DISCUSSION PAPER No.102

How enterprise strategies are related to innovation and productivity change: An empirical study of Japanese manufacturing firms

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文部科学省　科学技術・学術政策研究所

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November 2013

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要旨
　本稿では日本の 1,174 社のイノベーションや生産性の改善に関する戦略的マネジメントの要素に関するデータを使用して、全要素生産性 (Total factor productivity)について分析している。その結果、製品に関する知識やノウハウの保護やマネジメントを重視する企業は生産性を増加させることが分かった。さらに、生産性のフロンティアに到達する企業は、製品に関する知識やノウハウの保護やマネジメントを重視する傾向にあることが明らかになった。

How enterprise strategies are related to innovation and productivity change: An empirical study of Japanese manufacturing firms

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Abstract
This study analyzes the total factor productivity of 1,174 Japanese firms. This study uses R&D strategy data to determine which factors of strategic management relate to improvements in innovation and productivity. Our results show that the protection and management of production knowledge and expertise is related to an increase in productivity. We also report that the protection and management of production knowledge and expertise is a valid method of increasing global technological change.

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概要

本文

概要

1. 研究の背景と目的

生産性とは、生産における投入財(インプット)と産出財(アウトプット)の比率のことである。生産性の指標として、労働生産性、資本生産性、ならびに全要素生産性(Total Factor Productivity: TFP)が挙げられる。労働生産性とは、労働力をインプットとし、アウトプットとの比率を計算するものである。資本生産性とは、資本をインプットとし、アウトプットとの比率を計算するものである。これに対して、TFP とは、労働力や資本を含むすべての要素をインプットとし、アウトプットとの比率を計算するものである。

国レベルにおいて大きな経済的インパクトが創出されるためには、一定量のインプットに対して大きなアウトプットを生み出すことができる企業が多数存在するような環境を整備することが望まれる。すなわち、TFP を上昇させるための方策の検討は、国の科学技術イノベーション政策の立案においてきわめて重要な課題の一つであるといえる。

TFP を上昇させるための方策を検討する前提として、最初に、近年の日本企業において生産性がどのように変化しているかを把握する必要がある。そこで、本研究ではまず、近年の日本企業の生産性の変化を複数の業種に関して計算し、その動向を捉える。

次に本研究では、どのような企業戦略をとれば TFP を上昇させることができるのかを検討する。TFP 上昇率に寄与する要因を分析した先行研究はいくつか存在するが、企業の戦略的な意思決定が生産性に与える影響の分析はこれまで十分には行われてこなかった。本研究では、本研究所が実施している「民間企業の研究活動に関する調査」(以下、「民研調査」)の調査結果の一部を用いて、開発した新製品・サービスから利益を確保するために企業がとっている行動が、企業の生産性にどのように影響しているのかを分析する。

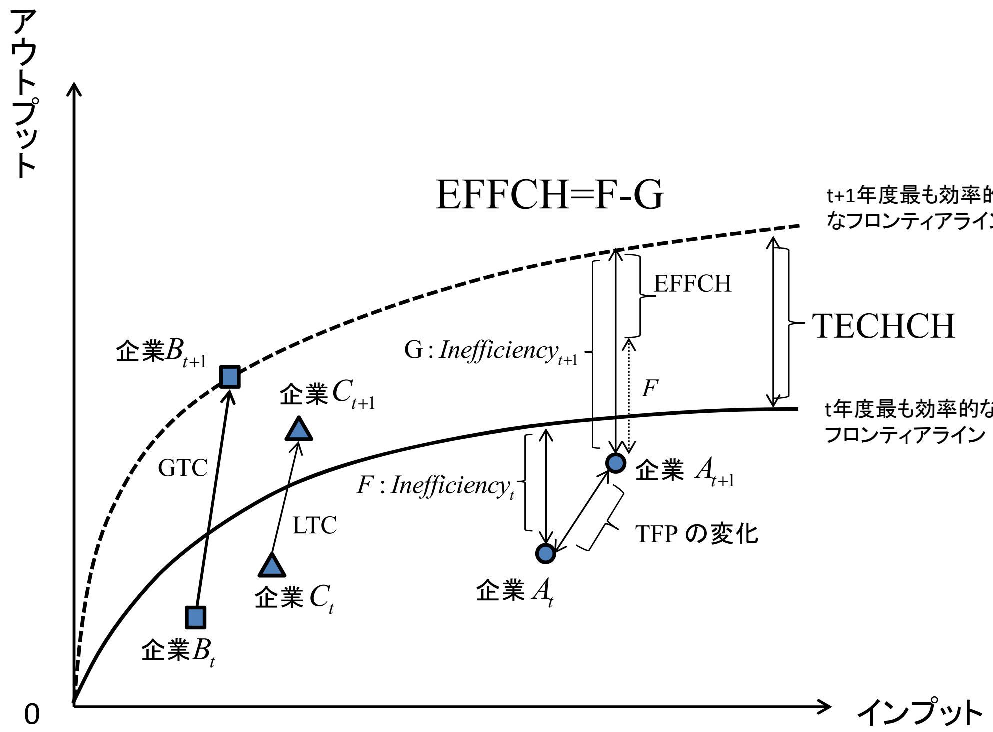
2. 本研究で用いる指標に関する先行研究

Chambers et al. (1998) によると、TFP の変化は、技術変化 (TECHCH) ならびに効率性変化 (EFFCH) という 2 つの生産性変化の指標に分割することができる。これらの指標は、Luendberger Productivity Indicator として用いられている。インプットを横軸、アウトプットを縦軸とする平面を想定すると、TECHCH は、ある業種において最も効率的な企業のインプットとアウトプットのプロットの集合を表すフロンティア・ラインの変化であり、産業全体の効率性の変化を意味する(図 1)。そのフロンティア・ラインからの各企業の乖離の程度を、生産性非効率性(Inefficiency)とよぶ。Kerstens and Managi (2012) は、各企業の Inefficiency を、DDF 関数(Directional distance function)を用いて算出する手法を確立した。EFFCH は、ある企業の生産性の効率がインプット-アウトプット平面上で 1 年前と比べてどの程度移動したかを示すものであり、個々の企業のキャッチアップの程度の変化を意味する。個別企業の TFP 変化は TECHCH と EFFCH によって求めることができる。

Atkinson and Stiglitz (1969) によると、技術的変化というものは、必ずしも生産技術を完全に変化させてしまうものである必要はなく、生産技術の特定の部分に対する局所的な変化につながるものもある。生産技術を完全に変化させてしまう技術的変化を GTC (Global Technological Change)とよび、生産技術の特定の部分に対する局所的な変化を LTC (Local Technological Change)とよぶ。Kerstens and Managi (2012) によると、GTC は、ある企業の生産性が t 年から t+1 年の間に t+1 年のフロンティア・ラインへと移動することを意味し(図-1 の $B_t \rightarrow B_{t+1}$ のケース)、LTC は、ある企

業の生産性が t 年から t+1 年の間に t 年のフロンティア･ラインを超えたものの t+1 年のフロンティア･ラインには達していないことを意味する(図-1 の $C_t \rightarrow C_{t+1}$ のケース)。すなわち、インプットを横軸、アウトプットを縦軸とする平面上で、上述の TECHCH との比較を行うことにより、特定の企業が GTC を達成したか、あるいは LTC を達成したかを同定することができる。

図-1. TFP の変化



3. 利用したデータと分析方法

本研究では、一定のデータを確保できる 16 業種(機械、建設、繊維製品、医薬品、電気機器、卸売業、窯業、化学、その他製品、精密機械、ゴム製品、輸送用機器、非鉄金属、食料品、パルプ･紙)の東証一部上場企業を対象として、分析を行った。

この分析で用いるデータセットは日本経済新聞社の財務データベース NEEDS から作成した。インプットとして、資本ストック、労働コスト、原材料費を用い、アウトプットとして売上高を用いた。これらのインプットとアウトプットを用いて、DDF 関数を用いることにより、企業ごとの Inefficiency を算出した。また、これらのインプットとアウトプットを用いて、Luendberger Productivity Indicator としての TFP 変化を算出した。

近年の日本企業の生産性の変化については、上記の生産性非効率性に加えて、業種別に、上述の生産性変化の指標である TECHCH と EFFCH を計算し、TFP 変化を算出した。さらに、業種別に、上述の GTC と LTC のそれぞれについて達成した企業数を同定した。これにより、2008 年から 2009 年にかけての各業種の生産性変化と、2009 年から 2010 年にかけての各業種の生産性変化について、比較検討を行った。

企業戦略と生産性の関係については、当研究所が実施している「民研調査」の 2010 年度および 2011 年度の調査結果の一部を使用した。民研調査の調査対象は、総務省が実施している「科学技術研究調査」において、研究開発を実施していると回答した資本金 1 億円以上の企業である。原則として、2010 年度調査では 2009 年度末の状況を、2011 年度調査では 2010 年度末の状況を回答していただくことになっている。2010 年度調査の調査対象企業数は 3,546 社であり、そのうち 1,268 社から回答を得ている(回収率 35.7%)。2011 年度調査の調査対象企業数は 3,380 社であり、そのうち 1,263 社から回答を得ている(回収率 37.4%)。これらの 2010 年度ならびに 2011 年度の民研調査の中で、各企業が、その主力製品・サービス分野において、開発した新製品・サービスからの利益を確保するための種々の方法に関して、どの程度の重要性を認識しているかを問う設問があり、その回答を本研究の分析のために使用した。これは、企業における利益確保の手段 18 項目の重要性を、「1:全く重視していない」から「5:非常に重視している」までの 5 段階リッカート尺度で測定したものである。これらの 18 項目を説明変数とし、TFP 変化を被説明変数とした Tobit 回帰分析、Inefficiency を被説明変数とした Tobit 回帰分析、ならびに GTC 及び LTC の達成に影響を与える要因についての Logit 回帰分析を行った。

