world) 3
 가 . FTA n
 가 1 가 .
 가 가
 .
 GATT 16 ,
 가 . 가
 (transport cost) 가 . 가가
 가 가 1 .
 GATT 1 MFN . 가 j i
 가 p_i^j 가 1 t_i^j 4).
 , 가 1 .
 가 가 가 . 가
 가 .
 가 .

$$U = c_0 + \sum_{i=1}^n u_i(c_i).$$

c_0 가 (numeraire) 0 , c_i
 i . $u_i(\cdot)$ (concave) 가 2
 (quadratic) . 가 가 0
 0 가 1 .

4) t_i^j non-prohibitive .

가 0

가 ()

1

(constant return to scale)

(sector specific input)

가

가

$$\pi_i = \pi_i(p_i).$$

(Hotelling's Lemma)

$$S_i = \pi_i'(p_i).$$

가 . i

$$S_i^A = \theta S \quad S_i^B = (1 - \theta)S, \quad i$$

s 가 . j

$$S_j^A = (1 - \theta)S \quad S_j^B = \theta S \quad 1-s \quad \text{가 .}$$

, S

가가 가

. s

,

. , $\theta > \frac{1}{2}$ $s \geq \frac{1}{2}$ 가 .

$u_i(\cdot)$ 2 가 i 가

$$D_i^j(p_i) = D - bp_i^j, \quad \text{for } i = 1, 2, \dots, n, \text{ and } j = A, B.$$

가 .

(lobby)

가 .

$$C_i = \max \{0; \pi_i(p_i) - B_i\}.$$

C_i (policy-contingent campaign contribution) . B_i 가 .

1. 國家 目的函數

가 가 (aggregate welfare) .

$$G \equiv \sum_{i=1}^n C_i + a W, \quad a \geq 0.$$

(CS; Consumer Surplus),

(voters) MFN

가 0, . a

가 . Grossman and Helpman (1994, 1995a)

Baldwin (1987) 가 (political economy framework)

가 가

. , 가

가
 , 가가
 가 가 , (+)
 가
 Grossman and Helpman (1994,
 1995a, 1995b)
 (policy-contingent campaign contribution)

,
 가
 (terms of trade) , 가

2. MFN 關稅

MFN GATT FTA 가
 가
 ()
 가 G
 MFN

$$G_i^j = C(p_i^j) + aW_i^j$$

$$= C(p_i^j) + a\{CS(p_i^j) + \pi(p_i^j) + t_i^j[D_i^j(p_i^j) - S_i^j]\},$$

for $i = 1, 2, \dots, n$, and $j = A, B$.

FTA

(1) $t_i^j = \frac{S_i^j}{ab} > 0$, for $i = 1, 2, \dots, n$, and $j = A, B$.⁵⁾

G&H FTA 가
가 .

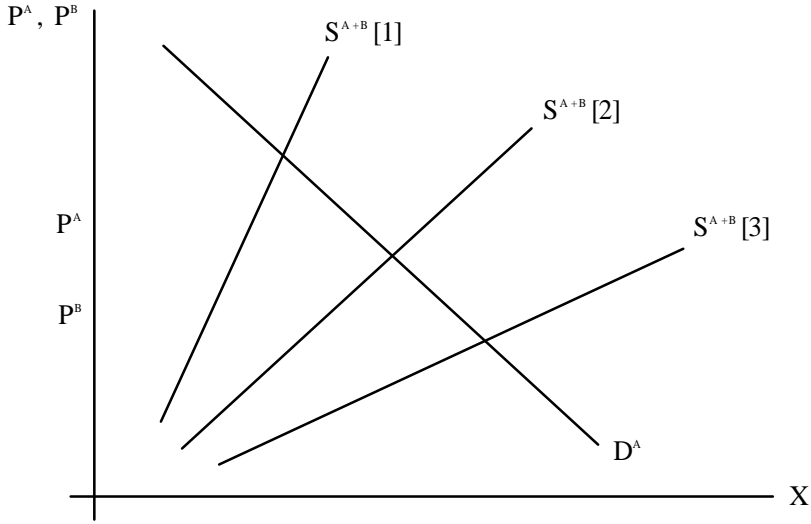
3. FTA 加入 後 消費者 生産者 價格 變化

FTA 가 가
6). FTA 가 가 (A B)
FTA 가 X
가 7).
가 i X t^i , 가
 $p^i (= p^w + t^i)$, $D^i(p^i)$ $S^i(p^i)$.
 $t^A > t^B = 0$, $p^A > p^B = p^w$ 가
가 B X 가 A X
8). A 가 B

5) G&H(1995) (5), pp. 677.
6) FTA 가 가 가 가
G&H 가
7) 가 X FTA 가 가 가
가 FTA 가 가
FTA 가 가
8) FTA가 (Rules of Origin) FTA FTA
FTA 가 FTA

X . [1] A (A B)
 가 S^{A+B} .

[1]



, A FTA 가 가 p^A A
 가 . 가 [1]

S^{A+B} [1] 9).

가 [1] $S^A(p^A) + S^B(p^A) < D^A(p^A)$.

A FTA X
 A 가 . B
 A B
 . , FTA A B

無稅 가 .

9) G&H 'enhanced protection'

FTA 가 ,
 가 (A 가) .
 , , A 가
 . 가 [1] S^{A+B} [3] 10).

가 [2] $S^A(p^B) + S^B(p^B) > D^A(p^B)$.

B 가 B A 가 A
 11).

B X . A
 , B A X
 B 가

. FTA B 가
 가 , A 가 B
 가 .

[1] S^{A+B} [2]

12).

가 [3] $S^A(p^{A'}) + S^B(p^{A'}) = D^A(p^{A'})$ where $p^B < p^{A'} < p^A$.

B A , A 가
 p^A p^B 가 . A
 B
 . B A X B
 가 FTA 가

10) G&H 'reduced protection'
 11) B 가 B A B
 , A 가 B
 가
 12) G&H 'intermediate case'

FTA 가 가
 13), 가 FTA
 FTA
 가

關稅가 固定的 (G&H)

G&H FTA가
 가 . 가 가 G&H
 FTA 가
 FTA $\sum_i C_{iF} + a W_F \geq \sum_i C_{iN} + a W_N$
 F N FTA가 FTA가
 FTA가 FTA가 가
 FTA가 FTA 가
 ($\sum_i G_{iF} \geq \sum_i G_{iN}$).

가 (nonnumeraire) 가
 가 . 가가 가
 가 가 [1] 가 .
 ‘enhanced protection’ 14).
 FTA (W)
 . FTA 가 i
 FTA 가 .

13) 가
 14) G&H $\frac{D-b}{X} > 1 + \frac{\theta}{a}$ 가 가 .

가 가 가 .
 가 가 가 . 가 [1] 가
 가 가 가 가 .
 가 가 가 가 .
 , 가 가 . FTA
 가 가 가
 가 가 가 .
 가 가 FTA
 가 가 .
 가
 FTA
 가 FTA
 FTA . 가

15).

$$(2) \Delta W_i^j = \begin{cases} \frac{\theta(1-\theta)S^2}{ab} > 0, & \text{if } t_i^j < t_i^k \\ \frac{\theta(1-\theta)S^2}{ab} < 0, & \text{if } t_i^j > t_i^k \end{cases}$$

for $j, k = A, B, j \neq k$.

15) G&H(1995) (6), p. 678.

FTA . 가 [1]
 enhanced protection 가 가
 . 가 FTA
 . FTA 16).

$$(3) \Delta\pi_i^j = \begin{cases} \frac{(2\theta - 1)(1 - \theta)S^2}{ab} > 0, & \text{if } t_i^j < t_i^k \\ 0, & \text{if } t_i^j > t_i^k \end{cases}$$

for $j, k = A, B, j \neq k$.

$s = \frac{1}{2}$ FTA .
 . s . ,

$$50 - 50(s = \frac{1}{2}) \quad (1)$$

0 . (2) (+)

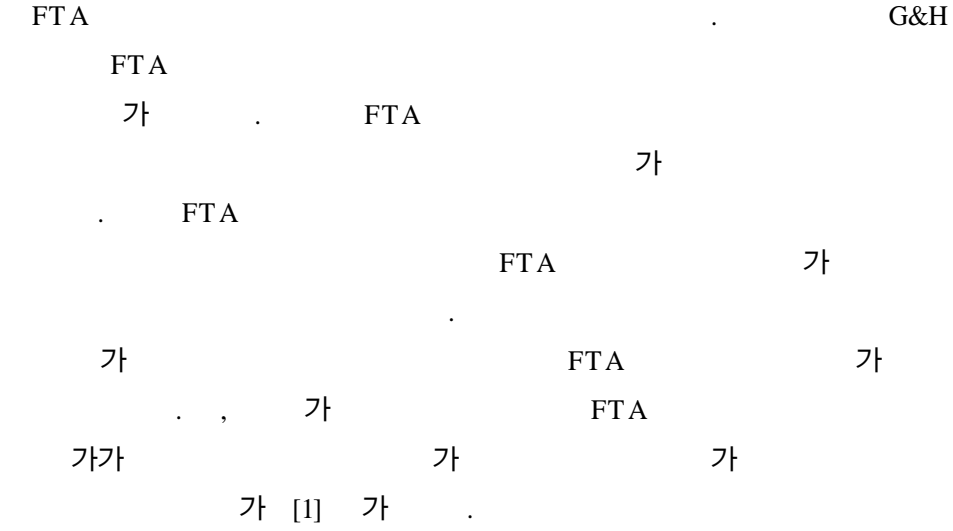
FTA . $s = \frac{1}{2}$
 s가 $\frac{1}{2}$ FTA 가
 (politically viable) . 가
 , 가
 가 가 FTA

G&H 가 [2] 가 [3]
 FTA . G&H
 , FTA FTA가 가 ,
 , enhanced protection FTA가 가
 . G&H FTA 가
 가 FTA 가

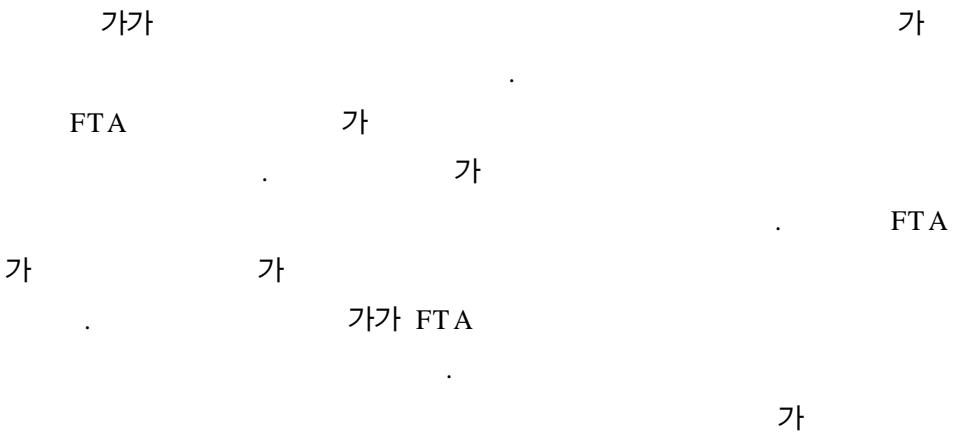
16) G&H(1995) (7), p. 678.

最適關稅 轉換

1. FTA 以後 最適關稅



가. 低關稅 賦課 財貨



0 .

PROPOSITION 1. A

가 . , FTA A
 無關稅 .

: , A $t^{A*} < t^B$
 가 t^{A*}

. A ($t^A \geq t^B$) 가

A 高關稅 가 ,

가 FTA .

$t^A (\geq t^B)$ 가 .

$t^{A*} < t^B$ A B

A B 가 . A

. A

$$G^A = C(p^B) + aW^A$$

$$= C(p^B) + a\{CS(p^A) + \pi(p^B) + t^A D^A(p^A)\}.$$

A .

$$Max_{t^A} G^A = C(p^B) + a\{CS(p^A) + \pi(p^B) + t^A D^A(p^A)\}$$

$$= C(1 + t^B) + a\{CS(1 + t^A) + \pi(1 + t^B) + t^A D^A(1 + t^A)\}$$

$$s.t \quad t^A \leq t^B$$

A A (+)

FTA

. Q.E.D.

. 高關稅 賦課 分野

가가 , 가

FTA 가 , 가 . FTA 가 가 (free rider problem)

가 , FTA

FTA

PROPOSITION 2.

, A FTA

$$t_F^A \text{ FTA } t_N^A \text{ }^{17)}.$$

: FTA A . A .

$$(4) \quad G_N^A = C(p) + a \{CS(p) + \pi(p) + t[D(p) - (1 - \theta)S]\}.$$

(4) t_N^A 가 . FTA ,

17) t_N^A N FTA 가 , t_F^A F FTA 가 .

A

A

$$t_F^{A*} \quad . \quad t_F^{A*}$$

$$(5) \quad G_F^A = C(p) + a \{ CS(p) + \pi(p) + t [D(p) - (1 - \theta)S - \theta S] \}.$$

(4) (5) FTA

$$a t \theta S$$

$$G_F^A = G_N^A - a t \theta S.$$

1 (first order condition) (4) (5)

$$G_N'(t_N^A) = G_N'(t_F^A) - a \theta S = 0.$$

$$a \theta S > 0 \quad G_N'(t_N^{A*}) < G_N'(t_F^{A*}) \quad t_F^{A*} \quad t_N^{A*}$$

($t_F^{A*} < t_N^{A*}$). Q.E.D.

