JOURNAL OF PUBLIC PROCUREMENT, VOLUME 14, ISSUE 4, 483-504 WINTER 2014

# PUBLIC PROCUREMENT OF INNOVATION POLICY: COMPETITION REGULATION, MARKET STRUCTURE AND DOMINANT DESIGN

Ruyi Wan*

**ABSTRACT.** Recently, industry policy researchers have been more interested in public procurement, as a "demand side" policy approach. The mainstream exclusively targeted public procurement demand to push innovation and furthermore leads to the "first mover strategy." This paper points out that procurement decisions are likely to have a broader innovation impacts, and mostly via their influence on intermediate outcomes such as the structure of industrial competition. In this paper, the author explores the specific features of public procurement as a competition shaping instrument, and conducts an empirical study to measure the correlations among the competition regulation of procurement contracts awarding, industry competition structure and dominant design cultivation efficiency.

## INTRODUCTION

Public procurement was first introduced as an industrial policy instrument about 30 years ago (Geroski, 1990; Rothwell, 1984). And now public procurement is increasingly regarded as an important feasible instrument for furthering the goals of innovation policy (Uyarra & Flanagan, 2010). Policy aspirations in relation to public procurement of innovation (PPI) have been backed by the recommendations of a number of inquiries, reports and policy documents, especially by EU countries (Edler, Ruhland, & Hafner, 2005; Lember, Kalvet, Kattel, Penna, & Suurna, M., 2007; Rigby et al., 2012; Stern, Hellman, Rignders-Nagle, Terrell, & Astrom, 2011). In a

-----------------

** Ruyi Wan is Ph. D. student of School of Policy and Public Management, Tsinghua University; and a Visiting Fellow (2013-2014), Kennedy School of Government, Harvard University. His research interests are in industry policy and public procurement. The views in this article are not those of his organization.*

clear demonstration of the advantage of the demand-side approach, policy discussion almost invariably points to the lead market strategy (Tushman & Murmann, 1998; BMBF, 2010), which is aimed at producing a dominant design in the international marketplace (Anderson & Tushman, 1990; Utterback, 1994).

In the debate on lead market strategy and dominant design, recent research has focused increasingly on pioneering demand as a driving force of innovation and, moreover, identified as the first-mover strategy (Geroski, 1990; Frynas & Mellahi, 2006; Magee & Galinsky, 2007). Some research has tried to fill the other gaps in demand-driven policy. Rolfstam (2005) applied the theory of interactive learning (Lundvall, 1988) in order to view public procurement as a special form of user-producer interaction. After intellectual property rights (IPR) strategies had become more crucial in global technology competition, Fernando Branco (2002) took into account the influence of the adoption of technological standards and examined the relationship between procurement favouritism and the adoption of technological standards among suppliers. Increasingly, research has shown that procurement decisions are likely to have a broader impact on innovation, mostly through their influence on intermediate outcomes such as the intensity of competition, the structure of industrial competition and network effects (Cabral, Cozzi, Denicolo, Spagnolo, & Zanza, 2006; Uyarra & Flanagan, 2010).

However, despite this policy interest, there is little research that closely examines intermediate outcomes such as industrial competition, or offers any significant empirical evidence on the implementation of such policy aspirations. In this paper, this study explores the specific features of public procurement as a competition-shaping instrument, and conducts an empirical study to measure the correlations between competition regulation on awarding procurement contracts, the structure of industrial competition and dominant design cultivation efficiency.

## THEORETICAL BACKGROUND

### Dominant Design and Lead Market Strategy

Dominant design is a technology management concept to identify key technological features that become a *de facto* standard of a certain product (Anderson & Tushman, 1990; Utterback, 1994;

Christensen & Utterback, 1998). This perspective changes the way firms compete, survive and prevail. Utterback and Abernathy (1975) proposed that the early emergence of a dominant design is a major milestone in the evolution of an industry.