4. 分析結果

(1)近年の日本企業の生産性の変化

一定のデータを確保できる 16 業種(機械、建設、繊維製品、医薬品、電気機器、卸売業、窯業、化学、その他製品、精密機械、ゴム製品、輸送用機器、非鉄金属、食料品、パルプ・紙)の東証一部上場企業を対象として、業種別に、Inefficiency、TECHCH、EFFCH、ならびに TFP 変化を算出した。また、業種別に、上述の GTC と LTC のそれぞれについて、達成した企業数を同定した。

表-1 は、2008 年から 2009 年にかけて業種ごとに Inefficiency、TECHCH、EFFCH、TFP 変化、ならびに GTC 及び LTC を達成した企業数をまとめたものである。これを見ると、製造業 16 業種のうち、繊維製品を除く 15 業種について、TFP の低下が観測された。これは、2008 年 9 月に生じたリーマン・ショックが日本の製造業の生産性を低下させた可能性を示唆している。また、TFP の低下が観測された 15 業種のうち、産業全体の効率性の変化を意味する TECHCH の低下が観測されたのは 14 業種であった。このことは、2008 年から 2009 年にかけて日本の製造業における生産性が低下した要因として、個々の企業による生産性低下の影響よりも、産業全体の生産性低下の影響が大きいことを示唆している。

2009 年から 2010 年にかけて表-1 と同様に業種ごとに計測した TECHCH と EFFCH と TFP 変化、ならびに GTC 及び LTC を達成した企業数をまとめたのが表-2 である。ここでは、TFP がほとんど全ての業種で上昇していることがわかる。また、EFFCH が上昇したのは 10 業種であり、産業全体の効率性の変化を意味する TECHCH が上昇したのは 13 業種である。GTC 及び LTC を達成している企業数については、2008 年から 2009 年の結果に比べて LTC を達成した企業数は 13 業種で増加し、GTC を達成した企業数は精密機械を除く 15 業種で増加している。以上の結果から、2009 年から 2010 年にかけて観察された日本の製造業における生産性向上に、個々の企業による生産性改善の効果だけでなく、産業全体の技術進歩による生産性改善の効果が大きく寄与している可能性が示唆される。

表-1. 2008 年から 2009 年にかけての生産性変化の業種平均、GTC 及び LTC を達成した企業数

企業数	業種	GTC	LTC	TFP 変化	EFFCH	TECHCH	Inefficiency
170	機械	2	17	-0.072	-0.079	0.007	0.503
113	建設	0	10	-0.039	0.053	-0.093	0.223
37	繊維製品	4	7	0.020	-0.006	0.025	0.279
38	医薬品	2	5	-0.047	0.014	-0.061	0.274
181	電気機器	4	24	-0.010	0.005	-0.015	0.494
49	卸売業	2	3	-0.054	0.001	-0.055	0.392
48	窯業	1	3	-0.093	0.015	-0.108	0.253
159	化学	3	1	-0.072	-0.004	-0.068	0.319
60	その他製品	2	2	-0.071	-0.005	-0.066	0.246
29	精密機械	3	5	-0.045	-0.006	-0.040	0.241
16	ゴム製品	1	0	-0.135	-0.003	-0.133	0.032
57	金属製品	5	6	-0.034	0.007	-0.041	0.170
90	輸送用機器	1	17	-0.057	0.032	-0.089	0.196
27	非鉄金属	1	0	-0.161	0.001	-0.163	0.103
85	食料品	4	10	-0.053	-0.002	-0.051	0.338
15	パルプ・紙	1	0	-0.102	-0.002	-0.100	0.114

表-2. 2009 年から 2010 年にかけての生産性変化の業種平均、GTC 及び LTC を達成した企業数

企業数	業種	GTC	LTC	TFP 変化	EFFCH	TECHCH	Inefficiency
170	機械	3	9	0.026	-0.115	0.141	0.617
113	建設	4	22	-0.016	0.014	-0.029	0.209
37	繊維製品	8	4	0.132	0.008	0.125	0.271
38	医薬品	3	19	0.103	0.024	0.078	0.249
181	電気機器	7	21	0.079	-0.005	0.084	0.498
49	卸売業	5	5	0.033	0.012	0.021	0.379
48	窯業	9	12	0.052	-0.008	0.060	0.261
159	化学	9	19	0.048	-0.005	0.053	0.324
60	その他製品	5	15	0.033	0.035	-0.002	0.211
29	精密機械	2	12	0.038	0.002	0.036	0.239
16	ゴム製品	6	4	0.092	0.012	0.081	0.020
57	金属製品	11	10	0.015	0.017	-0.002	0.153
90	輸送用機器	11	29	0.068	0.001	0.067	0.194
27	非鉄金属	7	12	0.104	-0.020	0.124	0.123
85	食料品	6	18	0.016	-0.014	0.030	0.351
15	パルプ・紙	3	4	0.010	0.001	0.009	0.113

（２） 企業戦略と生産性の関係

企業戦略と生産性の関係について、当研究所が実施している「民研調査」の 2010 年度および 2011 年度の調査結果の一部を使用して、分析を行った。民研調査の中で、各企業が、その主力製品・サービス分野において、開発した新製品・サービスからの利益を確保するための種々の方法に関して、どの程度の重要性を認識しているかを問う設問があり、その回答を本研究の分析のために使用した。この設問は、企業における新製品・サービスからの利益確保の手段として、(1)特許による保護、(2)意匠・商標による保護、(3)営業秘密による保護、(4)製品・サービス設計の複雑化、(5)要素技術・プロセスのブラックボックス化、(6)外形デザイン・感性的要素による差別化、(7)製品インターフェースの工夫による使い勝手の向上、(8)生産ノウハウの保護・管理、(9)製造装置・設備等の内製化、(10)大規模な設備投資を通じたスケールメリットの実現によるコスト優位の構築、(11)早期に生産を開始し、製造ノウハウ蓄積、製造に習熟することを通じた生産コストの削減、(12)製品・サービスのすばやい市場投入による、市場の先押さえ、(13)製品・サービスの先行的な市場化による顧客との関係性の確立、(14)製品・サービスに関連するオプション品・消耗品・アフターサービス等の展開、(15)製品・サービスの規格標準化への取り組み、(16)企業及び製品・サービスのブランド力の構築・活用、(17)需要変動に柔軟に対応しうる生産システムの確立、(18)販売・サービス網の整備、という 18 項目を設定し、それぞれの重要性を、「1：全く重視していない」から「5：非常に重視している」までの 5 段階リッカート尺度で測定したものである。

（２－１） TFP 変化を被説明変数とした回帰分析

まず、生産性の成長率や生産非効率性に影響を与える企業の戦略要因について、Tobit 回帰分析を行った(本文中、Table 4)。説明変数としては、上記の 18 項目を用いた。被説明変数としては、生産性の変化(TFP 変化)を用いた。

2009 年と 2010 年の 2 年間分の全データを使用した分析モデルでは、(16)企業及び製品・サービスのブランド力の構築・活用を重視する企業ほど、そうでない企業に比べて生産性の成長率が低い傾向があることが明らかになった。ブランド力は特許や意匠・商標との関わりがある企業戦略の要素であるが、すべてを権利として保護することが難しく、生産活動に直接的に関わらない要因であることから、生産性変化への影響が小さくなっているものと考えられる。

また、(10)大規模な設備投資を通じたスケールメリットの実現によるコスト優位の構築を重視する企業ほど、そうでない企業に比べて生産性の成長率が低い傾向が見られた。スケールメリットが生産性の成長率にマイナスに寄与する結果が得られた背景には、リーマン・ショックの影響が強く関係していると考えられる。一般的にはスケールメリットの実現は収益の向上に寄与すると考え、事実、次の分析で示す通り、スケールメリットの実現によるコスト優位の構築を重視する企業は効率的であるとの結果も得られている。しかし、リーマン・ショックのような予測不能あるいは予想を大きく上回る需要変動が生じた場合、スケールメリットを実現している企業は、一方でそうした需要変動への柔軟な対応が難しくなるといった問題に直面するものと想定される。リーマン・ショック以降の大幅な景気低迷による需要減に伴い生産規模が縮小した結果として生産設備の稼働率が下がり、コストの増加や収入の減少が生じ、そのことにより生産性の成長率の低下につながった可能性が考えられる。

（２－２）　Inefficiency を被説明変数とした回帰分析

続いて、上記の 18 項目を説明変数とし、企業の生産性非効率性(Inefficiency)を被説明変数として、Tobit 回帰分析を行った(本文中、Table 5)。

(7)製品インターフェースの工夫による使い勝手の向上、(9)製造装置・設備等の内製化、(13)製品・サービスの先行的な市場化による顧客との関係性の確立、(17)需要変動に柔軟に対応しうる生産システムの確立を重視する企業ほど、業種内では非効率であることが分かる。使い勝手の向上を重視すれば製品仕様や技術の細かい変更が必要となるため、生産設備等もそれに合わせて変更を行う必要が生じる。また、製造装置・設備等の内製化や需要変動に柔軟に対応しうる生産システムの確立も、そのために一定規模の先行的な設備投資が必要となる。そのため、少なくとも短期的には生産の効率性が低下するものと考えられる。また、製品・サービスの先行的な市場化には必然的に市場の不確実性が伴い、量産リスクが大きくなると考えられる。そのため、生産量を一定程度制限し、市場による受容状況を見ながら生産活動を行うことが求められる。こうした要因が全体の非効率性につながるものと考えられる。

そうした一方で、(6)外形デザイン・感性的要素による差別化、(8)生産ノウハウの保護・管理、(10)大規模な設備投資を通じたスケールメリットの実現によるコスト優位の構築、(16)企業及び製品・サービスのブランド力の構築・活用を重視する企業ほど、そうでない企業に比べて効率的と評価されている。外形デザイン・感性的要素による差別化やブランド力の構築・活用によって、大幅な技術変更や生産設備の変更を伴わずとも競争力のある製品開発や製品の付加価値の向上が可能になる。また、生産ノウハウの保護・管理やスケールメリットの実現によるコスト優位の構築によって、より生産コストを低減させることができる。こうしたことが効率性の向上に寄与していると考えられる。