. 最適關稅 決定

(reaction curve)

(Nash equilibrium)

Proposition 1 Proposition 2

가

,

가

0

[2] [3]

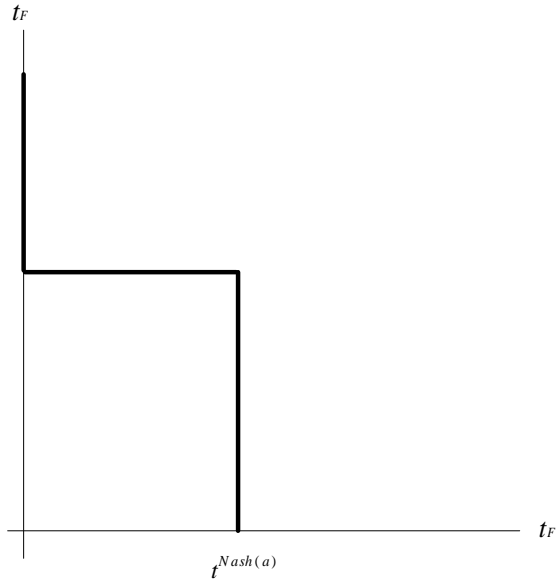
가 [2]

가

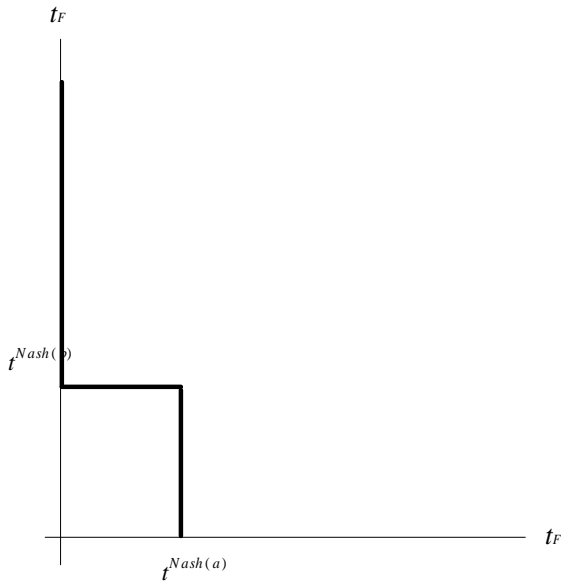
가 [3]

가

[2] 兩國間 關稅差異가



[3] 兩國間 關稅差異가



$$\Delta G_{EN} = \Delta G_{EX} + \Delta G_{EN-EX}.$$

$$\begin{matrix} \Delta G_{EN} & \Delta G_{EX} & \text{FTA 가} \\ \text{FTA 가} & & \text{FTA 가} \\ & \cdot & \Delta G_{EN-EX} \text{ 가} \\ & \cdot & \\ \Delta G_{EX} & \cdot & \Delta G_{EX} \end{matrix} \quad (2) \quad (3)$$

$$(6) \quad \Delta G_{EX} = \frac{(2\theta - 1)(1 - \theta)S^2}{ab} > 0.$$

$$\begin{matrix} > \frac{1}{2} & (6) & (+) \\ \text{EX} & \text{EN} & (\Delta G_{EN-EX}) \\ & & \text{EN} \quad \text{EX} \end{matrix} \quad \cdot \text{FTA} \quad \text{가} \quad \text{가}$$

, Proposition 1 ,
EX 가

$$(7) \quad \Delta G_{EN-EX} (1) = \frac{(1 - \theta)^2 S^2}{2ab} > 0.$$

, Proposition 2 ,
FTA
EX

$$(8) \quad \Delta G_{EN-EX} (2) = \frac{a(1 - \theta)^2 S^2}{2b} > 0.$$

, Proposition 2

(-)

$$(9) \quad \Delta G_{EN-EX}(3) = \frac{-(1+a)(1-\theta)^2 S^2}{b} < 0.$$

가 가

$$(10) \quad \Delta G_{EN-EX} = \frac{-(1+a)(3a-1)(1-\theta)^2 S^2}{2ab}.$$

$$\left(\frac{\theta S}{ab} - \frac{(1-\theta)S}{b} \geq 0 \right)$$

$$\theta \geq \frac{a}{a+1} \quad > \frac{1}{2} \quad a > 1$$

(10)

$$(6) \quad (10) \quad \Delta G_{EN}$$

$$(11) \quad \Delta G_{EN} < 0, \quad \text{if } \frac{1}{2} < \theta < \frac{(1+a)^2}{(1+a)^2 + 2},$$

$$\Delta G_{EN} \geq 0, \quad \text{if } \theta \geq \frac{(1+a)^2}{(1+a)^2 + 2}.$$

(6) (11)

PROPOSITION 3. FTA

가 FTA 가

Proposition 3 (6) (11)

가 EX(G&H) FTA 가

((6)>0) FTA

(s =

½) 가 FTA

가 EN (11) EN

G&H 가 FTA 가 FTA 가 가

가 FTA 가 G&H FTA

FTA 가 G&H FTA 가

(2) (3) FTA 가

FTA 가 FTA

(EN), FTA 가

FTA가

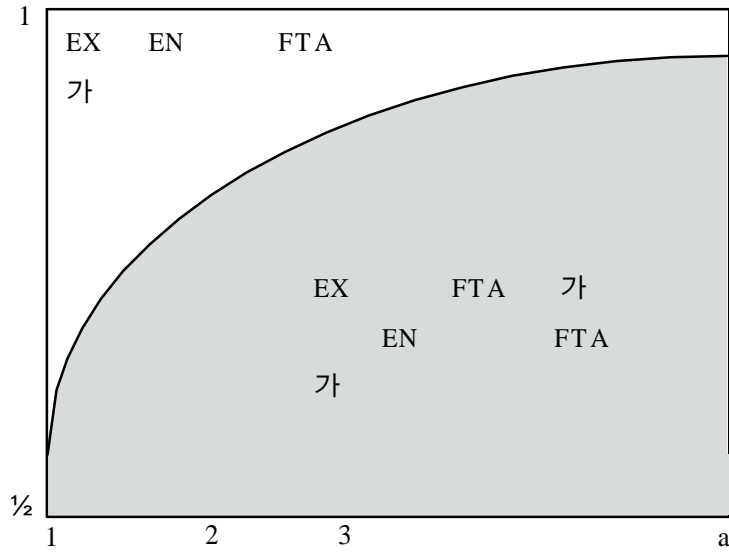
[4] .

$\theta = \frac{a}{a+1}$. $\theta = \frac{a}{a+1}$ FTA

0 .

$\Delta G_{EN} < 0$ 가 . $\theta = \frac{a}{a+1} < \frac{(1+a)^2}{(1+a)^2 + 2}$.

[4] 小國 FTA 締結



PROPOSITION 4. FTA 가 .
 가 .
 FTA 가 FTA (Pareto Optimal) .
 : FTA 가 가
 가 . 가
 가 FTA 가 FTA
 가 가 가
 가 가 가
 가 가 가
 가 FTA 가
 . Q.E.D.

. 結 論

(FTA) FTA
가 가

. Grossman and Helpman(1995b)
. G&H FTA 가 가

FTA 가 FTA 가
FTA 가 가 . ,
. FTA (Customs
Union) FTA 가

G&H
FTA 가
가 FTA 가 가
. G&H 가 가
FTA 가 가 .
FTA

가 가 FTA 가
. G&H
FTA 가
가 . , 가
가 .

가 가
. FTA 가
FTA 가
()

FTA 가 가 가

. FTA

.

FTA 가 . , FTA

가 .

(pre-FTA tariff) 가

가 .

, FTA 가 .

FTA

가 , (free riding problem)

FTA

. , FTA

,

. FTA 가 G&H

. , FTA

가 . G&H

가 18) FTA 가

.

, G&H FTA

가 .

가 G&H FTA ,

가 .

18) Enhanced protection 가 .

FTA
FTA 가 가 .
G&H 가 가
FTA 가 가 .

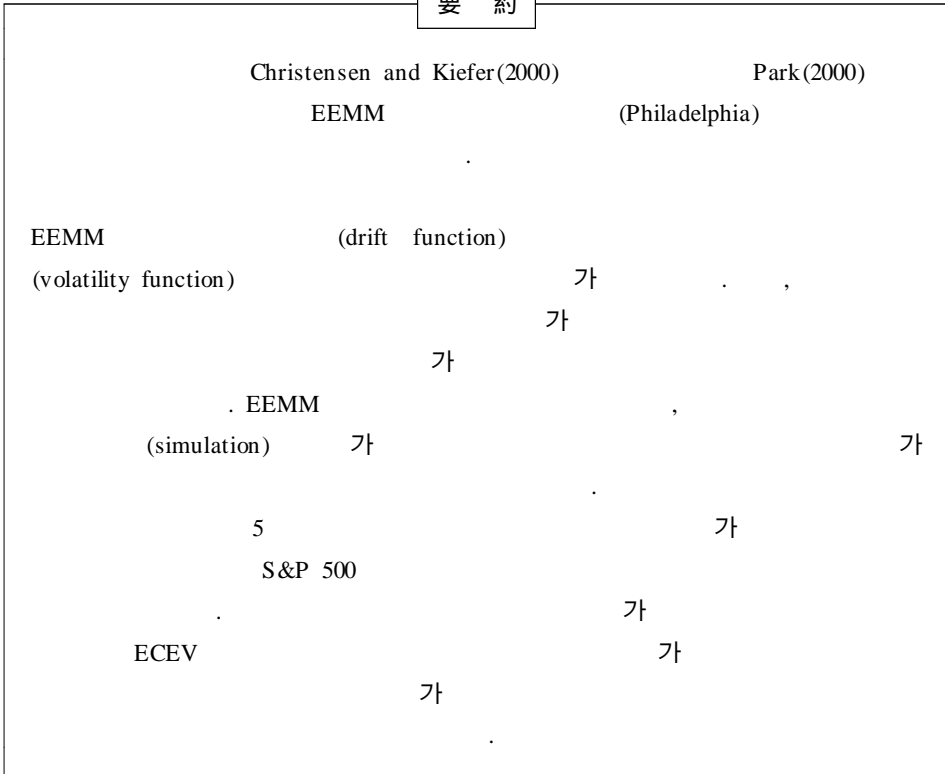
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通貨 外換 市場 變動性 推定

朴 倉 均*

要 約



*

. 序 論

Harrison and Kreps(1979) Equivalent Martingale Measure
 (EMM) 가 (mathematical
 financial economics) 가 . EMM

EMM 가
 (partial differential equation)
 (risk-neutral measure)

t

 Manski(1975)
 (stochastic structure) 가
 (simulation)
 가 . , McFadden
 (1989) (method of moments)
 (moments) 가
 (empirical approximation)

Simulated Maximum Likelihood(SML), Method of Simulated Scores
 (MSS), Efficient Method of Moments, Method of Simulated Moments(MSM)

Christensen and Kiefer(2000) EMM
 가 가
 (volatility)
 . , Park(2000) Christensen and

Kiefer(2000)
 (consistency) (asymptotic normality) .
 가 (volatility) ,
 가 1) 가
 , 가 가
 (Ait-Sahalia(1996), Lo(1986), Renault(1997)). ,
 가
 . 가 가 (input)가
 , 가
 . Christensen and Kiefer(2000)

가
 가
 (Generalized Method of
 Moments : GMM) . 가
 () 가 EMM
 가
 GMM (moment condition) .
 가
 (stochastic structure)가
 가 가 가 .

1) , (geometric Brownian motion) Black-
 Scholes 가 , (square-root Brownian motion)
 Cox-Ingersoll-Ross .

MSM

(foreign currency options)

EMM

가

가

가

(volatility)

· EMM 價格 決定 : 通貨

가

EMM

가

(implication) 가

가

(hedge)

(risk-

free interest rate)

(dividend yield)

가

가

(Jarrow

and Turnbull(2000)).

가

(transaction costs),

(differential taxes),

(credit constraints)

가

(no default),

가

가

(price taker)

가

(continuous time)

(arbitrage) 가 .
 本國 外國 (risk-free asset) 가 2)
 가 .

$$B_t^d = \exp(r_d t), B_t^f = \exp(r_f t) \quad (2.1)$$

가 , B_t^d , B_t^f , r_d , r_f , t 3). (2.1)

가 .
 , 가 F
 (stochastic differential equation)

$$dF_t = \mu(F_t, t)dt + \sigma(F_t, t)dW_t \quad (2.2)$$

(2.2) $\mu(F_t, t)$ 趨勢的 (drift-
 function), $\sigma(F_t, t)$ (volatility
 function diffusion function), W_t (complete probability
 space) (Ω, \mathcal{F}, P) (adapted) (Brownian
 motion) 4).

가 F_t^* ,
 가 t 가

2) , 0 money market account t
 가 .
 3) 가 . 가
 가 가
 4) (2.2)가 (technical conditions)
 Duffie(1996) Park(2000) .

$$F_t^* \equiv \frac{B_t^f F_t}{B_t^d} = \exp((r_f - r_d)t F_t) \quad (2.3)$$

F_t^*

가

r_f

(hedge)

$B_t^f F_t$

EMM

Ito (Ito's Lemma)

F_t^*

$$dF_t^* = [(r_f - r_d)F_t^* + e^{(r_f - r_d)t} \mu(F_t, t)]dt + e^{(r_f - r_d)t} \sigma(F_t, t) dW_t$$

$$\equiv \alpha(F_t, t)dt + \omega(F_t, t)dW_t \quad (2.4)$$

(2.4)

$$\gamma_t \equiv \frac{\alpha(F_t, t)}{\omega(F_t, t)} \quad (2.5)$$

가

가

5), Girsanov

P

EMM

Q 가

, P Q

Radon-Nykodime

$$\frac{dP}{dQ} = \exp\left(-\int_0^T \gamma_t dW_t - \frac{1}{2} \int_0^T \gamma_t^2 dt\right) \quad (2.6)$$

5)

Duffie(1966)

Park(2000)

(stochastic process) $W_t^* \equiv W_t + \int_0^t \gamma_s ds$

Q , (2.4) (2.6)

F_t^* Q (martingale)

$dF_t^* = \alpha(F_t, t) dt + \omega(F_t, t)[dW_t^* - \gamma_t dt] = \omega(F_t, t) dW_t^*$ (2.7)

, 가 (discount) Q . EMM (2.8)

$dF_t = \mu(F_t, t) dt + \sigma(F_t, t)[dW_t^* - \gamma_t dt]$
 $= (r_d - r_f)F_t dt + \sigma(F_t, t) dW_t^*$ (2.8)

(2.2) (2.8) (2.2) 가 (2.8) (dynamic structure)

가 (2.8)

(volatility function) (drift function) 가 (2.8)

$\tau(>t)$ 가 C_t 가 $e^{-r_d t} C_t$ 가 $e^{-r_d \tau} C_\tau$ EMM 가 $g(F_\tau)$

가 C_τ 가 $g(F_\tau)$. (2.9)

$C_t = e^{r_d t} E_t^Q [e^{-r_d \tau} g(F_\tau)] = \exp[-r_d(\tau - t)] E_t^Q [g(F_\tau)]$ (2.9)

τ 가 K

(call options) (put options) 가 .
 $C_t = \exp[-r_d(\tau-t)]E_t^Q[\max(F_t - K), 0]$ (2.10)

$C_t = \exp[-r_d(\tau-t)]E_t^Q[\max(K - F_t), 0]$ (2.11)

· 實證模型 設定

Christensen and Kiefer(2000) Park(2000) .
 Empirical Equivalent Martingale Measure(EEMM)

EEMM 가 (2.9) GMM 가
 h_t , 가 (mispricing)
 (error term) .