（２－３）GTC 及び LTC の達成に影響を与える要因についての回帰分析

次に GTC 及び LTC の達成に影響を与える要因について Logit 回帰による分析を行った(本文中、Table 6、Table7)。上記と同様に企業戦略の 18 項目を説明変数とし、被説明変数として GTC の達成状況および LTC の達成状況を用いた。

GTC の達成状況に影響を与える企業の戦略要因について見てみる。2009 年と 2010 年の 2 年間分の全データを使用した分析モデルでは、(8)生産ノウハウの保護・管理の重視は、企業の GTC の達成を促すことが分かる。その一方で、(17)需要変動に柔軟に対応しうる生産システムの確立を重視するほど企業の GTC の達成率が低い。以上の結果から、生産ノウハウの保護・管理や需要変動に柔軟に対応しうる生産システムの確立といった生産活動に直接的に影響する要因が GTC の達成に大きく影響する可能性が示唆される。こうした背景には、生産ノウハウの保護・管理が重視、徹底されることにより生産システムのより安定的な稼働が可能になると考えられることや、生産システムの柔軟性の追求が一面では生産システムの不安定さにつながる可能性があることなどが考えられる。ただし、本分析で使用した項目は、企業が新製品・サービスからの利益確保の手段としてどれだけ各項目を重視したかであり、各項目を実際に実施していることと重視していることでは意味合いが異なる。例えば(17)需要変動に柔軟に対応しうる生産システムの確立については、企業がまだ十分に対応できていないために重視している可能性があり、分析結果の解釈については注意が必要である。

LTC の達成状況に影響を与える企業の戦略要因としては、(15)製品・サービスの規格標準化への取り組みと、(13)製品・サービスの先行的な市場化による顧客との関係性の確立の 2 要因が挙げられる。規格標準化への取り組みは企業による LTC の達成を促すため、この要因を重視する企業は、そ

うでない企業に比べて LTC の達成率が高い。逆に、製品・サービスの先行的な市場化による顧客との関係性の確立を重視する場合、企業の LTC の達成比率は低くなる傾向がみられる。技術や製品の規格標準化が進むことで市場の安定が見込まれる。一方で、先行的な市場化は市場の不確実性が伴うことから、市場の不確実性と関連すると考えられる要因が LTC の達成に影響する可能性が考えられる。

5. まとめと課題

国レベルにおいて大きな経済的インパクトが創出されるためには、一定量のインプットに対して大きなアウトプットを生み出すことができる企業、すなわち生産性の高い企業が多数存在するような環境を整備することが望まれる。

本研究ではまず、近年の日本企業の生産性の変化を、複数の業種に関して計算し、その動向を捉えた。2008 年から 2009 年にかけては、ほとんどの業種について TFP の低下が観測された。これは、2008 年 9 月に生じたリーマン・ショックが日本の製造業の生産性を低下させた可能性を示唆している。一方、2009 年から 2010 年にかけては、TFP がほとんど全ての業種で上昇していることが明らかになった。この時期に観察された日本の製造業における生産性向上には、個々の企業による生産性改善の効果だけでなく、産業全体の技術進歩による生産性改善の効果が大きく寄与している可能性が示唆された。

次に、本研究では、どのような企業戦略をとれば生産性を向上させることができるのかを検討した。当研究所が実施している「民研調査」の 2010 年度と 2011 年度の調査結果の一部を用いて、開発した新製品・サービスから利益を確保するために企業がとっている行動が、企業の生産性にどのように影響しているのかを分析した。

企業の Inefficiency を被説明変数とした分析によると、製造装置・設備等の内製化や、需要変動に柔軟に対応しうる生産システムの確立を重視する企業ほど、他の企業と比べて非効率であることが示された。一方、生産ノウハウの保護・管理や、大規模な設備投資を通じたスケールメリットの実現によるコスト優位の構築を重視する企業ほど、他の企業と比べて効率的であることが示された。企業がスケールメリットを実現しようとすれば、それは直接的に生産量の増加につながるため、生産効率の向上につながっているものと理解できる。ただし、本分析は因果関係を明らかにするものではなく、各項目に関して企業が対処するべき問題があると考えたために、各項目を重視する姿勢がとられた可能性があり、効率性と各項目の重視度との関係についての解釈には注意が必要である。

今ここで、ある製品に対する新しい生産方法が確立されたと仮定する。この時、その企業が、製造装置・設備等の内製化や、需要変動に柔軟に対応しうる生産システムの確立をしようとすれば、そのことは、将来的な利益の獲得や、非常事態の際の利益逸失の防止にはつながるが、それらを実現するためには追加的なイノベーションの実現が必要となる。そのため、短期的に見るとそのような企業は他社と比べて非効率的となっている可能性がある。一方、その企業が当該生産方法を生産ノウハウとして保護しようとするならば、追加的なイノベーションがなされなくても実施が可能である。このため、新しい生産方法の確立後に利益を得る方法として生産ノウハウとして保護しつつ自社で用いることを選択する企業の方が、短期的な生産効率は高くなるものと考えられる。

生産ノウハウの保護・管理を重視している企業は、企業の生産性をフロンティア・ラインへと到達させる程度の生産性の変化である GTC の達成にも正の効果を持っていることが明らかになった。この

ことは、生産性のフロンティアへと自社を押し上げる動きをしている企業において生産ノウハウの保護・管理が効果的に実施されていることの顕れであると考えられる。[i]

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[i] 本分析は短期的な視点での結果であり、企業戦略と生産性についての関係を詳述するには、長期的な視点でのさらなる分析が必要である。

本文

1. Introduction

Innovation can be defined as new combinations of new or existing knowledge, resources, and equipment and can be categorized as follows: 1) the introduction of new products, 2) the introduction of new methods of production, 3) the opening of new markets, 4) the discovery of new supply sources for raw materials, and 5) the implementation of a new type of organization (Schumpeter, 1934). In this sense, technological innovation does not cover all innovation but can be considered a subgroup of innovation.

Further classification of innovation has been suggested by authors such as Utterback and Abernathy (1975), who referred to radical and incremental innovation and noted that even incremental innovation leads to productivity gains.

This paper focuses on the relationship between innovation and productivity, an area in which substantial research has been conducted, including an early study by Abernathy and Townsend (1975). Duguet (2006) concluded that only radical innovation significantly contributes to total factor productivity (TFP) growth in the French manufacturing industry. Chun and Nadiri (2008) analyzed the U.S. computer industry and found that technological changes that are associated with processes and product innovations contributes approximately 70% of TFP growth. Analyzing small and medium-sized Spanish manufacturing companies, Manez et al. (2012) found that the introduction of process innovation yields additional productivity growth. However, it remains unclear how the implementation of innovation within a corporation contributes to improvements in productivity.

This paper will clarify which innovation categories contribute to increased productivity. Given that innovation does not directly correspond to productivity growth, this paper examines how the strategic management of innovation can contribute to productivity growth. This study attempts to uncover the "missing link" between innovation and productivity growth by studying various types of profit-seeking innovation activities within corporations.

In addition to innovation, various strategic management mechanisms contribute to the competitiveness of corporations and their aims to maximize profitability. Cohen et al. (2002) suggested that patents, other legal protections, secrecy, lead time, complementary sales and service, and complementary manufacturing facilities are alternative mechanisms for the effective protection of competitive advantages gained from product/process innovation. We consider strategic management of innovation to be an additional alternative mechanism.

The protection of a newly implemented innovation by a patent provides exclusive rights to innovators and prevents others from using the same innovation. Such exclusive rights can also be obtained from the protection of a design patent and/or trademark. The time period of patent protection is limited, whereas protection by trade secret has an unlimited time period unless another organization implements the same innovation independently. If the design or architecture of a product or service is complex, then competitors are unable to replicate a similar innovation, even if the product or service is without patent protection. If the fundamental technology or production process is unknown (i.e., a black box), then competitors are prevented from implementing a similar innovation. If products are differentiated by external design or if products or services require substantial product-specific knowledge, then competitors will be unable to recognize similar profits as the original innovator. Numerous other measures also prevent competitors from imitating innovative products and thereby contribute to the profits of product creators: improvements in user convenience, including the repair and maintenance of product interfaces; the protection and proper management of production expertise; and the internalization of production and manufacturing. Innovators that are able to establish cost advantages through economies of scale can benefit from large-scale investments in equipment and increased competitiveness. Innovators that can reduce production costs by initiating the production process earlier than competitors can accumulate production expertise and knowledge ahead of competitors and can realize increased profit. Innovators that release products or services to markets earlier than competitors can attain a leading market position and be the first to establish customer relationships. This advantage can prevent competitors from occupying a significant portion of the market in the future, further maximizing innovator profit. The development of optional goods, articles of consumption, and after-sales service can contribute to innovator profit. Moreover, the standardization of products or services, the establishment and use of corporate branding and/or the branding of products or services, the construction of flexible production systems to ensure efficient responses to changes in customer demand, and the maintenance of network relationships for sales and service are also profit-maximizing measures that innovative corporations can employ.

In this study, we utilize unique data with respect to the different R&D strategies of Japanese corporations to determine which of the above-mentioned factors of strategic management relate to improvements in productivity.

2. Literature review

Existing studies that have analyzed TFP levels and firm growth rates have typically considered the influence of a macro element, such as R&D expenditure, internationalization, mergers, labor, the number of patents, machinery and equipment, innovation, and spillovers to TFP.

The influence of R&D expenditure on TFP has been analyzed using firm-level data (Mansfield, 1980; Link, 1981; Link, 1983; Griliches and Mairesse, 1990). Manufacturing in Japan has been analyzed by Odagiri (1983), Odagiri and Iwata (1986), Goto and Suzuki (1989), and Griliches and Mairesse (1990). In the works of Odagiri and Iwata (1986) and Goto and Suzuki (1989), the results indicate that R&D expenditure positively affects TFP growth. To calculate TFP, the current study uses the NEEDS financial database, which was applied to the case of *Nihon Keizai Shimbun Inc.* by Odagiri and Iwata (1986)

Fukao and Murakami (2005) investigated whether foreign-owned firms are more productive than domestically owned firms and whether firms involved in mergers and acquisitions improve their business efficiency after such transactions have occurred. The authors used micro data from 59 Japanese manufacturing firms covering the period from 1994 to 1998. The results show that foreign-owned firms had a significant positive influence and M&A with foreign firms have a positive effect on TFP levels and increased TFP rates. In addition, Fukao and Kwon (2006) measured the gap in TFP levels between a group of high-TFP (75th percentile) firms and a group of low-TFP (25th percentile) firms, and they compared the characteristics of these two groups with a t-test using the panel data of the firm levels from 1994 to 2001. The authors found that high-TFP firms typically have a lower liability/total asset ratio, greater R&D intensity, and higher levels of internationalization. However, this relationship may be the result of the high productivity in firms that are able to conduct intensive R&D and internationalize. Using firm-level panel data for the 1994-2002 period, Okudaira et al. (2013) showed that strict employment protection legislation significantly reduces a TFP in firms. In addition, Castellacci and Zheng (2010) deconstructed TFP growth into technical progress and efficiency changes by conducting a data envelopment analysis of a large sample of Norwegian manufacturing and service industry firms for the 1998-2004 period. The authors showed that TFP growth has been achieved primarily through technical progress and that technological methodologies are important determinants of firm-level productivity growth. These authors also showed that technical progress has been a more dynamic factor in Schumpeter Mark II industries, whereas efficiency change has been a more important factor in the Schumpeter Mark I[1] market.

Jung and Lee (2010) attempted to identify the determinants of TFP catch-up in Korean firms compared with those of Japanese firms using sector- and firm-level variables. The authors found that the number of patents registered/R&D expenditure, imported machinery rates, and the sales rates of the largest firms are the sector-level factor variables and that the export rate, the number of patents registered, and the wage rates are the firm-level factor variables.

Moreover, Antonelli and Scellato (2013) empirically investigated the role of knowledge interactions in the introduction of innovations through the analysis of Italian firm-level TFP measures in Italy for the period from 1996 to 2005. These authors showed that the ratio of intangible assets to tangible assets positively affects a firm's TFP. Although their study did not conduct a firm-level analysis, Bronzini and Piselli (2009) assessed the role of technological knowledge in Italian firms in enhancing TFP over the 1980-2001 period, as measured by the stock of R&D capital, the human capital, and the stock of public infrastructure. The results show that human capital has the strongest influence on productivity and that R&D activity and public infrastructure also positively affect productivity. In a study based on the Portuguese economy during the 1960-2001 period, Teixeira and Fortuna (2010) found that human capital, R&D efforts, machinery and equipment imports, royalties, and licensing imports positively influence growth. Furthermore, Quatraro (2010) showed that regional knowledge (measured by patents) had an effect on TFP growth in19 Italian regions over the period from 1981 to 2002. Other studies have also

[1] The Schumpeter Mark I is characterized by high ease of market entry, low concentration of innovative activity, and a turbulent population of new and old innovators with a significant role played by small firms. The Schumpeter Mark II is characterized by high barriers to entry for new innovators, high concentration of innovative activity, and a stable population primarily formed by large and well-established firms (Castellacci and Zheng, 2010).

shown that R&D expenditure, company size, direct foreign investment (Liu and Wang, 2003), and international trade (Souare, 2012) influence TFP growth in China and Canada.

Consideration various types of innovation, Duguet (2006) analyzed innovative inputs in French manufacturing to determine which inputs contribute to incremental and radical innovation and examined the contribution of these innovations to TFP growth at the firm level. The study showed that incremental innovation relies on the adoption of new equipment in addition to informal R&D. However, radical innovation is more dependent on spillovers than incremental innovation, and the former uses external sources of knowledge as well as knowledge that is codified in patents and licenses. The study found that only radical innovation significantly contributes to TFP growth.

In another study, Chun and Nadiri (2008) deconstructed TFP growth rate into the contribution of process and product innovation and scale economies. The authors reported that technological changes that are associated with process and product innovation were responsible for approximately 70% of the TFP growth in the U.S. computer industry from 1978 to 1999, whereas the effect of scale economies was responsible for approximately 30% of the TFP growth. Moreover, Manez et al. (2012) tested whether process innovation enhanced productivity in small and medium enterprises using a sample of Spanish manufacturing firms for the 1991-2002 period. Based on a t-test to compare firms that did not implement any process or product innovation (non-innovators) and firms that did implement process innovation (process innovators), the results showed that non-innovators exhibited lower TFP than process innovators. The results also showed that the introduction of process innovation yields additional productivity growth and that the life span consists of only one period. Although their study was not a firm-level analysis, Den Butter et al. (2008) showed that innovations that lower transaction costs (i.e., trade innovations) and R&D stock had a significantly positive contribution to TFP growth from 1950 to 1992 in the Netherlands.

In summary, although the existing literature analyzes the factors that contribute to TFP levels or growth, it remains unclear how the following micro-strategic decision-making factors of firms are associated with TFP: scale merit, branding (corporate and/or product or service), production expertise, and product/service standardization. Hence, this study focuses on important new product and service productivity factors that drive profit. Therefore, this study contributes to existing research by clarifying the extent to which innovation strategies influence productivity and profit.

3. Methodology

3.1. Productive inefficiency evaluation under convex and non-convex assumptions

There is significant debate surrounding the shape of the production function that should be analyzed (Kerstens and Managi, 2012). The choice between non-convexity and convexity in measuring TFP change relates to the nature of technological progress. One non-convex specification of production technology (NCP) is the non-convex Free Disposable Hull model (introduced by Deprins et al., 1984). The NCP model has the advantage of eventually allowing for local rather than global technological change (see, e.g., the discussion in Tulkens, 1993). Although this distinction between local and global technological change plays a role in some theoretical work (e.g., Atkinson and Stiglitz, 1969), only a few studies have analyzed this issue empirically (e.g., Kerstens and Managi, 2012).

We measure productivity change by examining relative productivity among Japanese manufacturing firms using a directional distance function (DDF). The CP formulation calculating the distance function for firm k can be computed using the following optimization problem:

$$\mathrm{D}_{cp}(x_k^n, y_k^m) = Maximize\ \beta_k^{cp} \tag{1}$$

subject to
$$\textstyle\sum_j^J \lambda_j y_j^m \geq (1+\beta_k^{cp}) y_k^m \quad m = 1, \cdots, M \tag{2}$$

$$\textstyle\sum_j^J \lambda_j x_j^n \leq (1-\beta_k^{cp}) x_k^n \quad n = 1, \cdots, N \tag{3}$$

$$\textstyle\sum_j^J \lambda_j = 1 \quad j = 1, \cdots, J \tag{4}$$

$$\lambda_j \geq 0 \quad j = 1, \cdots, J \tag{5}$$

where m is the output name, n is the input name, j is the firm name, and λ_j is the weight variable. Similarly, our NCP formulation calculates the distance function by solving the following optimization problem:

$$\mathrm{D}_{ncp}(x_k^n, y_k^m) = Maximize\ \beta_k^{ncp} \tag{6}$$

subject to
$$\textstyle\sum_j^J \lambda_j y_j^m \geq (1+\beta_k^{ncp}) y_k^m \quad m = 1, \cdots, M \tag{7}$$

$$\textstyle\sum_j^J \lambda_j x_j^n \leq (1-\beta_k^{ncp}) x_k^n \quad n = 1, \cdots, N \tag{8}$$

$$\textstyle\sum_j^J \lambda_j = 1 \quad j = 1, \cdots, J \tag{9}$$

$$\lambda_j \in \{0,1\} \quad j \tag{10}$$

$$\lambda_j \geq 0 \quad j = 1, \cdots, J \tag{11}$$

This algorithm highlights a difference between convex and non-convex methodologies. The role of the integrality constraint is especially important to recognize a relationship of dominance between observed products. An observation may be declared efficient and may be considered to be part of the boundary of the reference technology if it is un-dominated. However, in other cases, an observation may be declared inefficient (i.e., it lies in the interior of the technology) if it is dominated by at least one other observation. In the latter case, the mixed integer program identifies a dominating observation that serves as a reference because it corresponds to the maximum of the computed efficiency measure.

In contrast, the programs that are used in the convex case compute the distance to the frontier of a convex envelope of the data. Although dominance also plays a role in identifying this envelope, the additional requirement of convexity introduces the possibility that un-dominated observations can be found inefficient because they do not lie in the convex envelope of the data. Empirical studies that have employed the distance function model have typically assumed either constant returns to scale (CRSs) or variable returns to scale (VRSs). In this study, we assume that VRSs capture the firm scale effect.

3.2. Luenberger Productivity Indicator

The TFP is computed with the results of the distance function model and is derived as follows (Chambers et al., 1998):

$$\mathrm{TFP}_t^{t+1} = \mathrm{TECHCH}_t^{t+1} + \mathrm{EFFCH}_t^{t+1} \quad (12)$$

$$\mathrm{TECHCH}_t^{t+1} = \frac{1}{2}\left\{\vec{D}^{t+1}(x_t, y_t) + \vec{D}^{t+1}(x_{t+1}, y_{t+1}) - \vec{D}^{t}(x_t, y_t) - \vec{D}^{t}(x_{t+1}, y_{t+1})\right\} \quad (13)$$

$$\mathrm{EFFCH}_t^{t+1} = \vec{D}^{t}(x_t, y_t) - \vec{D}^{t+1}(x_{t+1}, y_{t+1}) \quad (14)$$

where x_t represents the input for year t, x_{t+1} is the input for year t+1, y_t is the desirable output for year t, and y_{t+1} is the desirable output for year t+1. $\vec{D}^{t}(x_t, y_t)$ is the inefficiency score of year t based on the frontier curve in year t. Similarly, $\vec{D}^{t+1}(x_t, y_t)$ is the inefficiency of year t+1 based on the frontier curve in year t+1.