$h_t(\theta) \equiv C_t - \exp[-r_d(\tau-t)]E_t^{Q(\theta)}[g(F_t)]$ (3.1)

Q ($R \times 1$) θ (parameterize) , 가
 가 가 . , $E_t^P[h_t(\theta_0)] = 0$.
 $\theta \neq \theta_0$ $E_t^P[h_t(\theta)] \neq 0$. 가 가
 가 P

EEMM Q .
 (3.1) GMM

$E_t^{Q(\theta)}[g(F_t)]$
 6) 가 .

6) 1 .

(2.8) EMM $g(\cdot)$

(law of large numbers)

\dots , 가 (3.1) 가

$$h_i^*(\theta) \equiv C_i \exp[-r_d(\tau - t)] - \frac{1}{M} \sum_{m=1}^M g(F_{\tau}^{*m}(\theta; F_i)) \quad (3.2)$$

(2.8)

M (3.2)가

(product measure) $(P \times Q)$ θ_0 0

(identification) (information set) \mathcal{F}_t

가 (measurable variables) $(q \times 1)$ z_t

(3.2)

$$f_i^*(\theta) \equiv h_i^*(\theta) \otimes z_t \quad (3.3)$$

$$f_T^*(\theta) = \frac{1}{T} \sum_{i=1}^T f_i^*(\theta) = \frac{1}{T} \sum_{i=1}^T h_i^*(\theta) \otimes z_t \quad (3.4)$$

(R) (q) (3.4)

積 0 가 가 GMM

加重積

$$\theta^* = \arg \min_{\theta \in \Theta} f_T^*(\theta)' \Lambda_T f_T^*(\theta) \quad (3.5)$$

Λ_T Λ $(q \times q)$. Park(2000) 가

A_T Hansen(1982) EEMM θ^*
 (asymptotic distribution)가

$$\sqrt{T} (\theta^* - \theta_0) \xrightarrow{d} \left(0, \left(1 + \frac{1}{M}\right) (D' \Pi^{-1} D)^{-1}\right) \quad (3.6)$$

$$D = \frac{1}{T} \sum_{t=1}^T \frac{\partial f_t^*(\theta_0)}{\partial \theta'}, \quad H = \lim_{T \rightarrow \infty} \text{Var} \left[T^{-\frac{1}{2}} \sum_{t=1}^T f_t(\theta_0) \right]$$

7). (3.6) , 가
 T가
 M

$M \rightarrow \infty$

(computational burden)

A_T Andrews(1991) HAC(heteroskedasticity - autocorrelation
 consistent) H^* 8). A_T
 (3.5) H^*

(3.5) 가

(3.6) (specifi-
 cation test)

$$Q_T = T [f_t^*(\theta^*)' A_T^* f_t^*(\theta^*)] \sim \chi^2(q - R) \quad (3.7)$$

$$(3.7) \quad A_T^* = \left[\left(1 + \frac{1}{M}\right) H^* \right]^{-1}$$

7) $f_t(\theta_0) = h_t(\theta_0) \otimes z_t$
 (3.2)

Park(2000)
 8) HAC Park(2000)

(2.2)

(volatility function)

가

(extended constant

elasticity of variance : ECEV) 가

$$dF_t = \mu(F_t, t) dt + [\alpha F_t + \beta F_t^\gamma] dW_t \quad (3.8)$$

(3.8) $\beta = 0, \gamma = 1$ Black and Scholes(1973)가 가
(geometric Brownian motion : GBM)

, $\alpha = 0, \gamma = 0$ (arithmetic Brownian motion :

ABM) , $\alpha = 0$ (constant

elasticity of variance : CEV)

가

(drift function)

(3.8) 가

. EMM 가

가

() EMM (2.8)

Euler (Euler approximation)

$$F_{t+\frac{i}{N}}^* = F_{t+\frac{i-1}{N}}^* \times$$

$$\exp \left(\left[(r_d - r_f)_t - \frac{1}{2} (\alpha + \beta (F_{t+\frac{i-1}{N}}^*)^{\gamma-1})^2 \right] \frac{1}{N} + [\alpha + \beta (F_{t+\frac{i-1}{N}}^*)^{\gamma-1}] \sqrt{\frac{1}{N}} \varepsilon_i \right)$$

$$i = 1, 2, \dots, N \quad \varepsilon_i \sim N(0, 1) \quad 9). \quad \varepsilon_i$$

9)

가

t 가

N

(2.8)

가

(3.6)

(stationary)

가

(non-stationary)

10),

(3.2)

$k_t^*(\theta)$

$$k_t^*(\theta) = \frac{C_t}{F_t} e^{-r_{d,t}(\tau_t - t)} \frac{1}{M} \sum_{m=1}^M \frac{g(F_{\tau_t}^{*m}(\theta; F_t))}{F_t} \quad (3.9)$$

(instrumental variables)

$$\left(\frac{F_{\tau_t} - F_t}{F_t} \right)$$

$$\left(\left(\frac{F_t - K_{\tau_t}}{C_t} \right)^+ \right)$$

$$\left(\left(\frac{K_{\tau_t} - F_t}{C_t} \right)^+ \right)$$

$$(r_{d,\tau_t} - r_{d,t})$$

$$(r_{f,\tau_t} - r_{f,t})$$

10)

가

(unit root)

가

. 實證分析 結果

(Philadelphia Stock Exchange : PHLX) 1982

PHLX

, , , , ,
, ,
, 1994 11

(United Currency Options Market)

가

가

PHLX 3 , 6 , 9 , 12 9

가

가

(expiration date)

(settlement

date)

62,500 가

가 가 . 100 1 가

가 .

1988 1 1997 12 10 PHLX

가 (strike price)

가 가 가 가 (nearest-to-the-money)

NTM

가 가

NTM

가

가 가

1

(one

month inter-bank loan rate)

()

가 가

1

가

가 , 1

< 1 >

CD	DM	JY	SF	UP
-0.0008	-0.0007	0.0000	-0.0006	-0.0008
0.0144	0.0344	0.0366	0.0360	0.0332
-0.0062	0.1200	0.2467	0.1100	-0.0474
0.3652	0.5730	1.1106	0.0498	2.2666
0.9302	0.9791	1.1951	1.7959	1.2889
1.4796	1.8301	2.8712	5.6491	2.8615
2.3957	2.9429	4.2672	7.8170	3.7993
8.3652	11.2785	23.4083	72.6966	18.5896
0.9001	1.0383	1.4259	0.5955	2.1811
1.5094	1.8388	3.1468	8.4872	15.9328
2.1212	2.5132	4.3471	8.5634	10.7711
7.4110	7.5343	24.3032	89.8488	116.9546
-0.0126	-0.0024	0.0226	0.0089	-0.0313
0.0213	0.0315	0.0250	0.0299	0.0246
0.4110	-0.5439	-0.2421	-0.2877	-0.3746
0.3979	1.0689	1.4623	1.1464	1.3464

: 1. CD : , DM : , JY : , SF : , UP :

2. =Skewness, =Kurtosis

가 (default)

,
1

(descriptive statistics) < 1>

$$\left(\frac{F_{t-1} - F_t}{F_{t-1}} \right)$$

(moments)

0

(random walk)

가

(em-

pirical density function)

(skewness)

(density) 가

(kurtosis)

. < 1>

$$\left(\frac{F_t - K_{t-1}}{C_{t-1}} \right)^+ \quad \left(\frac{K_{t-1} - F_t}{C_{t-1}} \right)^+$$

()

-40% (SF

) 118% (UP)

가

() 0

가

가

가

< 1> $(r_{d,t} - r_{f,t})$ ()

. 1988 1997 10 ,

(3.8) ,

(geometric Brownian motion :GBM) ,

(arithmetic Brownian motion :ABM) ,

(constant elasticity of variance :CEV) , (extended

constant elasticity of variance :ECEV) .

EEMM

T 가

M .

가 가

M 1, 10, 100 .

< 2> 가

가 .

가 - $M = 1$

10 - (standard error) 가 $M = 100$

가

가

가

가

EEMM

< 2 > :

		α	β	γ	Q_T	α	β	γ	Q_T
GBM	$M=1$	0.0332 (6.58E-3)			13.74	0.0322 (3.29E-3)			16.60
	$M=10$	0.0302 (1.71E-3)			12.30	0.0350 (3.24E-3)			12.79
	$M=100$	0.0330 (1.05-E3)			12.68	0.0369 (1.29E-3)			10.12
ABM	$M=1$		0.0190 (4.57-E3)		12.64		0.0218 (4.08E-3)		11.45
	$M=10$		0.0198 (1.38E-3)		12.84		0.0195 (1.45E-3)		11.37
	$M=100$		0.0199 (1.05-E3)		12.55		0.0202 (1.55E-3)		10.66
CEV	$M=1$		0.0399 (0.0341)	0.9529 (0.1924)	11.53		0.0347 (0.0712)	0.9535 (0.4017)	10.98
	$M=10$		0.0387 (0.0312)	0.9529 (0.2141)	10.40		0.0349 (0.0305)	0.9531 (0.1778)	9.95
	$M=100$		0.0336 (0.0151)	0.9527 (0.0883)	10.42		0.0372 (0.0176)	0.9531 (0.0969)	9.60
ECEV	$M=1$	0.2439 (0.0865)	-0.1750 (0.0855)	0.6341 (0.8934)	7.69	0.2534 (0.0729)	-0.1645 (0.0709)	0.5109 (0.1663)	7.16
	$M=10$	0.2361 (0.0526)	-0.1706 (0.0520)	0.6344 (0.6232)	7.72	0.2456 (0.0526)	-0.1779 (0.0508)	0.5508 (0.1216)	4.52
	$M=100$	0.2118 (0.0605)	-0.1478 (0.0597)	0.6287 (0.1271)	7.64	0.2358 (0.0676)	-0.1065 (0.0662)	0.5454 (0.1535)	4.53

1. (standard error)
2. GBM :geometric Brownian motion, ABM :arithmetic Brownian motion, CEV : constant elasticity of variance, ECEV : extended constant elasticity of variance.
3. $Q_T \chi^2$ (degrees of freedom) 5(GBM, ABM), 4(CEV), 3(ECEV) , 5% (critical value) 11.1, 9.49, 7.81 .

(computer resources)

(algorithm)

(initial value)

(computationally cheap) $M = 1$

가

(3.7) Q_T

(degree of freedom)가

5(GBM, ABM), 4(CEV), 3(ECEV)

²

GBM,

ABM, CEV

M

5%

CEV

M

GBM, ABM

M

ECEV

M

가

, CEV ECEV

가

가 0

가

Q_T

GBM

ABM

t-

10

t-

(instruments)

가

가

가

가

年間

10%

¹¹⁾

S&P 500

가

(S&P 500 Index)가

30%

11)

, GBM

$\sqrt{0.03 \times 0.03 \times 12} \approx 0.1$

12) . . . , S&P 500 가
 .
 , (theoretical rigor)
 가 가
 . 가
 1 (one factor model) 1
 1 가
 (hedge)가 가
 (redundant security) . ,
 () ,
 가 가
 가 가
 . 가 가 , ,
 가
 가 .
 (market participants) 가 (possibility of mispricing),
 가 (measurement errors)
 가 가 .
 가
 가 가
 近似 가
 遠近

13)

12) Bates(1996)

		S&P 500		30%	
Park(2000)	1988	1997	S&P 500	가	
30%					

13) 가 가 .

95%

14)

가

< 3>

가

가

$M = 100$

< 3>

年 5%
10%

가

가 ECEV

ECEV

t-

Cox, Ingersoll and Ross(1985)

(square root process

model)

95%

14)

< 3 > :

		Q_T				Q_T			
CD	GBM	0.0164 (7.36E-3)			10.35	0.0134 (4.59E-3)			15.14
	ABM		0.0121 (5.51E-3)		12.97		0.0112 (3.26E-3)		24.74
	CEV		0.0146 (3.85E-3)	0.5519 (0.1064)	7.73		0.0118 (6.84E-3)	0.5499 (0.2533)	8.16
	ECEV	0.1294 (0.0609)	-0.0949 (0.0608)	0.6664 (0.1270)	3.72	0.2154 (0.0467)	-0.2012 (0.0466)	0.6468 (0.2274)	4.30
JY	GBM	0.0161 (4.76E-4)			12.44	0.0153 (5.64E-4)			13.28
	ABM		0.0017 (1.90E-4)		15.71		0.0016 (3.67E-4)		9.66
	CEV		0.0002 (6.01E-4)	0.7513 (0.1373)	12.21		0.0006 (4.53E-4)	0.7518 (0.1637)	7.17
	ECEV	0.0346 (0.0068)	-0.0307 (0.0068)	0.6313 (0.3819)	6.12	0.0042 (0.0604)	-0.0033 (0.0603)	0.5518 (0.2735)	6.67
SF	GBM	0.0387 (1.15E-3)			7.82	0.0365 (1.19E-3)			10.29
	ABM		0.0289 (3.10E-3)		10.80		0.0269 (1.43E-3)		10.88
	CEV		0.0271 (0.0255)	0.7512 (0.2643)	9.44		0.0335 (0.0174)	0.7522 (0.1410)	8.92
	ECEV	-0.1911 (0.0763)	0.1924 (0.0756)	0.5477 (0.1543)	4.45	-0.1069 (0.0478)	0.1222 (0.0474)	0.5852 (0.1410)	6.26
UP	GBM	0.0310 (1.16E-3)			9.17	0.0375 (3.77E-3)			13.41
	ABM		0.0487 (2.18E-3)		11.58		0.0463 (1.85E-3)		9.95
	CEV		0.0351 (0.0042)	0.5470 (0.1166)	8.93		0.0494 (0.0034)	0.5476 (0.1198)	8.92
	ECEV	0.0219 (0.0071)	0.0106 (0.0069)	0.5281 (0.1433)	3.41	0.0205 (0.0183)	0.0204 (0.0057)	0.6342 (0.2466)	8.25

: 1. (standard error)

2. GBM :geometric Brownian motion, ABM :arithmetic Brownian motion, CEV : constant elasticity of variance, ECEV :extended constant elasticity of variance.

3. CD : , JY : , SF : , UP :

4. $Q_T \chi^2$ (degrees of freedom) 5(GBM, ABM), 4(CEV), 3(ECEV) . 5% (critical value) 11.1, 9.49, 7.81 .