The TFP score indicates the productivity change relative to the benchmark year. The TFP includes all types of productivity change, which is divided into technological change (TECHCH) and efficiency change (EFFCH). TECHCH shows shifts in the production frontier, and EFFCH indicates changes in a production unit's position relative to the frontier (i.e., catching up).

3.3. Global versus local technological change in the context of convex versus non-convex technologies

Recently, Kerstens and Managi (2012) developed the identification methodology for global technological change (GTC) and local technological change (LTC) using productivity indicators. The notion of global and local technological change has been discussed following its introduction by Atkinson and Stiglitz (1969). The basic premise is that technological change may not require a global shift in production technology but may lead to local change for specific segments of production technology.

CP and NCP models impose flexible VRS assumptions. Furthermore, LTC plays a role in part of the new growth theory. LTC is known to lead to path dependency, local learning, and efficiency dynamics (see, e.g., Stiglitz, 1987; Foray, 1997; Antonelli, 2006). Local technological change explains growth, convergence clubs, and divergence in the real economy (Basu and Weil, 1998) .

First, we define GTC as that resulting from efficient observations at two time periods that do experience positive TC between these periods t and t+1 relative to CP:

$$\mathrm{GTC}_c\left((x_t,y_t)(x_{t+1},y_{t+1})\right)=\left\{D_c^t(x_t,y_t)=0+D_c^{t+1}(x_t,y_t)=0+TECHCH_c^{t,t+1}>0\right\} \quad (15)$$

Note that arguments of the proportional distance function are suppressed to condense the notation. Next, we define LTC as that resulting from efficient observations at two time periods in terms of NCP, while being inefficient w.r.t. CP that experiences positive TC in terms of NCP between two time periods:

$$\mathrm{LTC}_{nc}\left((x_t,y_t)(x_{t+1},y_{t+1})\right)=$$
$$\left\{[D_{nc}^t(x_t,y_t)=0\cap D_c^t(x_t,y_t)>0]\cap[D_{nc}^{t+1}(x_t,y_t)=0\cap D_{nc}^{t+1}(x_t,y_t)>0]\cap TECHCH_{nc}^{t,t+1}>0\right\} \quad (16)$$

It is easier to follow the conditions in (16) than to satisfy the conditions in (15). However, it is not possible to abandon the efficiency requirement altogether because otherwise no global versus local distinction could be maintained. Both global and local are defined without recourse to a mathematical distance metric.

4. Data

The capital stock, labor cost, and material costs were used in the DDF model as inputs, and sales was used as the output. The firm-level panel data that were used in this paper are obtained from the "NEEDS" financial database of Nihon Keizai Shimbun Inc. The estimate of capital stock is calculated using the perpetual inventory method with a benchmark year of 1990. The capital depletion rate is 8.38%, as calculated by Hayashi and Inoue (1991), and the real price from the year 2000 is used. The nominal equipment investment and sales are made substantive using the GDP deflator of SNA from the Cabinet Office. Moreover, the labor cost (the labor and employment costs) is measured by the consumer price index that the Ministry of Internal Affairs and Communications makes public, and the intermediate is provided by the Corporate Goods Price Index from the Bank of Japan.

The firms that are used in this analysis are listed in the Tokyo Stock Exchange and represent 16 manufacturing sectors[2]. We calculate the mean TFP by industry and compare their transition and structure.

Additionally, data from fiscal year 2011 and fiscal year 2010 from the *Survey on Research Activities of Private Corporations in Japan* by the National Institute of Science and Technology Policy (NISTEP), Ministry of Education, Culture, Sports, Science and Technology (MEXT), is used in this study. The survey is unique, and our study is the first to apply this dataset. The survey was conducted among private corporations that have capital stock of at least 100 million yen and that conduct R&D activities. A total of 1,263 corporations out of 3,380 firms responded to the fiscal

[2] The 16 manufacturing industries are the following: Machinery; Construction; Textile and mill products; Medicine; Electric equipment; Wholesale trade; Ceramic products; Chemical products; Other manufacturing; Precision machinery; Rubber products; Fabricated metal products; Transportation equipment; Non-ferrous metals; Food; Pulp, paper and paper products.

year 2011 survey (the response rate was 37.4%), and a total of 1,268 out of 3,546 firms responded to the fiscal year 2010 survey (the response rate was 35.7%)[3].

The response rate by industry for the fiscal year 2011 survey is shown in Table 1. The industry with a higher response rate has a smaller number of firms in the sector. There is no remarkable difference in the industry response rate and among the firms in the sector. Therefore, we expect that responses that are specific to one industry will not bring exceptional bias to the industry-wide simple average.

Table 1. Return rate by industry for the fiscal year 2011 survey

Category of bisiness	Number of sending A	Number of response B	The response rate B/A
1 Agriculture, forestry and fisheries	8	6	75.0%
2 Mining and quarrying of stone and gravel	9	6	66.7%
3 Construction	151	89	58.9%
4 Food	230	90	39.1%
5 Textile mill products	67	20	29.9%
6 Pulp, paper, and paper products	42	12	28.6%
7 Printing and allied industries	16	6	37.5%
8 Drugs and medicines	130	40	30.8%
9 Chemical products	177	73	41.2%
10 Oils and fat products and paints	71	22	31.0%
11 Other chemical products	93	49	52.7%
12 Petroleum and coal products	29	13	44.8%
13 Plastic products, except otherwise classified	101	36	35.6%
14 Rubber products	57	15	26.3%
15 Ceramic, stone and clay products	108	46	42.6%
16 Iron and steel	80	45	56.3%
17 Non-ferrous metals and products	69	34	49.3%
18 Fabricated metal products	111	39	35.1%
19 General-purpose machinery	109	32	29.4%
20 Production machinery	301	100	33.2%
21 Business oriented machinery	140	43	30.7%
22 Electronic parts, devices and electronic circuits	144	36	25.0%
23 Electrical equipment and electric measuring instruments	60	22	36.7%
24 Other electrical machinery equipment and supplies	163	65	39.9%
25 Information and communication electronics equipment	136	45	33.1%
26 Motor vehicles, parts and accessories	146	63	43.2%
27 Other transportation equipment	33	13	39.4%
28 Other manufacturing	112	45	40.2%
29 Electricity, gas, heat supply, and water	21	16	76.2%
30 Communications	9	4	44.4%
31 Broadcasting	7	0	0.0%
32 Information service	191	48	25.1%
33 Internet based services and other data processing	9	4	44.4%
34 Transportation and postal activities	16	6	37.5%
35 Wholesale trade and retail	103	32	31.1%
36 Finance and insurance	10	2	20.0%
37 Science and development research institutes	49	15	30.6%
38 Other Professional services	23	8	34.8%
39 Other technical services	39	17	43.6%
40 Other services	10	2	20.0%
41 Others	0	4	-
Total	3380	1263	37.4%

[3] The survey does not have sample bias between responding and non-responding firms. We couldn't find statistically significant difference in sales per capita, profit per capita, and R&D expenditure per capita between them. Please refer to the appendix for more detail.

The fiscal year 2011 and 2010 surveys explore profit acquisition methods. In this study, we consider responses to the following question: "How is the enterprise recognizing the importance of some methods in appropriating profit from a new product in the core product field?" Recognition of importance was measured by a Likert scale ranging from 1 for "It is not valued at all" to 5 for "It is valued very much".

The majority of the survey questions are limited to the main category of business (the business field with the largest sales volume). This choice was made to avoid coexistence of data of various business categories from enterprise diversification. Therefore, the analytical objective in this study is limited to the activity of the main category of business in the enterprise concerned.

5. Results

The EFFCH shows the difference in efficacy between an efficient firm and an inefficient firm. The TECHCH shows the change in the production frontier constructed by sets of the most efficient firms, measured by TFP. Table 2 shows calculated inefficiency, TFP change, the number of firms that achieve the GTC, and the LTC during the period from 2008 to 2009. Table 2 also shows that a decrease in TFP was observed in approximately 15 of the 16 industries, with the exception of textiles. In fact, the Lehman shock may have decreased the productivity of the manufacturing sector in Japan. Moreover, in 14 out of 15 industries exhibiting a decrease in TFP, their TECHCH values also decreased. This result suggests that productivity in the Japanese manufacturing sector decreased between 2008 and 2009 because the productivity of the manufacturing sector as a whole decreased rather than because of decreases in the productivity of individual firms.

Table 2. Productivity change scores: 2008-2009

Number of firms	Category of business	GTC	LTC	TFP	EFFCH	TECHCH	Inefficiency
170	Machinery	2	17	-0.072	-0.079	0.007	0.503
113	Construction	0	10	-0.039	0.053	-0.093	0.223
37	Textile and mill products	4	7	0.020	-0.006	0.025	0.279
38	Medicine	2	5	-0.047	0.014	-0.061	0.274
181	Electric equipment	4	24	-0.010	0.005	-0.015	0.494
49	Wholesale trade	2	3	-0.054	0.001	-0.055	0.392
48	Ceramic products	1	3	-0.093	0.015	-0.108	0.253
159	Chemical products	3	1	-0.072	-0.004	-0.068	0.319
60	Other manufacturing	2	2	-0.071	-0.005	-0.066	0.246
29	Precision machinery	3	5	-0.045	-0.006	-0.040	0.241
16	Rubber products	1	0	-0.135	-0.003	-0.133	0.032
57	Fabricated metal products	5	6	-0.034	0.007	-0.041	0.170
90	Transportation equipment	1	17	-0.057	0.032	-0.089	0.196
27	Non-ferrous metals	1	0	-0.161	0.001	-0.163	0.103
85	Food	4	10	-0.053	-0.002	-0.051	0.338
15	Pulp, paper and paper products	1	0	-0.102	-0.002	-0.100	0.114

Table 3 shows the inefficiency, the TFP change, and the number of firms that achieved GTC and LTC during the period between 2009 and 2010. Table 3 shows that TFP increased in nearly all industries. Moreover, EFFCH increased in 10 industries, and TECHCH increased in 13 industries. In addition, there are 13 industries with an increase in the number of firms that achieved LTC and 15 industries (with the exception of precision machinery) with an increase in the number of firms that achieved GTC relative to the results observed for the 2008-2009 period. This finding suggests that manufacturing productivity increased between 2009 and 2010 not only because individual firm productivity increased but also because the productivity of the manufacturing sector as a whole benefitted from technological progress. However, there could have been a rebound influence one year following the Lehman shock.