가

· 結 論

(2000) Christensen and Kiefer(2000) Park
EEMM PHLX

EEMM

가 . EEMM

가 가
가 가 . , EEMM

가 가
(reliable) . 가
5 가

S&P 500 가
ECEV 가

가 가

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The Environmental Kuznets Curve, Sustainable Development, and Policy Analysis for the Social Optimum

權 五 盛*

要 約

environmental Kuznets curve, 內生經濟成長模型(endogenous growth model), 動態分析(dynamic analysis), 持續可能發展(sustainable development), 가, 一般均衡分析(general equilibrium analysis), 外部效果(externality), 社會最適(socially optimal) 解, 環境稅

. Introduction

Investigating the potential conflict between economic growth and environmental quality will provide important implications for the optimal strategic policies with respect to economic growth and pollution control. Developed countries that are currently concerned about the long-run effects of enviro-

mental deterioration are seeking to enforce more and more stringent environmental policies. On the contrary, less-developed countries that are concerned with fast economic growth are likely to allow less stringent environmental policies. Installing pollution abatement equipment and adopting clean technology may be very costly for less-developed countries that are currently unable to meet their desired level of investment in productive capital. Consequently, forcing them to implement stricter environmental policies will be detrimental to their economic growth because of the costs at the economy level.

Many papers in both theoretical and empirical research have addressed different aspects of the relationship between economic growth and environmental degradation. Early studies on pollution problems placed emphasis on measuring the impact of environmental regulation on the industry productivity and competitiveness at the industry level. At the same time, these studies motivated a further research investigating the long-run effect of the optimal preservation of environmental quality on the per capita income or economic growth at the economy level. A large body of work in the theoretical side of this literature has employed neoclassical growth models to examine the link between growth and the environment (e.g., Forster (1972, 1973), Gifford (1973), Gruver(1976), Stephens(1976), Tahvonen and Kuuluvainen(1993), López(1994), and Selden and Song(1995)). Since these models are based on the assumption of exogenously determined growth and ignore that growth is endogenous to the economy, the typical results stress the negative relationship between the environmental quality and economic growth. Furthermore, because the change in environmental policy or the change in preference towards environmental quality does not affect the long-run growth rate in neoclassical growth models, these models are not suitable to examine whether or not growth can be sustained with the maintenance of environmental quality. On the other hand, many studies that have made contributions to the advent of new growth theory

identified the key determinants of long-run growth that are endogenous to the economy, but they ignored the environmental externalities (e.g., Romer(1986, 1990), Lucas(1988), Barro(1990), and Rebelo(1991)).

If we turn our attention to the empirical side of this literature, Shafik and Bandyopadhyay(1992), Grossman and Krueger(1993, 1995), and many other papers have investigated the relationship between economic growth and pollution by using both cross-sectional and time-series data since the early 1990s. Most interestingly, substantial evidence has shown that there is an inverted U-shaped relationship between per capita income and pollution levels. Empirical evidence of such relationship, which is often called the environmental Kuznets curve” in the literature, suggests that economic growth might bring damage or remedy to environmental quality, depending on the current stage of economic growth. However, they do not provide a theoretical basis that explains why pollution follows such a pattern along the growth path. This is a major limitation of their studies because their interesting results are not derived from theoretical models but from the reduced-form regressions of pollution on per capita income and other related variables.

The main purpose of this paper is to study the interaction between economic growth and the environment by developing a simple theoretical model that is consistent with empirically confirmed evidence of inverted U-shaped relationship between growth and pollution. Thus, we try to provide a theoretical basis to explain why pollution follows such an inverted-U pattern with respect to income.

If one of the important objectives for the study of economic growth is to explore its implication on welfare, then there is also a strong motivation for investigating the interaction between growth and the environment because the environment affects welfare in both direct and indirect ways. Since we are concerned about the long-run effect of environmental externalities on welfare,

we incorporate the issue of sustainable development into our model. The World Commission on the Environment and Development(1987) (the 'Brundtland' Commission) defined the term "sustainable development" as development that meets the needs of present generation without compromising the ability of future generations to meet their needs. We reinterpret the above definition of sustainable development in general as development that takes into account the welfare of future generations as well as that of present generation, which depend not only on the consumption of produced goods but also on the environmental quality as a public consumption good. Although there is no working definition of sustainable development to use in an analytical framework, we follow Byrne(1997) and Aghion and Howitt(1998) in the sense that the long-run growth of instantaneous utility could be an appropriate measure of sustainable development. Thus, our objectives for investigating the interaction between economic growth and the environment are not only to provide a theoretical basis for the empirical evidence, but also to explore the long-run growth implications in the presence of pollution.

For the goal of our research, we are in need of modeling the link between growth and the environment in a framework of endogenous growth theory for at least two reasons. First, endogenous growth models are more suitable to analyze the interaction between growth and environment than are neoclassical models, because we are also concerned about the central question addressed in this literature — whether or not growth can be sustained with environmental maintenance. Second, we need government intervention to internalize the problem of environmental externalities, so the treatment of environmental problems could be more usefully analyzed in an endogenous growth model in which policy prescriptions affect the long-run growth paths and rates. Thus, this paper also extends the recent use of endogenous growth models to address the environmental issues.

In this paper, we emphasize the role of human capital as an important source of growth in the presence of pollution control. Because the process of human capital accumulation can be interpreted as investment in education, training, or advance in knowledge, it is clear that the process of producing human capital is relatively less pollution-intensive than that of producing physical capital. Thus, we assume that human capital accumulation does not generate pollution. On the other hand, the production of physical capital generates pollution, but physical capital is differentiated in terms of pollution intensities and costs so that pollution can be controlled by the choice of differentiated physical capital used in the final output production.

Finally, we study the issue of implementing the social optimum in a decentralized economy with government intervention. Specifically, we analyze how the government should set the pollution tax for the equilibrium to be Pareto-efficient. When we deal with the firm's problem, we treat pollution as a normal input of production in order to analyze the firm's behavior on the input mix between pollution and other conventional inputs.

. The Basic Model

A simple two-sector endogenous growth model is developed to investigate the interactions between growth and environmental degradation, and also to analyze the long-run growth implication in the presence of pollution. There are two factors in the production side of the economy in this model—physical and human capital. The “general” physical capital can be transformed into infinitely many types of capital goods to be used in the final output production, which are differentiated in terms of pollution generating level and cost. With an assumption of zero population growth, we normalize the fixed amount of

labor to one. Also, we assume that the worker is endowed with one unit of non-leisure time that is devoted to final output production, and to human capital accumulation, which is the engine of growth in the basic models of human capital, as in Lucas(1988), Rebelo(1991), and Caballé and Santos(1993). Thus, the final output is produced using both human capital and the differentiated physical capital. Pollution is the undesirable but inevitable byproduct that is generated in the process of final output production, and it has a negative impact on the instantaneous utility.

1. Production

There are two-sectors in the production side of the economy. The first sector produces a final output using two factors : a composite of differentiated physical capital goods and a human capital. The final output can be either consumed or invested for the purpose of accumulating general physical capital that will be used to produce differentiated physical capital goods.

We assume that there are N identical workers and each worker is endowed with one unit of non-leisure time, which is allocated between final output production by the fraction $1-u$ and human capital accumulation by u , where u is between 0 and 1. The level of human capital of each worker is denoted by h . Since we assume that population growth is zero, we normalize the number of workers to unity (i.e., $N = 1$) and deal with every variable as being measured in per capita terms. Thus, the effective labor devoted to the final output production is $(1-u) \cdot h$, and that to the human capital accumulation is $u \cdot h$.

Combined with human capital, differentiated physical capital is used to produce the final output. The production technology using a composite of differentiated physical capital goods is similar to that of Jones and Manuelli (1995), while most of the other parts in their model are quite different from

ours. A composite physical capital good used as an input of final output production can be composed of infinitely many capital goods differentiated in terms of the marginal productivity and pollution generating levels, which are perfect substitutes in production. The differentiated physical capital goods are made from the existing stock of general physical capital. In order to avoid a trivial solution, it is necessary to assume some trade off between the economy's ability to produce more output and the choice to attain the cleaner environment by polluting less. In this context, it is reasonable to assume that physical capital goods that pollute less are more costly to produce. Thus, the firm's choice of how much to sacrifice from the "potential" output — an output that could be achieved by using the only "dirtiest" physical capital — for a cleaner environment depends on the firm's decision about which type(or types) of differentiated physical capital good(s) to use in production. Hence depending on the types of physical capital goods used in production, there is an infinite set of production technologies, which results in the different output and pollution levels.

The types of differentiated physical capital goods are indexed by $z \in [0, \infty)$, in such an order that higher indexed(i.e. the greater z) physical capital good is less polluting but more costly to produce. Let $p(z) = 1+z$ be the price of type z physical capital, $k(z)$, in terms of the amount of general physical capital needed to produce one unit of type z physical capital. We note that since $p(0)=1$ (i.e., the price of general physical capital), and $p(z)$ is increasing and convex in z , it is more costly to use environmentally cleaner technology. In our model, the choice of cleaner technology implies that more physical capital is used for pollution abatement¹). Therefore, given the existing stock of physical capital, a

1) Using a neoclassical growth model, Gruver(1976) studied the optimal division of investment between pollution control capital and directly productive capital. He derived the optimal investment pattern from the shadow prices of the two types

productive physical capital that is equipped with self-cleaning or pollution-abatement devices (e.g., mufflers for noise, bag houses for particulates, scrubbers, stacks, electrostatic precipitators for air pollution, water treatment plants, water recycling and conservation systems for water pollution, etc.) produces less output than the one that is used for only production without pollution abatement. Based on the price of each type physical capital good, the differentiated physical capital goods can be produced from the existing stock of general physical capital, k , according to the following constraint :

$$k = \int_0^{\infty} p(z)k(z)dz = \int_0^{\infty} (1+z)k(z)dz \quad (2.1)$$

Although many differentiated physical capital goods can be used in the production of final output, only one type physical capital will be chosen at any given point in time. For example, if the government regulates pollution directly by setting the emission standard such that any physical capital of a type below $\bar{z} > 0$ cannot be used, then only \bar{z} type capital will be used by firms to maximize the output, subject to the constraint on the available types of physical capital, $k(z)$, $z \in [\bar{z}, \infty)$. Assuming that only one type physical capital good is used in production at time t , say $k(z(t))$, then from equation (2.1), the total amount of a physical capital good of type $z(t)$ is given as

$$k(z(t)) = \left(\frac{1}{1+z(t)} \right) k(t), \quad (2.2)$$

of capital. In our model, there is no distinction between pollution control capital and productive capital, and we do not focus on analyzing the optimal investment pattern between these two types of capital. However, our model implicitly assumes that physical capital is used for pollution abatement by the choice of production technology using a cleaner physical capital. A differentiated physical capital, which is used in a production process in our model, can be interpreted as the one incorporating both pollution abatement capital and directly productive capital.

where $k(t)$ is the existing stock of general capital at time t . For analytical convenience, we assume that we can produce any specific type of differentiated physical capital good from general physical capital at any point in time with no extra cost.

The final output is produced using human capital and differentiated physical capital, according to the following production function:

$$y(t) = k(z(t))^\alpha (1 - u(t))h(t)^{1-\alpha} = \left(\frac{1}{1+z(t)} \right)^\alpha k(t)^\alpha (1 - u(t))h(t)^{1-\alpha}, \quad (2.3)$$

$$0 < \alpha < 1, \quad z(t) \geq 0,$$

where $k(z(t))$ is the differentiated physical capital of type $z(t)$, and $k(t)$ is the stock of general physical capital at time t . A Cobb-Douglas relationship exists between human capital and differentiated physical capital in the final output production function given in (2.3). However, the differentiated physical capital input is divided into two factors—general physical capital, $k(t)$, and the quality level of differentiated physical capital, $z(t)$. Therefore, the production technology exhibits constant returns to scale in human capital, $h(t)$, and general physical capital, $k(t)$, but is decreasing in the quality level of differentiated physical capital, $z(t)$. This implies that given the existing stock of general physical capital, using a cleaner physical capital in production reduces the output level.

While a certain type of differentiated physical capital is used in production of the final output, the produced output is used for the purpose of accumulating general physical capital as well as consumption. Assuming that physical capital doesn't depreciate, the stock of general physical capital, $k(t)$, evolves according to the following standard accumulation equation:

$$\dot{k}(t) = y(t) - c(t), \quad (2.4)$$

where $c(t)$ denotes consumption at time t .

The second sector is an investment sector because the output is not used for consumption but for the purpose of accumulating human capital, which also can be broadly interpreted as intellectual capital or technological knowledge. Assuming that human capital does not depreciate, human capital is produced using only human capital, according to the linear technology as in Lucas (1988):

$$\dot{h}(t) = \delta u(t)h(t), \quad (2.5)$$

where $\delta > 0$ is a productivity parameter and $u(t)$ is the fraction of one unit of non-leisure time devoted to human capital accumulation at time t . As in Lucas (1988), Rebelo(1991), and Caballé and Santos(1993), human capital accumulation increases effective labor, and a higher effective labor raises the productivity of physical capital. Also, an increase in human capital raises the worker's wage per unit of time, which equals the marginal product of human capital in the final output production, multiplied by the current level of human capital. Because human capital accumulates through the process of education, training, and research and development, the technology of human capital accumulation is relatively clean compared to the production technology of final output. Thus, we assume that the process of producing human capital does not generate pollution at all, so pollution does not affect the marginal productivity of human capital in its production.

2. Pollution

Since pollution²⁾ can be defined as any stock or flow of physical substance

2) Here, we follow the definition of pollution by Keeler, Spence and Zeckhauser (1972, 1977). When pollution is more broadly defined, it is also referred to as the extractive use of the environment, or the intense exploitation of the resource such as deforestation (López(1994), Bovenberg and Smulders (1995)).

that impairs our physical or mental capacity to enjoy life—harms on human health or damage to the amenity value of the environment—it enters the instantaneous utility function with a negative marginal utility.

Pollution is assumed to have positive marginal product in the production side because any increase in pollution allowed in the production process can release resources from pollution abatement to produce more output³). Moreover, in the absence of pollution control and pollution abatement efforts, potential output of the economy can be achieved by using the dirtiest technology (e.g., Copeland and Taylor(1994), Jones and Manuelli(1995), and Stokey(1998)). In this sense, pollution in the production side can be defined as a joint product or “undesirable” but “inevitable” byproduct caused by final output production. Also, because of the positive marginal productivity of pollution, some analytical papers in this literature treat pollution as a normal input of production (e.g., Pittman(1981), Tahvonen and Kuuluvainen(1993), López(1994), and Bovenberg and Smulders(1995)).

Basically we assume that pollution is generated in the production process of final output. In contrast with the previous studies dealing with pollution, however, in which total pollution is simply proportional to output (e.g., Keeler et al(1972), Gruver(1976), John and Pecchenino(1994), Ligthart and Ploeg (1994), Copeland and Taylor(1994) and Elbasha and Roe(1996)), or to the pollution-generating inputs (e.g., Forster(1972), Hung, Chang, and Blackburn (1994), Selden and Song(1995), Jones and Maunelli(1995) and Byrne(1997)), we make a distinction from those by assuming that pollution level depends on the type of differentiated physical capital used in production and the production technology as well as the output level.