According to Tables 2 and 3, the number of firms that achieved both GTC and LTC in the textile industry increased. This result suggests that various technological changes occurred in the Japanese textile industry. Moreover, the number of firms that achieved GTC in the metals industry increased despite the Lehman shock. This finding suggests that the metals industry maintained an increase in frontier levels. With respect to the transport equipment industry, the number of firms that achieved LTC is higher than that of other industries. This result suggests that this industry has larger R&D expenditures and more patent applications and that innovation is increasing incrementally.

Table 3. Productivity change scores: 2009-2010

Number of enterprises	Category of business	GTC	LTC	TFP	EFFCH	TECHCH	Inefficiency
170	Machinery	3	9	0.026	-0.115	0.141	0.617
113	Construction	4	22	-0.016	0.014	-0.029	0.209
37	Textile and mill products	8	4	0.132	0.008	0.125	0.271
38	Medicine	3	19	0.103	0.024	0.078	0.249
181	Electric equipment	7	21	0.079	-0.005	0.084	0.498
49	Wholesale trade	5	5	0.033	0.012	0.021	0.379
48	Ceramic products	9	12	0.052	-0.008	0.060	0.261
159	Chemical products	9	19	0.048	-0.005	0.053	0.324
60	Other manufacturing	5	15	0.033	0.035	-0.002	0.211
29	Precision machinery	2	12	0.038	0.002	0.036	0.239
16	Rubber products	6	4	0.092	0.012	0.081	0.020
57	Fabricated metal products	11	10	0.015	0.017	-0.002	0.153
90	Transportation equipment	11	29	0.068	0.001	0.067	0.194
27	Non-ferrous metals	7	12	0.104	-0.020	0.124	0.123
85	Food	6	18	0.016	-0.014	0.030	0.351
15	Pulp, paper and paper products	3	4	0.010	0.001	0.009	0.113

This study used the Tobit regression for the strategic factors of enterprises that are associated with productivity change and inefficiency. Table 4 shows the results using change in TFP as the dependent variable and using enterprise recognition of the importance of profit acquisition methods as the explanatory variable. Recognition of this importance was measured by a Likert scale ranging from 1 for "weak" to 5 for "strong".

Using pooled data from 2009 and 2010, the productivity change of enterprises that valued brand power is less than the productivity change of enterprises that did not value it. Moreover, the productivity change is less for enterprises that attach importance to the achievement of scale merit.

Table 5 shows the results when the inefficiency of the enterprise is used as the dependent variable. The results show that enterprises are more inefficient when they value 1) improvement of convenience by product interface, 2) internal production of manufacturing device and equipment, 3) establishment of relationship with customer by early commercialization, and 4) construction of flexible production system for demand change. By contrast, an enterprise is evaluated as being more efficient when it values 1) differentiation by external design and sensibility element, 2) protection and management of production know-how, 3) cost advantages by the achievement of scale merit, and 4) establishment and use of brand (corporate and/or product, service).

Table 4. The regression analysis model that employed productivity (TFP: Luenberger Productivity Indicator) change as the explanatory variable

Recognition by enterprise to importance of method of acquiring profit	Model that uses 2009 and 2010 year with pooled						Consequence analyzed by data only in 2010					
	VRS_both-oriented						VRS_both-oriented					
	Coef.	Std.Err.	t	P>|t|	[95% Conf. Interval]		Coef.	Std.Err.	t	P>|t|	[95% Conf. Interval]	
a. Protection by patent	0.000	0.005	0.030	0.975	-0.010	0.010	0.01	0.01	0.85	0.40	-0.01	0.02
b. Protection by design patent and trademark	0.006	0.005	1.250	0.211	-0.004	0.016	0.00	0.01	0.05	0.96	-0.01	0.01
c. Protection by trade secret	-0.006	0.005	-1.100	0.274	-0.016	0.005	0.00	0.01	0.13	0.90	-0.01	0.02
d. Complication of product architecture and service design	0.006	0.005	1.130	0.260	-0.004	0.015	0.00	0.01	0.75	0.45	-0.01	0.02
e. Making the “Black Box” (elemental technology and/or productive process)	0.005	0.005	1.070	0.284	-0.004	0.015	0.01	0.01	1.16	0.25	-0.01	0.02
f. Differentiation by external design and sensibility element	-0.004	0.004	-0.850	0.397	-0.012	0.005	-0.01	0.01	-1.84	0.07	-0.02	0.00
g. Improvement of convenience by product interface	0.005	0.005	0.880	0.380	-0.006	0.015	0.01	0.01	0.74	0.46	-0.01	0.02
h. Protection and management of production know-how	0.007	0.006	1.050	0.296	-0.006	0.019	0.01	0.01	1.79	0.08	-0.00	0.03
i. Internal production of manufacturing device and equipment	0.000	0.005	0.040	0.965	-0.009	0.009	-0.00	0.01	-0.04	0.97	-0.01	0.01
j. Cost advantages by achievement of scale merit	-0.008	0.004	-1.720	0.086	-0.016	0.001	-0.01	0.01	-1.65	0.10	-0.02	0.00
k. Cost reduction by early entry into production and accumulation of manufacturing know-how	-0.001	0.006	-0.130	0.895	-0.013	0.011	-0.00	0.01	-0.17	0.87	-0.02	0.01
l. Acquisition of market share by early product/service launch	-0.000	0.006	-0.060	0.953	-0.013	0.012	-0.01	0.01	-0.67	0.50	-0.02	0.01
m. Establishment of relationship with customer by early commercialization	-0.003	0.006	-0.490	0.625	-0.016	0.009	0.00	0.01	0.50	0.62	-0.01	0.02
n. Development of optional goods, articles of consumption, and after-sales service	-0.005	0.005	-1.030	0.305	-0.014	0.005	-0.01	0.01	-1.71	0.09	-0.02	0.00
o. Standardization of product/service	0.004	0.005	0.840	0.399	-0.006	0.014	0.01	0.01	1.02	0.31	-0.01	0.02
p. Establishment and use of brand (corporate and/or product, service)	-0.010	0.006	-1.740	0.083	-0.021	0.001	-0.02	0.01	-2.12	0.04	-0.03	-0.00
q. Construction of flexible production system for demand change	-0.004	0.006	-0.740	0.459	-0.015	0.007	-0.00	0.01	-0.33	0.74	-0.02	0.01
r. Maintenance of network for sales and service	0.005	0.006	0.830	0.406	-0.007	0.016	0.01	0.01	1.71	0.09	-0.00	0.03
Age dummy (2009=0 or 2010 years =1)	0.112	0.008	14.670	0.000	0.097	0.127	0.00	(omitted)				
Constant	-0.051	0.030	-1.720	0.087	-0.109	0.007	0.02	0.04	0.43	0.67	-0.06	0.10
Obj			345						175			
R2			0.422						0.14			
Adj R2			0.388						0.04			
P>F			0.000						0.15			

Table 5. The regression analysis model that employed the inefficiency of enterprise as the explanatory variable

Recognition by enterprise to importance of method of acquiring profit	Model that uses 2009 and 2010 year with pooled: VRS_both-oriented Coef.	Std.Err.	t	P>|t|	[95% Conf. Interval]		Consequence analyzed by data only in 2010: VRS_both-oriented Coef.	Std.Err.	t	P>|t|	[95% Conf. Interval]	
a. Protection by patent	-0.014	0.018	-0.770	0.442	-0.049	0.021	0.01	0.03	0.35	0.72	-0.04	0.06
b. Protection by design patent and trademark	-0.026	0.018	-1.440	0.150	-0.061	0.009	-0.04	0.03	-1.43	0.16	-0.09	0.01
c. Protection by trade secret	-0.001	0.018	-0.050	0.961	-0.037	0.035	0.01	0.03	0.47	0.64	-0.04	0.07
d. Complication of product architecture and service design	0.017	0.017	0.990	0.321	-0.017	0.051	0.04	0.02	1.58	0.12	-0.01	0.09
e. Making the “Black Box” (elemental technology and/or productive process)	-0.001	0.017	-0.060	0.952	-0.034	0.032	-0.02	0.02	-0.77	0.44	-0.07	0.03
f. Differentiation by external design and sensibility element	-0.043	0.015	-2.840	0.005	-0.073	-0.013	-0.02	0.02	-1.00	0.32	-0.06	0.02
g. Improvement of convenience by product interface	0.051	0.018	2.790	0.006	0.015	0.086	0.03	0.03	1.03	0.31	-0.03	0.08
h. Protection and management of production know-how	-0.072	0.022	-3.300	0.001	-0.115	-0.029	-0.09	0.03	-2.86	0.01	-0.15	-0.03
i. Internal production of manufacturing device and equipment	0.040	0.016	2.500	0.013	0.009	0.071	0.06	0.02	2.77	0.01	0.02	0.11
j. Cost advantages by achievement of scale merit	-0.034	0.016	-2.190	0.029	-0.064	-0.003	-0.02	0.02	-0.95	0.34	-0.07	0.02
k. Cost reduction by early entry into production and accumulation of manufacturing know-how	0.001	0.021	0.050	0.960	-0.040	0.042	-0.01	0.03	-0.21	0.83	-0.07	0.05
l. Acquisition of market share by early product/service launch	-0.012	0.022	-0.550	0.584	-0.055	0.031	-0.01	0.03	-0.49	0.63	-0.07	0.05
m. Establishment of relationship with customer by early commercialization	0.049	0.022	2.250	0.025	0.006	0.093	0.05	0.03	1.51	0.13	-0.01	0.11
n. Development of optional goods, articles of consumption, and after-sales service	0.019	0.017	1.160	0.246	-0.013	0.052	0.04	0.02	1.75	0.08	-0.01	0.09
o. Standardization of product/service	-0.027	0.017	-1.550	0.121	-0.061	0.007	-0.06	0.02	-2.23	0.03	-0.10	-0.01
p. Establishment and use of brand (corporate and/or product, service)	-0.042	0.020	-2.100	0.037	-0.081	-0.003	-0.06	0.03	-1.79	0.08	-0.12	0.01
q. Construction of flexible production system for demand change	0.044	0.020	2.230	0.027	0.005	0.082	0.04	0.03	1.54	0.13	-0.01	0.10
r. Maintenance of network for sales and service	0.018	0.020	0.880	0.378	-0.022	0.057	0.03	0.03	0.95	0.34	-0.03	0.09
Age dummy (2009=0 or 2010 years =1)	0.010	0.027	0.360	0.717	-0.043	0.062	0.00 (omitted)					
Constant	0.450	0.103	4.390	0.000	0.248	0.652	0.39	0.15	2.63	0.01	0.10	0.68
Obj				345						175		
Log likelihood				-44.575						-20.43		
Pseudo R2				0.405						0.50		
P>Chi2				0.000						0.00		