3) This may not be true when pollution has its impact as a stock on production. Environmental degradation can affect individual welfare indirectly by reducing the productivity in the respective industry.

We assume that although human capital devoted to its own accumulation does not generate pollution, human capital nevertheless generates pollution when it participates in the final output production either by raising the marginal productivities of other pollution-intensive inputs, or by increasing the output level. Since we already assumed that all workers are identical, the pollution generating level per effective labor is constant, so we normalize it to one. On the other hand, the physical capital goods are differentiated in their emission rates in production as stated earlier. Let $q(z(t)) = \left(\frac{1}{1+z(t)}\right)^\beta$, where $\beta > 1, z(t) \geq 0$, denote the pollution generating level per unit of type $z(t)$ physical capital used in production at time t . From the above expression of $q(z(t))$, we see that $q(0) = 1$, and $q(z(t))$ is decreasing and convex in $z(t)$, so higher quality physical capital generates less pollution per unit. Also, we assume that pollution intensity of production differs depending on the share of using more polluting inputs in the total cost of production, which can be represented by the production technology parameter α .

Therefore, the specification of pollution generating process is given by

$$x(t) = (q(z(t))k(z(t)))^\alpha (1-u(t))h(t)^{1-\alpha} = \left(\frac{1}{1+z(t)}\right)^{\alpha(\beta+1)} k(t)^\alpha (1-u(t))h(t)^{1-\alpha}, \quad (2.6)$$

where $x(t)$ is the pollution generated per individual production at time t . From the above formulation, we see that pollution can be measured in the same units of output. Our research objective is not to estimate the exact amount of pollution in the correct measure of units, but to observe the change in pollution level with respect to the change in other variables of the economy. Thus, we will not be in pursuit of studying how to measure the pollution in both quantitative and qualitative dimensions in this paper⁴⁾.

4) See D' Arge and Kogiku (1973) for the study on this matter.

3. Preferences

There are many identical infinitely lived consumers. As we assumed before, population growth is taken to be zero. The intertemporal utility of a representative consumer is defined as

$$\int_0^{\infty} e^{-\rho t} U(c(t), x(t)) dt, \quad (2.7)$$

where ρ represents the rate of time preference. $U(c(t), x(t))$ is the instantaneous utility function which represents an individual consumer's preferences over consumption and pollution at time t , and takes the following form :

$$U(c(t), x(t)) = u(c(t)) - v(x(t)) = \frac{c(t)^{1-\sigma}}{1-\sigma} - \frac{\phi x(t)^\gamma}{\gamma}, \quad \left| \sigma > 0, \gamma > 1, \phi > 0 \right|, \quad (2.8)$$

where u is increasing and concave in c , and v is increasing and convex in x , i.e., $u' > 0$, $u'' < 0$, $v' > 0$, and $v'' > 0$. Since we assume that the utility function is additively separable in consumption and pollution, an increase in consumption will not affect the marginal disutility from pollution, and vice versa (i.e., $U_{cx} = 0$). Note that preferences expressed in the utility function in (2.8) are non-homothetic⁵⁾ in consumption and pollution. This is in contrast to the previous studies in this literature in which preferences are assumed to be homothetic (e.g., Bovenberg and Smulders (1995), Elbasha and Roe (1995, 1996), and Byrne (1997)). The assumption of homothetic preferences implies unitary

5) López (1994) assumed non-homothetic preferences in order to derive the inverted U-shaped relationship between pollution and income using a neoclassical model. Also, he assumed that the coefficient of relative risk aversion changes as income level changes. He argued that if preferences are homothetic, the increase in output will necessarily cause the level of pollution, even if optimally controlled, to proportionally increase. However, non-homotheticity assumption can be a necessary but not sufficient condition to derive the inverted U-shaped relationship between pollution and income in our model.

income elasticity with respect to the environmental goods. In the early stage of economic development, per capita income is relatively low and so is the environmental cost of production, so people are concerned more about economic growth than about environmental preservation. In this case, income and pollution are likely to increase simultaneously. However, as a per capita income level is increased, environmental quality will become a scarce and luxurious good as a result of the bias toward growth. In this respect, the homotheticity assumption may not be appropriate to represent our preferences toward consumption and environmental quality as per capita income changes.

One more thing to note about the utility function given in (2.8) is that ϕ can be a function of population density. We are concerned about how the damage caused by total pollution in the economy affects an individual consumer's utility. The impact of total pollution on individual's utility depends not only on the pollution generated per individual but also on the population density. While an individual generates pollution by participating in productive activities, he/she is also affected by the pollution generated by others of a certain local community. As population density increases, individuals are harmed more by pollution generated by others, and ϕ will be greater⁶). However, since we assume that the size of population, as a measure of the population density in our model, is constant, $\phi > 0$ is taken to be constant for analytical convenience.

6) In most of the papers in this literature, pollution enters the individual utility function as a per capita term, which implicitly assumes that people are harmed by their own pollution only. Furthermore, Copeland and Taylor(1994) assume that population size will lessen the impact of total pollution on individual utility by treating the population size as the physical size of the economy. However, if the population size matters, we basically assume that the individual is affected by the total amount of pollution that increases as more people participate in production in a local area.

4. Social Planners Problem

First, we study the interaction between pollution and growth as a social planner's problem. The social planner will choose time paths for consumption, $c(t)$, quality of differentiated physical capital for pollution control, $z(t)$, and a fraction of non-leisure time devoted to human capital accumulation, $u(t)$, to maximize the lifetime utility of an infinitely lived representative individual :

$$\begin{aligned} \max \int_0^{\infty} e^{-\rho t} \left[\frac{c^{1-\sigma}(t)}{1-\sigma} - \frac{\phi x(t)^\gamma}{\gamma} \right] dt & \quad (2.9) \\ \text{s.t.} \quad \dot{k}(t) &= \omega^\alpha(t) k^\alpha(t) ((1-u(t))h(t))^{1-\alpha} - c(t), \\ \dot{h}(t) &= \delta u(t)h(t), \\ x(t) &= \omega^{\alpha(\beta+1)}(t) k^\alpha(t) ((1-u(t))h(t))^{1-\alpha}, \\ \omega(t) &= \frac{1}{1+z(t)}, \quad z(t) \geq 0, \quad \omega(t) \leq 1, \end{aligned}$$

where the initial stocks of physical and human capital are given as $k(0) = k_0$ and $h(0) = h_0$, respectively.

. Transition of the Economy

Solving the first-order conditions with respect to the control variables c and ω , and using Kuhn-Tucker condition associated with inequality condition of ω , we get the optimal paths of consumption and the quality of differentiated physical capital over time as below:

$$c^{-\sigma} = \lambda_1, \quad (3.1)$$

$$\omega = \begin{cases} 1, & \text{if } \lambda_1 \geq \frac{1}{\Psi} \left[k^\alpha (1-u)h^{1-\alpha} \right]^{-1}, & (3.2a) \\ \left[\Psi \lambda_1 \left[k^\alpha (1-u)h^{1-\alpha} \right]^{-1} \right]^{\frac{1}{\alpha(\beta+1)-1}}, & \text{if } \lambda_1 < \frac{1}{\Psi} \left[k^\alpha (1-u)h^{1-\alpha} \right]^{-1}, & (3.2b) \end{cases}$$

where Ψ is a predetermined function of the parameters of production technology and preference, defined as $\Psi \equiv \frac{1}{\phi(\beta+1)}$. Equation (3.1) implies that the marginal utility of consumption is equal to the shadow value of physical capital all the time for the optimal path of consumption. However, equations (3.2a) and (3.2b) imply that the optimal quality of differentiated physical capital is divided into the corner and interior solutions depending on whether the inequality constraint is binding or not. More specifically, the optimal strategy for pollution control, represented by ω , depends on the level of potential output, defined as $y_p(t) = k(t)^\alpha (1-u(t))h(t)^{1-\alpha}$, relative to the shadow value of physical capital, $\lambda_1(t)$. It is clear from (3.1) that the shadow value of physical capital falls if consumption rises over time:

$$\frac{\dot{\lambda}_1}{\lambda_1} = -\sigma \frac{\dot{c}}{c} < 0. \quad (3.3)$$

In this case, there is a critical point of time in the evolution of λ_1 , defined as τ such that $\lambda_1(\tau) = \frac{1}{\Psi} \left[k(\tau)^\alpha (1-u(\tau))h(\tau)^{1-\alpha} \right]^{-1}$, before which there is no pollution control at all, and after which pollution should be optimally controlled. In other words, if the economy's current level of potential output is relatively low, it is optimal not to control pollution but to use the dirtiest physical capital to maximize output. However, if the potential output grows enough to reach the critical level of output, defined as $y_c(t) = (\Psi \lambda_1(t))^{-\frac{1}{\alpha}}$, it is optimal to control pollution by using the cleaner physical capital in the final output production at the cost of fewer output produced. Hence the economy has a transition from the initial

stage of economic growth in which $\omega = 1$], to the subsequent stage in which $\omega < 1$].

. Asymptotic Long-Run Growth Path

In the long run the economy asymptotically approaches to the steady-state growth path⁷⁾ along which all endogenous variables grow at constant rates. In this section, we focus on analyzing the asymptotic steady-state growth path rather than the transition, in order to investigate the long-run growth implications in the presence of pollution. Let g_η denote the asymptotic long-run growth rate of η , where $\eta = k, y, c, h, \omega,$ and x . The common growth rate of physical capital, output, and consumption along the asymptotic steady-state growth path is

$$g_k = g_y = g_c = \frac{1}{\sigma + \vartheta}(\delta - \rho), \quad (4.1)$$

where $\vartheta \equiv \frac{\sigma + \gamma - 1}{(1 - \alpha)\beta\gamma} > 0$, and the growth rate of human capital stock along the long-run steady-state growth path is

$$g_h = (1 + \vartheta)g_y = \left(\frac{1 + \vartheta}{\sigma + \vartheta}\right)(\delta - \rho) > g_y. \quad (4.2)$$

We assume that $\delta > \rho$, which is a necessary and sufficient condition for growth to be sustainable in a standard model of human capital in which there is no

7) Since some authors in the literature of economic growth defined the term “balanced growth path” as a path along which all non-stationary variables are growing at a common, constant rate (e.g., Romer(1990), Victor, Chang and Blackburn(1994), Stokey(1998)), we use the more general term “steady-state growth path” to describe a path with constant (not necessarily the same and possibly zero) rates of growth in the stock and control variables of the model.

consideration of environmental externalities. The assumption of $\delta > \rho$ is also necessary in this model for making the production technology of human capital productive enough to avoid a corner solution with no human capital accumulation and no growth in both output and pollution. Because $\theta > 0$, human capital grows faster than physical capital, output, and consumption. If we do not take into account the environmental externalities in this model, output, consumption, physical capital, and human capital all would grow at the common rate of $\frac{1}{\sigma}(\delta - \rho)$. Hence, with the presence of environmental considerations, output, consumption, and physical capital stock grow slower than those in the model with no pollution. However, the comparison of the growth rate of human capital between two models depends on the value of σ . If $\sigma > 1$ ($1 > \sigma > 0$), human capital grows faster (slower) in the model with environmental considerations than in the model without pollution, and if $\sigma = 1$, the growth rates of human capital in the two models are the same.

Along the asymptotic long-run growth path after the potential output level begins to exceed the critical level, the quality of differentiated physical capital improves at the rate.

$$g_{\omega} = \left(\frac{1 - \gamma - \sigma}{\alpha \beta \gamma} \right) g_{\gamma} = \left(\frac{1 - \gamma - \sigma}{\alpha \beta \sigma} \right) \left(\frac{\delta - \rho}{\sigma + \theta} \right) < 0. \quad (4.3)$$

Intuitively, the question of whether or not growth is sustainable is related to the behavior of the real rate of return on physical capital. Using the first-order condition with respect to consumption (3.1) and the Euler equation for λ_1 (shadow value of physical capital), consumption growth can be expressed as

$$\frac{\dot{c}}{c} = \frac{1}{\sigma} \left(\frac{\alpha \beta}{\beta + 1} \frac{y}{k} - \rho \right) = \frac{1}{\sigma} \left[\left(\frac{\alpha \beta}{\beta + 1} \right) \omega^{\alpha} \left(\frac{(1-u)h}{k} \right)^{1-\alpha} - \rho \right], \quad (4.4)$$

where the term $\frac{\alpha \beta}{\beta + 1} \frac{y}{k}$ is the social marginal product of physical capital,

which can be interpreted as the net gain in utility from an additional unit of physical capital. Measured in terms of marginal utility of consumption, the term represents the difference between additional utility from increased output for consumption and the decrease in utility due to increased pollution, both caused by an additional unit of physical capital. Hence, the real rate of return on physical capital is

$$r = \frac{\frac{\partial U}{\partial c} \frac{\partial y}{\partial k} - \frac{\partial U}{\partial X} \frac{\partial X}{\partial k}}{\frac{\partial U}{\partial c}} = \frac{\alpha \beta}{\beta + 1} \frac{y}{k} = \left(\frac{\alpha \beta}{\beta + 1} \right) \omega^\alpha \left(\frac{(1-u)h}{k} \right)^{1-\alpha} \quad (4.5)$$

The essential feature to note in equation (4.5) is that $k(t)$ and $y(t)$ grow at the same rate along the asymptotic steady-state growth path so that the real rate of return to physical capital could remain constant indefinitely in the long run. This is only possible because human capital accumulates faster than physical capital by just enough to compensate for the fall in ω along the asymptotic long-run growth path, i.e., $g_h = g_k + \left(-\frac{\alpha}{1-\alpha} g_\omega \right)$. Thus, consumption in (4.4) can grow at a constant rate as long as the real rate of return to physical capital remains constant and is greater than the rate of time preference. This result of sustained growth in the presence of an environmental externality is contrasted with the AK model with pollution, developed by Stokey(1998). In her model, growth is not sustainable because the stricter emission standard reduces the real rate of return on physical capital below the rate needed for sustained growth. The major reason for the difference from Stokey's(1998) model in the sustainability of growth is that we make distinction between physical and human capital in terms of pollution generating levels in their own production processes. According to the AK approach in the presence of pollution, the optimal quality of differentiated physical capital improves as output level increases, which implies that we need more physical

capital to produce the same unit of output as the cost of reducing pollution. Hence, the social marginal product of physical capital eventually declines below the rate of time preference in the presence of the optimal pollution control. In this model, by contrast, because the technology of producing human capital is clean and does not generate pollution, the presence of pollution does not reduce the social marginal product of human capital. Furthermore, the social marginal product of physical capital can remain constant as long as human capital grows faster than physical capital, and it has a positive effect on the marginal product of physical capital to offset the cost of using more physical capital for pollution control.