We then analyzed the factors that influenced the achievement of GTC and LTC through the Tobit regression. The dependent variables are the achievement of GTC (Table 6) and LTC (Table 7). The enterprises' recognition of the importance of methods of acquiring profit was used as the explanatory variable.

The strategic factors of the enterprises that are associated with the achievement of GTC are shown in Table 6. The data from 2009 and 2010 indicate that attaching importance to the "protection and management of production know-how" has the effect of promoting the achievement of GTC. This finding suggests that the frontier undergoes a positive shift through the protection and management of production know-how. However, this result also reveals a lower accomplishment rate of GTC by enterprises that valued the "construction of flexible production system for demand change".

According to Table 7, two strategic factors influence the achievement of LTC: the "standardization of product/service" and the "establishment of relationship with customer by early commercialization". Because approaches to standardization are associated with promoting the achievement of LTC by enterprises, the accomplishment rate of LTC by enterprises that value this factor is higher than for other enterprises. The achievement of LTC may be promoted because achievement in the direction of standardization brings incremental technological progress. Meanwhile, when firms prioritize the "establishment of relationship with customer by early commercialization", the LTC achievement levels for such enterprises tend to be lower.

In this study, we have analyzed whether the method for appropriating profit (operating income) from a newly developed product and service affects TFP growth, inefficiency, and the achievement of GTC or LTC. The results suggest that the methods that are used to achieve positive association with TFP growth and inefficiency are not only related to the achievement of GTC or LTC but also positively shift the technological frontier. The results for the protection and management of production expertise suggest that the management environment is valid as a method of increasing TFP for those firms with specific characteristics and positive shifts in the technological frontier. However, standardization is not a valid method of dramatically increasing TFP. Nevertheless, the effect accumulates so incrementally that standardization may induce incremental innovation.

Table 6. The regression analysis model that employed the achievement of GTC as the explanatory variable

Recognition by enterprise to importance of method of acquiring profit	Model that uses 2009 and 2010 year with pooled: VRS_both-oriented Coef.	Std.Err.	t	P>|t|	[95% Conf. Interval]		Consequence analyzed by data only in 2010: VRS_both-oriented Coef.	Std.Err.	t	P>|t|	[95% Conf. Interval]	
a. Protection by patent	-0.025	0.442	-0.060	0.956	-0.891	0.841	-0.34	0.49	-0.70	0.48	-1.31	0.62
b. Protection by design patent and trademark	0.585	0.454	1.290	0.198	-0.305	1.474	0.59	0.46	1.30	0.19	-0.30	1.49
c. Protection by trade secret	0.213	0.456	0.470	0.640	-0.680	1.106	0.30	0.48	0.63	0.53	-0.64	1.25
d. Complication of product architecture and service design	0.151	0.397	0.380	0.703	-0.628	0.930	0.19	0.41	0.46	0.64	-0.61	0.98
e. Making the "Black Box" (elemental technology and/or productive process)	0.043	0.422	0.100	0.918	-0.783	0.869	0.16	0.44	0.36	0.72	-0.70	1.02
f. Differentiation by external design and sensibility element	0.186	0.304	0.610	0.539	-0.409	0.782	0.22	0.33	0.68	0.50	-0.42	0.86
g. Improvement of convenience by product interface	-0.321	0.477	-0.670	0.501	-1.257	0.614	-0.70	0.54	-1.30	0.20	-1.76	0.36
h. Protection and management of production know-how	0.838	0.497	1.680	0.092	-0.137	1.813	1.32	0.57	2.30	0.02	0.20	2.44
i. Internal production of manufacturing device and equipment	-0.553	0.371	-1.490	0.136	-1.280	0.173	-0.95	0.43	-2.21	0.03	-1.78	-0.11
j. Cost advantages by achievement of scale merit	0.356	0.377	0.940	0.345	-0.382	1.094	0.21	0.40	0.53	0.60	-0.58	1.01
k. Cost reduction by early entry into production and accumulation of manufacturing know-how	-0.149	0.463	-0.320	0.748	-1.057	0.759	-0.38	0.49	-0.78	0.44	-1.34	0.58
l. Acquisition of market share by early product/service launch	0.322	0.436	0.740	0.460	-0.533	1.177	0.16	0.48	0.34	0.73	-0.78	1.10
m. Establishment of relationship with customer by early commercialization	-0.402	0.462	-0.870	0.384	-1.307	0.504	-0.11	0.51	-0.22	0.82	-1.10	0.88
n. Development of optional goods, articles of consumption, and after-sales service	0.170	0.399	0.430	0.669	-0.612	0.953	0.01	0.44	0.03	0.98	-0.85	0.88
o. Standardization of product/service	0.176	0.424	0.420	0.677	-0.654	1.006	0.66	0.46	1.42	0.16	-0.25	1.57
p. Establishment and use of brand (corporate and/or product, service)	0.502	0.504	1.000	0.319	-0.485	1.490	0.01	0.54	0.01	0.99	-1.06	1.07
q. Construction of flexible production system for demand change	-1.250	0.485	-2.580	0.010	-2.201	-0.299	-1.04	0.49	-2.14	0.03	-1.99	-0.09
r. Maintenance of network for sales and service	-0.219	0.503	-0.440	0.663	-1.204	0.766	0.06	0.55	0.12	0.91	-1.01	1.13
Age dummy (2009=0 or 2010 years =1)	2.829	1.065	2.660	0.008	0.741	4.917	0.00 (omitted)					
Constant	-8.316	2.717	-3.060	0.002	-13.642	-2.990	-4.60	2.57	-1.79	0.07	-9.64	0.45
Obj			345						175			
Log likelihood			-17.453						-39.97			
Pseudo R2			0.423						0.22			
P>Chi2			0.141						0.21			

Table 7. The regression analysis model that employed the achievement of LTC as the explanatory variable

Recognition by enterprise to importance of method of acquiring profit	VRS_both-oriented						VRS_both-oriented					
	Coef.	Std.Err.	t	P>|t|	[95% Conf. Interval]		Coef.	Std.Err.	t	P>|t|	[95% Conf. Interval]	
a. Protection by patent	-0.141	0.228	-0.620	0.536	-0.588	0.306	-0.33	0.30	-1.09	0.28	-0.92	0.26
b. Protection by design patent and trademark	0.123	0.222	0.550	0.582	-0.313	0.558	0.42	0.29	1.44	0.15	-0.15	0.99
c. Protection by trade secret	-0.237	0.238	-1.000	0.319	-0.704	0.230	-0.45	0.32	-1.43	0.15	-1.08	0.17
d. Complication of product architecture and service design	-0.099	0.213	-0.460	0.643	-0.517	0.319	-0.01	0.26	-0.05	0.96	-0.53	0.50
e. Making the “Black Box” (elemental technology and/or productive process)	0.194	0.213	0.910	0.362	-0.223	0.612	0.21	0.26	0.81	0.42	-0.30	0.73
f. Differentiation by external design and sensibility element	-0.008	0.181	-0.050	0.963	-0.363	0.346	-0.22	0.23	-0.97	0.33	-0.66	0.22
g. Improvement of convenience by product interface	-0.097	0.235	-0.410	0.681	-0.558	0.365	0.03	0.30	0.09	0.93	-0.57	0.62
h. Protection and management of production know-how	0.230	0.265	0.870	0.385	-0.289	0.749	0.33	0.33	1.00	0.32	-0.31	0.96
i. Internal production of manufacturing device and equipment	-0.215	0.199	-1.080	0.279	-0.605	0.175	-0.46	0.26	-1.76	0.08	-0.97	0.05
j. Cost advantages by achievement of scale merit	0.289	0.200	1.440	0.149	-0.103	0.680	0.31	0.25	1.24	0.21	-0.18	0.81
k. Cost reduction by early entry into production and accumulation of manufacturing know-how	-0.151	0.259	-0.580	0.561	-0.658	0.357	-0.27	0.33	-0.83	0.41	-0.91	0.37
l. Acquisition of market share by early product/service launch	0.235	0.274	0.860	0.390	-0.302	0.772	0.45	0.34	1.35	0.18	-0.21	1.11
m. Establishment of relationship with customer by early commercialization	-0.832	0.288	-2.890	0.004	-1.398	-0.267	-0.81	0.35	-2.29	0.02	-1.50	-0.12
n. Development of optional goods, articles of consumption, and after-sales service	0.188	0.208	0.900	0.367	-0.220	0.597	0.26	0.27	0.98	0.33	-0.26	0.79
o. Standardization of product/service	0.836	0.242	3.460	0.001	0.363	1.309	0.95	0.30	3.16	0.00	0.36	1.54
p. Establishment and use of brand (corporate and/or product, service)	-0.197	0.252	-0.780	0.434	-0.691	0.297	-0.37	0.33	-1.12	0.26	-1.02	0.28
q. Construction of flexible production system for demand change	0.229	0.251	0.910	0.362	-0.264	0.722	0.53	0.31	1.69	0.09	-0.08	1.14
r. Maintenance of network for sales and service	-0.109	0.258	-0.420	0.672	-0.614	0.396	-0.26	0.34	-0.77	0.44	-0.93	0.41
Age dummy (2009=0 or 2010 years =1)	1.418	0.361	3.920	0.000	0.709	2.126	0.00 (omitted)					
Constant	-3.231	1.282	-2.520	0.012	-5.744	-0.717	-2.16	1.57	-1.37	0.17	-5.25	0.92
Obj			345						175			
Log likelihood			-46.104						-78.23			
Pseudo R2			0.288						0.16			
P>Chi2			0.007						0.05			

6. Conclusions and Discussions

This study examined the relationship between innovation and productivity using R&D activity data from Japanese corporations to analyze which strategic management factors are associated with improvements in productivity.

The study is unique because it applies the *Survey on Research Activities of Private Corporations in Japan* from fiscal years 2011 and 2010. We measured the efficiency change (EFFCH), which shows the difference in efficacy between efficient and inefficient firms; measured the technological change (TECHCH), which is the change in the production frontier constructed by sets of the most efficient firms; and measured the TFP change.

During 2008 and 2009, a decrease in TFP was found in nearly all industries, implying that the Lehman shock triggered in September 2008 was associated with a decline in manufacturing productivity. By contrast, during 2009 and 2010, an increase in TFP was found in nearly all industries, implying that the productivity of the Japanese manufacturing sector increased between 2009 and 2010.

We then analyzed the relationship between corporate strategies for obtaining profit from innovation and productivity. Compared with other industry firms, firms that considered the "internal production of manufacturing device and equipment" or the "construction of flexible production system for demand change" to be important corporate strategies for increasing profit from innovation were found to be more inefficient. However, firms that considered the "protection and management of production know-how" or "cost advantages by achievement of scale merit" to be important strategies were revealed to be more efficient than other industry firms. When a corporation strives to achieve scale merit, this pursuit directly increases production levels. Therefore, a corporate strategy that implements scale merit contributes to achieving productivity.

The establishing of new production methods, attempts to achieve "internal production of manufacturing device and equipment", and the "construction of flexible production system for demand change" could be rational corporate strategies for generating future profit. However, additional innovation would be required to implement these methods, which may appear to be inefficient in the short term. Nevertheless, a firm could protect new methods of production without additional innovation. Therefore, the "internal production of manufacturing devices and equipment" and the "construction of flexible production system for demand change" are related to production inefficiency, whereas the "protection and management of production know-how" is related to increased productivity.

Studying the corporate strategies that influence the achievement of GTC, we found that the "protection and management of production know-how" had the effect of promoting the achievement of GTC. Firms that valued the "construction of flexible production system for demand change" showed a lower GTC accomplishment rate. The results pertaining to the protection and management of production know-how suggest that the management environment is valid as a method of increasing TFP for those firms with specific characteristics and positive shifts in the technological frontier.

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Appendix 1

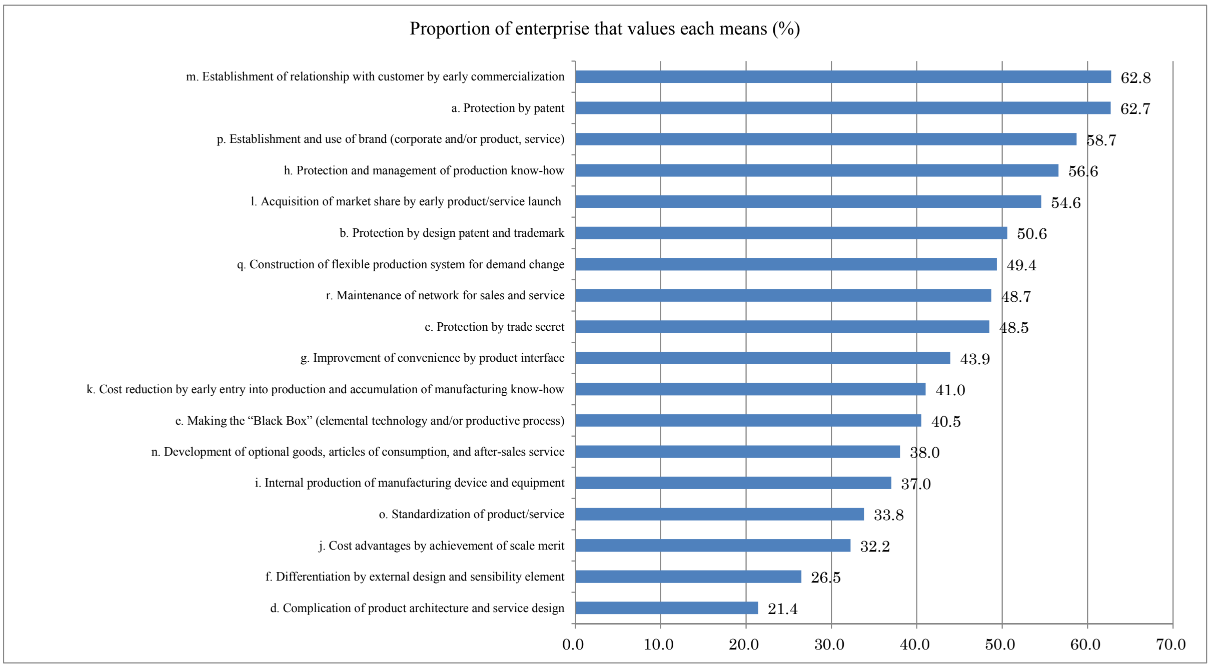
Strategies to secure profit from new products and services

In the "Survey on Research Activities of Private Corporations Report 2011", the methods that firms use to appropriate profit from the innovation of products and services are sought with confidentiality assured for firm names. We reveal the 18 strategies that were used to obtain profit by developing new products and services. For each question, importance is rated on a scale from 1 for "Do not value it at all" to 5 for "Value it very much" in the field of bread-and-butter products and services. Table A1 shows the distributions and summaries. The results reveal that the most important strategies for appropriating profit are "protection by patent" (4.0), "establishment of relationship with customer by early commercialization" (3.9), and the "protection and management of production know-how" (3.9). Figure A1 shows the ratio of firms that scored four points or more.

Table A1. How firms value each strategy for securing profit

	N	Mean value (five point standard)	It doesn't value it at all. 1	2	Usually 3	4	It values it very much. 5
a. Protection by patent	1046	4.0	2.1	5.1	30.1	24.1	38.6
b. Protection by design patent and trademark	1010	3.8	2.9	9.4	37.1	27.5	23.1
c. Protection by trade secret	1046	3.8	0.6	5.4	45.5	25.8	22.7
d. Complication of product architecture and service design	952	3.4	7.0	17.3	54.2	16.6	4.8
e. Making the "Black Box" (elemental technology and/or productive process)	987	3.6	3.3	12.5	43.7	25.9	14.6
f. Differentiation by external design and sensibility element	922	3.4	9.2	23.4	40.9	19.0	7.5
g. Improvement of convenience by product interface	913	3.8	3.0	9.7	43.4	32.4	11.5
h. Protection and management of production know-how	1046	3.9	0.4	4.4	38.6	33.1	23.5
i. Internal production of manufacturing device and equipment	981	3.5	5.9	16.0	41.1	26.0	11.0
j. Cost advantages by achievement of scale merit	987	3.4	7.1	21.8	38.9	23.8	8.4
k. Cost reduction by early entry into production and accumulation of manufacturing know-how	987	3.6	2.0	13.0	44.0	30.7	10.3
l. Acquisition of market share by early product/service launch	1019	3.8	0.9	7.9	36.6	37.3	17.3
m. Establishment of relationship with customer by early commercialization	1031	3.9	0.8	5.6	30.8	40.3	22.5
n. Development of optional goods, articles of consumption, and after-sales service	923	3.7	4.0	14.1	43.9	27.5	10.5
o. Standardization of product/service	967	3.5	5.0	14.0	47.3	25.3	8.5
p. Establishment and use of brand (corporate and/or product, service)	1044	3.8	1.1	5.6	34.7	40.6	18.1
q. Construction of flexible production system for demand change	1017	3.7	0.9	8.8	40.9	34.8	14.6
r. Maintenance of network for sales and service	1024	3.7	1.4	6.8	43.1	33.1	15.6

Figure A1. Proportion of firms' ideas to achieve competiveness (%)



Appendix 2

The "Survey on Research Activities of Private Corporations Report 2011" had responding and non-responding firm (response rate is 37.4%). The means of performances (sales per capita, profit per capita, and R&D expenditure per capita) between them are the following.

Table A2. Differences in the performances

	sales per capita	profit per capita	R&D per capita
responding firms	105.24	2.32	1753.74
	(33.51)	(1.10)	(101.56)
non-responding firms	74.07	-0.56	1769.61
	(20.07)	(2.04)	(112.29)
difference	-31.17	-2.87	15.87
	(36.68)	(2.80)	(166.53)

unit:million Yen
standard errors in parentheses

DISCUSSION PAPER No.102

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