. Inverted U- Shaped Relationship between Pollution and Income

Now we investigate the dynamic behavior of pollution. The asymptotic long-run growth rate of pollution is given as

$$g_x = \frac{1-\sigma}{\gamma} g_y = \left(\frac{1-\sigma}{\gamma} \right) \left(\frac{\delta-\rho}{\sigma+\theta} \right) < g_y. \quad (5.1)$$

When it is not optimal to control pollution in the early stage of economic development, θ is constant (i.e., $\theta=1$) and pollution grows at the same rate as output. The growth rate of pollution along the asymptotic steady-state growth path critically depends on the value of σ . If $0 < \sigma < 1$, pollution grows at a constant (positive) rate but slower than output because we assume that $\gamma > 1$. Pollution remains unchanged if $\sigma=1$, and declines if $\sigma > 1$ along the asymptotic long-run growth path. Hence, if the condition of $\sigma > 1$ is satisfied, this model yields the consistent result with empirically confirmed evidence of an inverted

U-shaped pattern of pollution with respect to income. Moreover, if the condition of $\sigma > 1$ holds, it is sufficient for the transversality conditions for physical and human capital to be satisfied, and this condition also guarantees that the long-run growth path of the economy is at least locally stable⁸).

. Sustainable Development

Although there is no working definition of sustainable development to use in an analytical framework, we follow Byrne (1997) and Aghion and Howitt (1998) in the sense that the long-run growth of utility could be an appropriate measure of sustainable development. Therefore, in this section, we analyze the long-run growth of instantaneous utility as an index of sustainable development, which incorporates the growth rates of both consumption and pollution. Differentiating the instantaneous utility function $U=U(c, x)$ with respect to time yields the growth of instantaneous utility over time as

$$\dot{U} = U_c \dot{c} + U_x \dot{x}, \text{ or } \frac{\dot{U}}{U} = \left(\frac{U_c c}{U}\right) \frac{\dot{c}}{c} + \left(\frac{U_x x}{U}\right) \frac{\dot{x}}{x}. \tag{6.1}$$

Because $U_c > 0$ and $U_x < 0$, instantaneous utility grows over time if $\dot{c} > 0$ and $\dot{x} < 0$ ($\sigma > 1$), or if U_x is not too large to be greater than $|U_c \dot{c}/\dot{x}|$ in the absolute values when $\dot{x} > 0$ ($\sigma < 1$), which implies that $\dot{U} > 0$. Along the asymptotic long-run growth path, the instantaneous utility grows at the rate

$$g_U = \left(\frac{U_c c}{U}\right) g_y + \left(\frac{U_x x}{U}\right) \left(\frac{1-\sigma}{\gamma}\right) g_y = (1-\sigma) g_y. \tag{6.2}$$

Hence, the social utility grows at a constant rate along the asymptotic long-

8) The transversality conditions for physical and human capital hold if $(1-\sigma)g_k < \rho$, which is satisfied if $\sigma \geq 1$, or if $0 < \sigma < 1$ and $g_k < \rho/(1-\sigma)$.

run growth path except when $\sigma=1$. If $\sigma=1$ for the case of logarithmic utility function of consumption, the asymptotic growth rate of the instantaneous utility is zero. As the growth rate of output in the absence of environmental considerations is greater than that in the presence of pollution, the same holds for the utility growth rate⁹⁾. Although the pollution level increases if $0 < \sigma < 1$, or declines if $\sigma > 1$, along the asymptotic long-run growth path, the social utility increases in both cases. In case of $0 < \sigma < 1$, g_U is positive so that $\dot{U} > 0$ and $U > 0$. In case of $\sigma > 1$, both $U < 0$ and $g_U < 0$ hold, implying that $\dot{U} > 0$. Hence, the instantaneous utility as a measure of the standard of living affected by environmental quality as well as consumption improves over time, and consumers become better off along the asymptotic long-run growth path. Moreover, as σ becomes larger, pollution declines faster and social utility improves at a higher rate. Hence, utility growth can be sustained regardless of the magnitude of σ as long as $\sigma \neq 1$. Sustained growth of social utility or sustainable development is possible due to the fact that when pollution is linked with output growth, the social planner chooses the cleaner production technology by allocating resources to internalize the negative externalities. When pollution does affect utility, the utility growth in a decentralized economy cannot be the same as that obtained by the social planner's optimal solutions, which we will also investigate later. Some previous studies in this literature often argue that a possible path for sustainable development with the maintenance of environmental quality is no economic growth. This model shows that the growth of social utility as an index of sustainable development can be sustained with an optimal control of pollution when the important sources of growth are not affected by the presence of pollution.

9) The growth rate of utility in the absence of pollution is $(1-\sigma)g_y^n$, where g_y^n is the growth rate of output in a standard human capital model with no pollution.

. Policy Analysis for the Social Optimum: Pollution Tax

So far, we have studied the issue of economic growth and pollution in the context of social planner's problem. We characterized the optimal dynamic behaviors of consumption, saving, the allocation of non-leisure time between two sectors, and pollution during the transition and along the asymptotic long-run growth path.

However, without government intervention, the decentralized economy generally suffers from a market failure associated with the negative externality of pollution. Although consumers benefit from better environmental quality, there is generally no market for environmental quality or pollution. Consumers take the pollution level as given while they make decisions on consumption, saving, and the allocation of their labor between additions to human capital and final goods production. Producers, on the other hand, would face no cost at all for pollution, but only a benefit from producing more output with more pollution input. In the absence of government regulation of pollution, a cleaner technology can be chosen at the expense of fewer goods produced. Therefore, the producers will always choose the dirtiest technology to maximize their output and profit.

Therefore, we introduce the governments role in order to study the issue of implementing the social optimum in a decentralized economy. In particular, we analyze how the government set the pollution tax to implement a social optimum through market mechanism.

Let $k_0, h_0 > 0$ be given, and let $\{c^*(t), \omega^*(t), u^*(t), k^*(t), h^*(t), \lambda_1^*(t), \lambda_2^*(t), t \geq 0\}$ be the optimal paths for consumption and others, which are found by solving the social planner's problem. Also, let $x^*(t) \equiv \omega^*(t)^{\alpha(\beta+1)} k^*(t)^\alpha \left((1-u^*(t))h^*(t) \right)^{1-\alpha}$

be the optimal path of pollution. Suppose the government wants to implement the social optimum by imposing a pollution tax, $\tau(t)$, to firms. We assume that the households (consumers) and firms (producers) are the same as before.

1. The Representative Household's Problem

Each household owns physical and human capital, and one unit of non-leisure time. The household takes as given the rates of return on physical and human capital, $r(t)$ and $w(t)$, respectively. The household receives rental income, $r(t)k(t)$, by renting physical capital to firms. Also, the household with human capital $h(t)$ receives wage income, $w(t)(1-u(t))h(t)$, by devoting the fraction, $(1-u(t))$, of non-leisure time to production. Although the pollution level, $x(t)$, varies over time by the firms decision under government regulation, the household takes the pollution level as given. We assume that government returns the pollution tax revenue, $R(t) = \tau(t)x(t)$, to the household as a lump sum subsidy. The lump sum subsidy from government, $R(t)$, which is a part of households income, is also taken as given by the household. Given the households income, $r(t)k(t)+w(t)(1-u(t))h(t)+R(t)$, the household makes decisions on consumption, saving (physical capital accumulation), and the allocation of non-leisure time between two sectors to maximize the lifetime utility.

So the representative household's problem is

$$\begin{aligned} \max \quad & \int_0^{\infty} e^{-\rho t} \left(\frac{c(t)^{1-\sigma}}{1-\sigma} - \frac{\phi x(t)^\gamma}{\gamma} \right) dt \quad (7.1) \\ \text{s.t.} \quad & \dot{k}(t) = r(t)k(t) + w(t)(1-u(t))h(t) + R(t) - c(t), \\ & \dot{h}(t) = \delta u(t)h(t), \end{aligned}$$

where $k(0) = k_0 > 0$, $h(0) = h_0 > 0$ are given, and the household take as given

$r(t)$, $w(t)$, $R(t)$, and $x(t)$.

The current value Hamiltonian for the representative households problem is

$$H = \frac{c^{1-\sigma}}{1-\sigma} - \frac{\phi x^\gamma}{\gamma} + \lambda_1 (rk + w(1-u)h + R - c) + \lambda_2 \delta uh, \quad (7.2)$$

where λ_1 and λ_2 denote the costate variables associated with physical and human capital, respectively.

The first-order conditions with respect to c and u and the Euler equations for λ_1 and λ_2 are as below :

$$\frac{\partial H}{\partial c} = 0 \Rightarrow c^{-\sigma} = \lambda_1, \quad (7.3)$$

$$\frac{\partial H}{\partial u} = 0 \Rightarrow \lambda_1 w = \lambda_2 \delta \quad \text{or} \quad w = \frac{\lambda_2}{\lambda_1} \delta \quad (7.4)$$

$$\dot{\lambda}_1 = \rho \lambda_1 - \frac{\partial H}{\partial k} \Rightarrow \frac{\dot{\lambda}_1}{\lambda_1} = \rho - r(t), \quad (7.5)$$

$$\frac{\dot{\lambda}_2}{\lambda_2} = \rho - \delta. \quad (7.6)$$

Comparing these conditions for a maximum in a decentralized economy with those for the social planners problem, we see that the optimum can be implemented if and only if the paths for λ_1 , λ_2 , and hence for consumption are identical with the optimal ones. If we assume that all the variables except $R(t)$ start at the same levels as those in the social planner's problem, then the growth rate and the time path of λ_2 are the same as those obtained from the social planners problem. In the social planner's problem, the Euler equation for λ_1 is

$$\frac{\dot{\lambda}_1}{\lambda_1} = \begin{cases} \rho - \alpha \left(\frac{(1-u)h}{k} \right)^{1-\alpha} + \left(\frac{\alpha}{\beta+1} \right) \left(\frac{(1-u)h}{k} \right)^{1-\alpha} \left[\lambda_1 \Psi \left[k^\alpha ((1-u)h)^{1-\alpha} \right]^{-\tau} \right]^{-1}, & \text{if } \omega = 1, \\ \rho - \left(\frac{\alpha\beta}{\beta+1} \right) \left(\frac{(1-u)h}{k} \right)^{1-\alpha} \omega^\alpha, & \text{if } \omega < 1, \end{cases} \quad (7.7)$$

where all notations are the same as before; α and β are parameters of production technology and pollution function, respectively, $\Psi = \frac{1}{\phi(\beta+1)}$, $\eta = \frac{1}{\gamma(\beta+1)-1} > 0$. Also, ω is a quality index of differentiated physical capital that is used by firms, and the optimal value of ω in the social planners problem is given as

$$\omega = \begin{cases} 1, & \text{if } \lambda_1 \geq \frac{1}{\Psi} \left[k^\alpha ((1-u)h)^{1-\alpha} \right]^{-1}, \\ \left[\Psi \lambda_1 \left[k^\alpha ((1-u)h)^{1-\alpha} \right]^{-\tau} \right]^{\frac{1}{\tau}}, & \text{if } \lambda_1 < \frac{1}{\Psi} \left[k^\alpha ((1-u)h)^{1-\alpha} \right]^{-1}. \end{cases} \quad (7.8)$$

Thus, the path for λ_1 in (7.5) matches with the optimal one if and only if the equilibrium rental rate on physical capital, $r^*(t)$, should satisfy

$$r^*(t) = \begin{cases} \alpha \left(\frac{h_y^*(t)}{k^*(t)} \right)^{1-\alpha} \left[1 - \frac{1}{(\beta+1)\Psi \lambda_1^*(t)} \left(k^*(t)^\alpha h_y^*(t)^{1-\alpha} \right)^{-1} \right], & \text{if } \omega^*(t) = 1, \\ \frac{\alpha\beta}{\beta+1} \left(\frac{h_y^*(t)}{k^*(t)} \right)^{1-\alpha} \omega^*(t)^\alpha, & \text{if } \omega^*(t) < 1, \end{cases} \quad (7.9)$$

where $h_y^*(t) \equiv (1-u^*(t))h^*(t)$ and $\omega^*(t)$ is the optimal value given in (7.8). In this case, the equilibrium rate of return on human capital is determined as

$$w^*(t) = \delta \frac{\lambda_2^*(t)}{\lambda_1^*(t)}. \quad (7.10)$$

The fraction, $u^*(t)$, of non-leisure time devoted to human capital accumulation is automatically determined¹⁰⁾ if $h_y^*(t)$ and the growth rate of $h_y^*(t)$ (and $h^*(t)$) are determined by solving the firm's problem.

2. The Representative Firm's Problem

Now we turn to the firm's problem to solve for the competitive equilibrium. The representative firm's problem is to maximize profit at each point of time t , taking as given the rental rates of physical and human capital, $r(t)$, $w(t)$, and the pollution tax, $\tau(t)$.

As before, physical capital is differentiated into infinitely many physical capital goods in terms of productivity and pollution-generating level. Since government regulation through pollution tax restricts the use of lower quality but more productive physical capital, more physical capital is needed to produce the same amount of output with less pollution. Therefore, the firm's problem is a static one to choose its input levels, k and h_y , and the type of differentiated physical capital, ω , to maximize profit at any given point of time as below :

$$\begin{aligned} \max_{\omega, k, h_y} \pi &= (\omega k)^\alpha h_y^{1-\alpha} - [rk + wh_y + \tau((\omega^\beta (\omega k))^\alpha h_y^{1-\alpha})] \\ \text{s.t. } & \omega \leq 1. \end{aligned} \tag{7.11}$$

In effect, the firm's choice of the type of differentiated physical capital is essentially the same as that of how much pollution to emit in the production process. Thus, for analytical convenience, it is equivalent to use the model in which pollution is treated as a normal input of production. In this case, the firm

10) Note that $u(t) = \frac{1}{\delta} \frac{\dot{h}(t)}{h(t)}$.

makes decisions on its input levels, k , h_y , and x to maximize profit, taking r , w , and τ as given :

$$\max_{k, h_y, x} \pi = \left(k^\alpha h_y^{1-\alpha} \right)^{\frac{1}{\beta+1}} x^{\frac{1}{\beta+1}} - (rk + wh_y + \tau x) \quad (7.12)$$

$$\text{s.t. } x \leq k^\alpha h_y^{1-\alpha}.$$

The Lagrangian for this problem is

$$L = \left(k^\alpha h_y^{1-\alpha} \right)^{\frac{1}{\beta+1}} x^{\frac{1}{\beta+1}} - (rk + wh_y + \tau x) + \mu(k^\alpha h_y^{1-\alpha} - x), \quad (7.13)$$

where $\mu \geq 0$ is the Lagrange multiplier associated with the inequality constraint for pollution input, x .

Solving the Kuhn–Tucker condition for a maximum subject to inequality constraint yields that

$$\frac{\partial L}{\partial \mu} = k^\alpha h_y^{1-\alpha} - x \geq 0, \mu \geq 0, \text{ and if } x < k^\alpha h_y^{1-\alpha}, \text{ then } \mu = 0. \quad (7.14)$$

Thus, the first-order conditions for a maximum with respect to x , k , and h_y are

$$\frac{\partial L}{\partial x} = 0 \Rightarrow \tau \leq \frac{1}{\beta+1} \left(\frac{x}{k^\alpha h_y^{1-\alpha}} \right)^{\frac{1}{\beta+1}}, \quad (7.15)$$

$$\frac{\partial L}{\partial k} = 0 \Rightarrow r \geq \alpha \left(\frac{\beta}{\beta+1} \right) \frac{(k^\alpha h_y^{1-\alpha})^{\frac{1}{\beta+1}} x^{\frac{1}{\beta+1}}}{k}, \quad (7.16)$$

$$\frac{\partial L}{\partial h_y} = 0 \Rightarrow w \geq (1-\alpha) \left(\frac{\beta}{\beta+1} \right) \frac{(k^\alpha h_y^{1-\alpha})^{\frac{1}{\beta+1}} x^{\frac{1}{\beta+1}}}{h_y}, \quad (7.17)$$

with equality if $x < k^\alpha h_y^{1-\alpha}$. Since the production technology exhibits constant returns to scale to its inputs, k , h_y , and x , the firms zero-profit condition is

satisfied as below:

$$(k^\alpha h_y^{1-\alpha})^{\frac{1}{\beta+1}} x^{\frac{1}{\beta+1}} = rk + wh_y + \tau x. \quad (7.18)$$

If the inequality constraint is not binding (i.e., $x < k^\alpha h_y^{1-\alpha}$), then the first-order conditions for profit maximization are enough to determine the equilibrium prices. In order to implement the social optimum, government should set the tax rate so that pollution level is the same as that obtained from the social planners problem :

$$x = (\psi \lambda_1)^{(\beta+1)\eta} (k^\alpha h_y^{1-\alpha})^{\beta\eta}, \text{ if } x < k^\alpha h_y^{1-\alpha}. \quad (7.19)$$

Thus, when the inequality constraint is not binding, in the sense that pollution is optimally controlled, the equilibrium prices that implement the social optimum are obtained by substituting (7.19) into (7.15), (7.16), and (7.17) :

$$\tau = \frac{1}{\beta+1} (\psi \lambda_1 (k^\alpha h_y^{1-\alpha})^{1-\gamma})^{\beta\eta}, \quad (7.20)$$

$$r = \alpha \left(\frac{\beta}{\beta+1} \right) \left(\frac{h_y}{k} \right)^{1-\alpha} (\psi \lambda_1 (k^\alpha h_y^{1-\alpha})^{1-\gamma})^\eta, \quad (7.21)$$

$$w = (1-\alpha) \left(\frac{\beta}{\beta+1} \right) \left(\frac{k}{h_y} \right)^\alpha (\psi \lambda_1 (k^\alpha h_y^{1-\alpha})^{1-\gamma})^\eta. \quad (7.22)$$

The competitive prices given in (7.20), (7.21), and (7.22) can also be obtained by solving the firms problem given in (7.11) and substituting the optimal value of ω , $\omega = (\psi \lambda_1 (k^\alpha h_y^{1-\alpha})^{1-\gamma})^\eta$, into the first-order conditions to implement the social optimum.

On the other hand, if the inequality constraint is binding, in the sense that pollution is not controlled at all, then the highest tax is $\frac{1}{\beta+1}$, below which the

firm will use the dirtiest technology, so the equilibrium tax rate can lie anywhere in the interval

$$\tau \in \left[0, \frac{1}{\beta+1} \right]. \quad (7.23)$$

In this case, both the first-order conditions and zero-profit condition should be used to determine the equilibrium rates of return on physical and human capital as below:

$$\left. \begin{aligned} r &\geq \alpha \left(\frac{\beta}{\beta+1} \right) \left(\frac{h_y}{k} \right)^{1-\alpha}, \quad w \geq (1-\alpha) \left(\frac{\beta}{\beta+1} \right) \left(\frac{k}{h_y} \right)^\alpha, \\ rk + wh_y &= (1-\tau\phi^{1-\alpha})k^\alpha h_y^{1-\alpha}, \text{ and } \frac{rk}{wh_y} = \frac{\alpha}{1-\alpha}. \end{aligned} \right\} \quad (7.24)$$

Combining (7.23) and (7.24), we can solve for the equilibrium prices of physical and human capital, in terms of the equilibrium tax rate, and their possible ranges:

$$r = \alpha(1-\tau) \left(\frac{h_y}{k} \right)^{1-\alpha} \Rightarrow r \in \left[\alpha \left(\frac{\beta}{\beta+1} \right) \left(\frac{h_y}{k} \right)^{1-\alpha}, \alpha \left(\frac{h_y}{k} \right)^{1-\alpha} \right], \quad (7.25)$$

$$w = (1-\alpha)(1-\tau) \left(\frac{k}{h_y} \right)^\alpha \Rightarrow w \in \left[(1-\alpha) \left(\frac{\beta}{\beta+1} \right) \left(\frac{k}{h_y} \right)^\alpha, (1-\alpha) \left(\frac{k}{h_y} \right)^\alpha \right]. \quad (7.26)$$

Hence at the input prices given by (7.20), (7.21), and (7.22), (or (7.23), (7.25), and (7.26)), the firm will choose its input levels, x , k , and h_y , so that the pollution level is the same as the optimal one obtained from the social planners problem.

3. Pareto-Efficient Equilibrium

Now we put the household and firms problems together to solve for the competitive equilibrium under the government tax policy for pollution control.

First, when the inequality constraint is not binding, i.e., $x(t) < k(t)^\alpha h_y(t)^{1-\alpha}$, or $\omega(t) < 1$, the rental rate on physical capital, $r(t)$, obtained by solving the firms problem given in (7.21) exactly matches with the rental rate on physical capital given in (7.9). Therefore, it satisfies the condition for the equilibrium path of λ_1 given in (7.5), which is obtained by solving the households problem, to be the same as the optimal one. Hence, the equilibrium tax rate and return on human capital, which implement the social optimum for periods when $x(t) < k(t)^\alpha h_y(t)^{1-\alpha}$, are determined by (7.20) and (7.22), respectively.

Second, when the inequality constraint is binding so that $x(t) = k(t)^\alpha h_y(t)^{1-\alpha}$, or $\omega(t) = 1$, the equilibrium values of τ , r , and w should lie in the intervals given in (7.23), (7.25), and (7.26), respectively. Since the optimal rental rate on physical capital given in (7.9) lies in the interval of (7.25), the equilibrium tax rate that implements the optimum is determined by combining the first equation in (7.9) and equation in (7.25). Also, the equilibrium tax rate solves the equilibrium prices of physical and human capital given in (7.25) and (7.26), and consequently, the competitive equilibrium prices of x , k , and h_y are given as

$$\tau^*(t) = \begin{cases} \frac{\left(k^*(t)^\alpha h_y^*(t)^{1-\alpha}\right)^{\beta-1}}{(\beta+1)\psi\lambda_1^*(t)}, & \text{if } x^*(t) = k^*(t)^\alpha h_y^*(t)^{1-\alpha} \\ \frac{\left(\psi\lambda_1^*(t)\left(k^*(t)^\alpha h_y^*(t)^{1-\alpha}\right)^{\beta-1}\right)^{\beta\eta}}{\beta+1}, & \text{if } x^*(t) < k^*(t)^\alpha h_y^*(t)^{1-\alpha}, \end{cases} \quad (7.27a)$$

or alternatively,

$$\tau^*(t) = \begin{cases} \frac{\left(k^*(t)^\alpha h_y^*(t)^{1-\alpha}\right)^{\gamma-1}}{(\beta+1)\psi\lambda_1^*(t)}, & \text{if } \omega^*(t) = 1, \\ \frac{\omega^*(t)^{-\alpha\beta}}{\beta+1}, & \text{if } \omega^*(t) < 1, \end{cases} \quad (7.27b)$$

$$r^*(t) = \alpha(1 - \tau^*(t)) \left(\frac{h_y^*(t)}{k^*(t)} \right)^{1-\alpha}, \quad (7.28)$$

$$w^*(t) = (1 - \alpha)(1 - \tau^*(t)) \left(\frac{k^*(t)}{h_y^*(t)} \right)^\alpha. \quad (7.29)$$

From equations (7.27a) and (7.27b), it is interesting to note that the optimal tax rate is not zero, but strictly positive, even when the firms do not make efforts to reduce pollution by using the dirtiest technology. To put it in another way, firms pay the positive taxes for pollution even when the tax has no effect on pollution reduction. However, the positive tax rate in effect reduces the market rates of return on physical and human capital. The lower rates of return reduce the incentive for the new investment in physical and human capital, and hence, preventing pollution from increasing at a faster rate over time.

At the prices $\{r^*(t), w^*(t), \tau^*(t)\}$ given as the above in (7.27), (7.28), and (7.29), the firm will choose the optimal inputs $\{k^*(t), h_y^*(t), x^*(t)\}$ at any point in time t . The resulting path for the quality of differentiated physical capital used by firms, $\omega^*(t)$, which can be viewed as an index of emission standard, is also optimal. Since government tax revenue, $R^*(t) = \tau^*(t) x^*(t)$, is distributed to household's as a lump sum subsidy, the households income is equal to the sum of returns to physical and human capital, and a lump sum subsidy from government. Given $\{r^*, w^*, x^*, R^*\}$, the values $\{c^*, k^*, h_y^*, u^*, h^*, \lambda_1^*, \lambda_2^*\}$ that solve the households problem are the same as those obtained from the social planners problem, so the competitive equilibrium is a social optimum. Thus, the social optimum can be implemented in a decentralized economy at all times

with a pollution tax, $\tau^*(t)$.

Finally, consider the long-run growth rate of the pollution tax. Taking logarithms and differentiating the second equation in (7.27b) yields the long-run growth rate of pollution tax as below:

$$\frac{\dot{\tau}}{\tau} = -\alpha\beta g_{\omega} = \frac{\gamma - 1 + \sigma}{\gamma} g_y > 0, \quad (7.30)$$

where $g_{\omega} < 0$ and $g_y > 0$ are the long-run growth rates of ω and y , respectively. Along the steady-state growth path when $\omega(t) < 1$, the pollution tax rate should rise at a constant rate as above. It implies that as economic growth increase the value of environmental quality, the firms have to pay a higher price for pollution input. Thus, the firms are willing to substitute more conventional inputs (physical and human capital) for pollution, which induces the firms to choose cleaner technology, leading the improvement in environmental quality as in the social planner's problem.

Now suppose the government directly regulates firms by setting an emission standard on how much pollution is allowed to emit in production at each time t . In this case, firms are entitled to emit the allowed level of pollution without paying for the right to emit the corresponding level of pollution. Intuitively, the question of which policy instrument can implement the social optimum is related to the market mechanism associated with input prices. Under the pollution tax or voucher system, it is implicitly assumed that price of pollution is determined in a separate market for pollution, and firms buy the right to pollute at the given price of pollution. The price of pollution affects the market rates of return on physical and human capital, and in turn, these input prices affect the households decisions for investment in physical and human capital. By contrast, under direct regulation of the pollution level or the type of differentiated physical capital, it is assumed that there is no separate market

for pollution, and the markets for physical (human) capital and pollution are actually mixed together. Hence, the market rental rates of physical and human capital are determined in the mixed markets, and they include the price of pollution, i.e., the value of the right to pollute. In other words, the market rental rate of physical (human) capital accounts for not only the true return on physical (human) capital, but also the value of the right to emit additional units of pollution for each unit of physical (human) capital. Since the market returns on physical and human capital are higher than the true (i.e., socially optimal) returns, these overvalued market returns on physical and human capital are misleading the households behavior into over investment in physical and human capital. As a consequence, the social optimum is not implemented under these types of direct regulation.

Based on the results that we have derived so far, we see that government should choose the pollution tax rather than a certain type of direct regulation, in order to implement the social optimum. These results may help to provide the theoretical basis for the actual evidence of increasing use of the “incentive-based” mechanisms for environmental regulation rather than the “command-and control” approaches in the U.S. and over the world (Hahn (2000)).

. Concluding Remarks

This paper undertakes an extensive analysis of the interaction between economic growth and the environment. We have developed a simple theoretical model that is consistent with the empirical evidence of an inverted U-shaped pattern of pollution relative to income, the so-called environmental Kuznets curve. This model, however, is different from the previous studies modeling the link between growth and environment. In particular, we present a unique and

realistic specification of the pollution generating process, and we incorporate the environmental externality into an endogenous growth model of human capital with differentiated physical capital. Utilizing our analytical framework, we have studied different issues regarding economic growth and the environment, such as: (i) theoretical analysis of an environmental Kuznets curve, (ii) the long-run growth and sustainable development in the presence of pollution, and (iii) a policy analysis for implementing the social optimum in a decentralized economy.

In Chapter , we present a simple theoretical model that yields consistent results with the empirical evidence of an inverted U-shaped pattern of pollution relative to income. Although many empirical studies find the inverted U-shaped relationship between per capita income and pollution levels, the reason for such a relationship has been left open in that research. Hence, we make a contribution to the literature on growth and the environment by providing a theoretical basis to explain why pollution follows an inverted U-shaped pattern with respect to income level.

Through Chapter to Chapter , we show that one of the important factors determining the pattern of pollution growth with respect to income is the potential output level of the economy. We find that it is optimal not to control pollution when potential output is low but it may be optimal to control it at higher level of potential output. Since our result indicates that it is optimal not to control pollution when the potential output level is relatively low, it supports the position of less-developed countries that claim that they should be allowed to have a less stringent environmental policy for faster economic growth.

Another important factor that is crucial in determining the income-pollution relationship is the elasticity of marginal utility of consumption (σ_c) relative to the elasticity of substitution in production between pollution and conventional

inputs (σ_y)¹¹⁾. A higher level of σ_c implies that consumers are willing to give up more consumption to reduce a given amount of pollution as income level increases. On the other hand, a higher level of σ_y implies that if pollution is treated as an input of production, firms are willing to use more conventional inputs, instead of reducing the pollution input, in response to an increase in the price of the pollution input. If both σ_c and σ_y are high enough for σ_c to be greater than $1/\sigma_y$, the price of pollution will increase sharply with income and firms will reduce pollution by a large amount in response to a higher price of pollution.

Therefore, if we assume that σ_c is greater than $1/\sigma_y$, an inverted U-shaped relationship between per capita income and pollution is derived from our model. As the potential output level grows, the economy has a transition from the region in which pollution is not controlled to the region in which pollution is controlled. When pollution is not controlled at all, it is clear that pollution increases with income. However, when potential output exceeds a critical level, it is optimal to control pollution. Moreover, the pollution level decreases if and only if σ_c is greater than $1/\sigma_y$, so in this case the optimal behavior of pollution displays an inverted U-shaped pattern with respect to income level.

Since we believe that one of the important objectives for the study of economic growth is to explore its implications on welfare, we have used our model to address the issue of sustainable development in Chapter . We interpreted the term “sustainable development” as development that improves the quality of life, which depends on environmental quality as well as consumption of produced goods. In this context, we analyzed the long-run growth of the instantaneous utility, which depends on both consumption and

11) This elasticity can be derived from the generalized functional forms of our model. This equals one for the Cobb-Douglas production technology in our model.

pollution levels, as an index of sustainable development. Thus, one of the major contributions of this paper lies in applying the concept of sustainable development to a model of economic growth.

When pollution is linked with output production, the social planner chooses the cleaner production technology by allocating resources to internalize the negative externality. Optimal control of pollution leads to quality improvement in physical capital used in production, while human capital plays an important role as a source of sustained growth of the economy. We have shown that long-run growth and sustainable development are achieved with more stringent environmental policy, provided that the social marginal product of human capital is not affected by the presence of pollution.

In Chapter , we have studied the issue of implementing the social optimum in a decentralized economy by introducing pollution tax as a government policy instrument.

We have shown that the pollution tax can implement the social optimum. The intuition behind this result is that the effectiveness of government policy depends on the market mechanism associated with the price of pollution and the rates of return on physical and human capital. If pollution is regulated using a pollution tax, then the pollution input has its own market price that is separate from the rental rates of physical and human capital. Therefore, the market rental rates of physical and human capital reflect their true (i.e., socially optimal) values under the pollution tax, which enable the household to make optimal decisions for investment in physical and human capital.

The results that we have discussed so far suggest some important issues ignored in this paper for further research. Thus, the basic framework of the model we have developed in this paper can be extended to study a number of additional related issues.

Since pollution can be defined in a broad sense as the extractive use of the

natural environment, and the environment can be modeled as a renewable resource because of its nature of regenerative capacity (e.g., López(1994), Bovenberg and Smulders(1995), and Aghion and Howitt(1998)), our model of pollution can be used to deal with the issue of renewable natural resource such as the optimal management of forests or fisheries.

In this paper, we assumed that there already exist infinitely many differentiated physical capital among which a certain type of physical capital can be chosen for use in the final output production. It implies that cleaner production technology, which enables the final output to be produced in a less polluting way, is embedded in the cleaner type of differentiated physical capital. It would be interesting to study an economy in which we model the endogenous pollution–abatement technological progress, which should be distinguished from the growth–enhancing technology improvement. The key issues that we could deal with in this framework include the question of whether there is sufficient market incentive to develop pollution–abatement technology in the private sector. Also, we could discuss the role of government not only because of the market failure associated with environmental externality, but because the pollution–abatement technology has a public good character.

Our analysis of economic growth and the environment in this paper was based on a single closed economy. With an emergence of trade liberalization, such as the North American Free Trade Agreement, there have been conflicting arguments about the interaction between trade and the environment. It would be interesting to consider an open economy to investigate how the pattern of trade, income level, and the environment are affected by the free trade policy in developed vs. less–developed countries. In this case, for example, we must assume that different countries have different production technologies and different policies for environmental regulation.

Population size was assumed to be exogenously taken as constant in this paper for analytical convenience. However, population growth is related to per capita income and pollution in the sense that an expansion of the aggregate labor force could raise the per capita growth rate if there is a scale effect of the economy, and that pollution damage depends on the economy's population density. Therefore, population growth should be an important factor to be taken into account when investigating the linkage between economic growth and the environment. If the population growth rate is assumed to be positive, however, then our model of human capital would yield no balanced growth path, but the growth rate would explode because of the scale effect. In this context, we need to develop a new framework, such as non-scale model of economic growth (e.g., Eicher and Turnovsky (1999)), in order to study the effect of population growth on per capita income and pollution levels.

Finally, it would be worth calibrating our model to real data of both developed and less-developed countries to examine the pattern of pollution with respect to income at different stages of economic growth. Based on the calibration results, we might be able to suggest policy prescriptions on when and how strictly the pollution should be controlled in each country.

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金 珍 永*

· 經濟學 隣接學問 接點：國家 富 貧困

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1800 \$450, \$807, 1989 \$3,500, \$18,300
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(American mode of production)

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(China lack institutions for findings and learning- schools, academies, learned society, challenges and competitions)” “ 가

(...consider Tokugawa Japan as an approximate, rough miniature of medieval Europe)”

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(No

one can understand the economic performance of Muslim nations without attending to the experience of faith and culture)

. 가 (Ottomans were too busy fighting) , 가 (...Ottoman rulers took the surplus, though at first they apparently squeezed the masses less, or less effectively, than Moghul India)

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가 (monumental misfortune)

1860

가 ‘ (Winners)’ , 가 ‘ (Losers)’

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- () , . (the key factor—the driving force— has been Western civilization and its dissemination: the knowledge, the techniques, the political and social ideologies, for better or worse).

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7) Development is long; logic, short. The economic theory is static, based on conditions of the day. The process is dynamic, building on today's abstinence to tomorrow's abundance.

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millenium. No apocalypse).”

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(empirical economic

growth)

(Robert Hall)

(Charles Jones)

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8) Robert Hall and Charles Jones, “Why Do Some Countries Produce So Much More Output per Worker than Others?” *Quarterly Journal of Economics*, February 1999, Vol. 114, pp. 83–116. “Output per worker varies enormously across countries. Why? On an accounting basis, our analysis shows that differences in physical capital and educational attainment can only partially explain the variation in output per worker — we find a large amount of variation in the level of the Solow residual across countries. At a deeper level, we document that the differences in capital accumulation, productivity, and therefore output per worker are driven by differences in institutions and government policies, which we call social infrastructure. We treat social infrastructure as endogenous, determined historically by location and other factors captured in part by language”.

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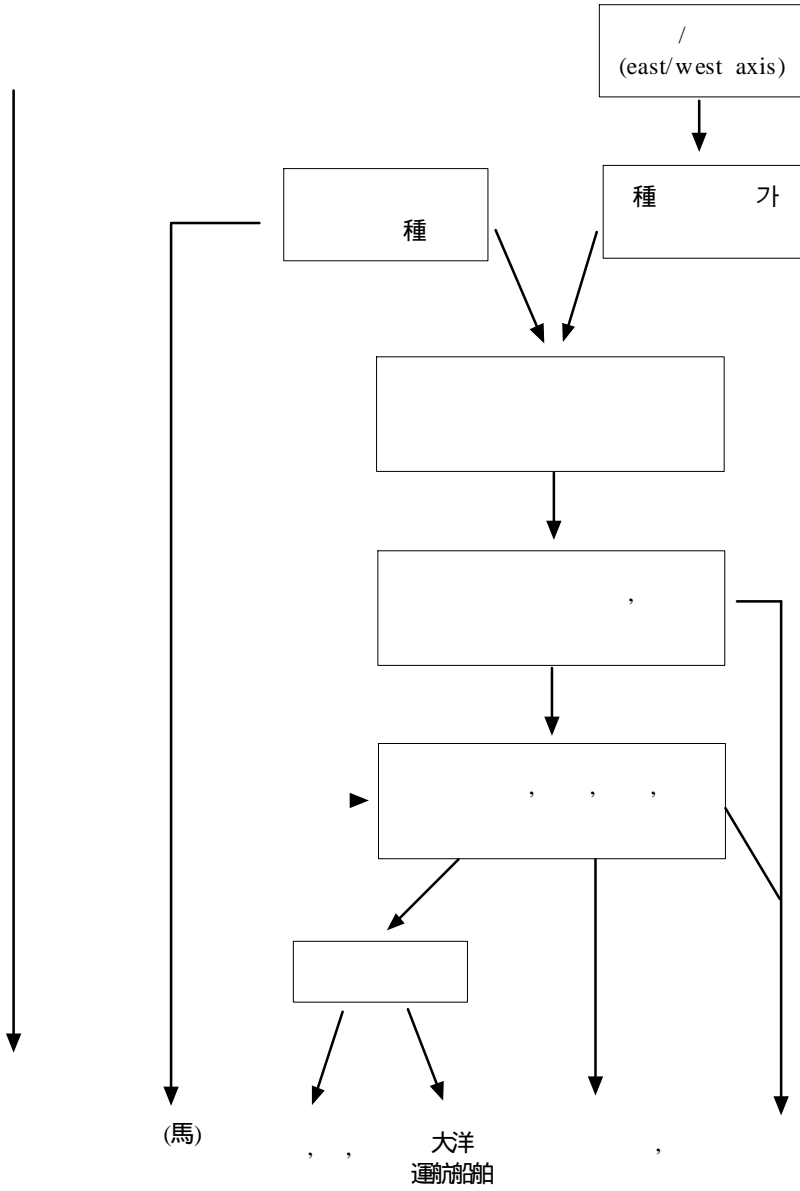
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Review of Fiscal Studies

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ABSTRACT

A Study on Estimating the Effects of Changes in Tax Structures and Distributions of Income and Consumption on Tax Burden

Myung Jae Sung

This study analyzes the effects on tax burden of the changes in tax structures, separately from those in the distributions of income and consumption, using the Family Income and Expenditure Survey raw data : 1982 - 1999.

It turns out that the changes in income tax law increased progressivity in tax burden, for example, increasing the income tax exemption levels, however, changes in income and its distribution decreased its progressivity. As a result, the overall progressivity of income tax burden remained almost unchanged.

The changes in consumption tax laws did not have significant effects on the tax burden. To the contrary, the changes in income and consumption patterns had significant effects and, therefore, played a crucial role in

determining the overall shape of consumption tax distribution. The consumption tax burden was slightly regressive as expected. However, we might conclude that the consumption tax burden would be proportional rather than regressive, since its regressivity was so small.

Changing External Tariff Under a Free Trade Agreement

- Grossman and Helpman's Case

Jaeho Cheung

This paper explores the effect of external tariff changes on aggregate welfare when two small countries join a Free Trade Agreement(FTA). This paper builds primarily from the Grossman and Helpman(G&H)(1995), which ask “will an FTA between two small countries be politically viable?” When they answer this question, they assume that the tariffs of small countries are fixed exogenously.

Because an FTA, unlike a Customs Union, allows members to select their external tariffs, the politicians who receive contributions from the various interest groups may try to manipulate tariffs to maximize governments objective function.

Treating the external tariffs as endogenous variables, we find that after the FTA, small countries not only remove internal tariffs against the partner, but also remove or to reduce external tariffs against the rest of the world.

Understanding these new optimal tariffs, we derive the important result: even when the FTA is viable in the exogenous-tariff case(G&H), it might not be viable in the endogenous-tariff case where member countries have new optimal post-FTA tariffs. Thus, treating tariffs exogenously tends to overestimate the viability of establishing the FTA. Consequently, G&H's analysis may tend to overestimate the political viability of establishing the FTA.

Volatility in Foreign Exchange Market

Chang-Gyun Park

This paper examines the procedure of empirical equivalent martingale procedure (EEMM), first designed by Christensen and Kiefer (2000) and further developed by Park(2000), to estimate the volatility parameters in a stochastic differential equation governing the evolution of foreign exchange rates.

The EEMM estimator is based on a smart combination of the equivalent martingale measure, one of the most remarkable innovations in mathematical finance in recent years, and the development of asymptotic theory for simulation-based estimators in econometrics. The derivative pricing formula expressed as the conditional expectation of future payoffs with respect to the equivalent martingale measure constitutes the moment condition required for the generalized method of moments (GMM) estimator. On the other hand, GMM is operationalized by evaluating through simulation the conditional expectation in the moment condition which does not have a closed form solution.

The new estimator requires information from both underlying asset prices and derivative security prices in estimating the volatility parameters, as opposed to the traditional approaches where information from derivative security prices plays only a minor role. The beauty of the new estimation procedure is that the drift function in the stochastic differential equation under estimation is totally irrelevant in estimating volatility function so that the computational burden is relatively light compared to the case when we have to simultaneously estimate both drift and volatility functions. The new estimator is \sqrt{T} -consistent and asymptotically normal. The consistency does

not require the number of simulations per observation to become infinite, but the number of observations in the sample to go to infinity, which lessens computational burden significantly.

Five currency options actively traded in Philadelphia stock exchange are analyzed. We discover that market for foreign exchange has less volatility than market for stocks represented by the S&P 500 Index. We also reveal the fact that the extended constant elasticity of variance (ECEV) model is well suited to describe the volatility in foreign exchange markets. Finally, employing call options and put options two sets of estimates show that they are closed enough that the one factor model can be regarded as a reasonable approximation as far as foreign exchange markets are concerned.

**The Environmental Kuznets Curve,
Sustainable Development, and
Policy Analysis for the Social Optimum**

O-Sung Kwon

This paper develops a simple theoretical model that is consistent with the empirical evidence of an inverted U-shaped relationship between pollution and per capita income. It is shown that the dynamic behavior of pollution is determined by the relative magnitude of the elasticity of the marginal utility of consumption and the elasticity of substitution in production between pollution and conventional inputs. Also, by incorporating the issue of environmental externality into an endogenous growth model, I investigate the circumstances under which growth can be sustained with the optimal control of pollution, and hence the sustainable development can be achieved. I show that the more stringent pollution control leads the improvement in environmental quality, while the human capital plays an important role as a source of the sustained growth. Finally, in order to study the problem of implementing the social optimum in a market economy, I analyze the pollution tax as one of the government's policy instruments. The general equilibrium analysis shows that the socially optimal tax rate of pollution should increase proportionally to the growth rate of consumption.

原稿作成 要領

1. 漢字 學術用語, 專門用語, 固有
名詞 中心語句 漢字
2. 外來語 ‘外來語 表記法’ 漢字
特殊 學術用語
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6. 『財政研究』編輯委員會

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