In the case of Internet Protocol television (IPTV), operating systems (OS), airplanes, modems, internet browsers and 3G/4G wireless services, the dominant design theory has become a cornerstone of industrial policy research. There has been an ever-growing interest from researchers into organization theory, strategic management and even technology history (Tushman & Murmann, 1998; Suarez, 2004). Many of these studies revealed that a certain cadre of early users is crucial for the emergence of a dominant design. Beise (2003, 2004) named this early-user demand as a "lead market"; this can be defined as a country where users prefer and demand a specific innovation design that not only appeals to domestic users but can be subsequently commercialized successfully in other countries as well. The technical design preferred by the lead market squeezes out designs initially preferred in other countries and becomes the globally dominant design. Innovations that have been successful among domestic users in lead markets are more likely to be adopted worldwide than are other designs preferred in other countries.

## Public Procurement as an Instrument Driving Demand

According to Beise's (2004) definition, an ideal lead market is one that can boast the following features: (1) sophistication of demand, which means sufficient demand for innovated purchases; and (2) scale of demand, which is sufficient demand for the technology on which the product is based and the services provided. Public procurement is an ideal policy tool for creating a lead market because it can secure both the scale and sophistication of demand required by such a market. On the one hand, as noted above, public procurement accounts for a large part of overall demand for goods and services. On the other hand, a good governance needs more and more sophisticated technology, which heavily relies on the public procurement. For example, increased traffic volumes require increased purchases of road cameras and electronic toll collection equipment. As a result, governments tend to be lead users or even first users in many technology industries (Dalpe, 1979).

Recent research has focused increasingly on pioneering demand as a driving force of innovation. Regular public procurement involves public agencies buying ready-made and simple products like pens and paper, for which further research and development (R&D) is required; only the price and performance of the (already existing) product is taken into consideration (Edquist, Hommen, & Tsipouri, 2000). But as regards innovation, many researchers have shown the critical role of demand as a key driver and public procurement as a key element of demand-oriented innovation policy (Edler, 2006; Edler & Georghiou, 2007). From acceptance of this role, one can imply that the impact of innovation extends to the procurement of goods and services that do not yet exist.

Indeed, innovation theory long ago revealed the influence of procurement. Nelson (1982) illustrated how innovations such as the global positioning system (GPS) and code division multiple access (CDMA) technology were driven by pioneering defence procurement. Dalpe's (1979) survey showed how the first-user influence of public procurement was widespread, including in the railway industry, broadcasting, energy, shipping and pharmaceuticals. More recently, the European Commission (2006) revealed how public procurement has had a diverse influence on the reform of information and communications (ICT) technology – from the e-ID system in Belgium and Italy, the e-document system in Austria and the e-tax system in Finland to the 24/7 public service system in Sweden and the nationwide information system for patients and hospitals in the Netherlands.

However, some researchers recently began arguing that such research pays too much attention to a limited set of examples that are not representative of the bulk of public procurement. They proposed that public procurement should first and foremost remain concerned with proximate public policy goals and that, rather than trying to co-opt public procurement into the innovation policy toolbox, policymakers should focus on promoting innovation-friendly practices across all types of procurement at all levels of governance (Uyarra & Flanagan, 2010). At the same time, some researchers argued that public procurement should have a broader influence on innovation. In those industries in which public procurement plays a role, decisions on pricing, volumes and standards all have an impact – either positive or negative – on innovation (Dalpe, 1994).

## Procurement as a Competition-Shaping Instrument

Some recent studies have tried to fill the gap in research on demand-driven policy. Rolfstam (2005) applied the theory of interactive learning (Lundvall, 1988) in order to view public procurement as a special form of user-producer interaction. He pointed out that the explicit expression and understanding of demand is the fundamental driving force of product innovation, which relies on close interaction between user and producer. After intellectual property rights (IPR) strategies had become more crucial in global technology competition, Fernando Branco (2002) took into account the influence of the adoption of technological standards and examined the relationship between procurement favouritism and the adoption of technological standards among suppliers.

As a complex instrument consisting of multiple decisions and multiple forms of intervention, procurement has varied effects on innovation. An important implication from this reality is that, regardless of whether demand-driving public procurement is explicitly oriented towards innovation, procurement decisions are likely to have an impact on innovation through their influence on intermediate outcomes such as the structure of industrial competition (Cabral et al., 2006; Uyarra & Flanagan, 2010). In this paper, the focus is on the correlation between innovation performance and the influence of public procurement on market structure.

Another incentive for carrying out research on PPI policy as a competition-shaping instrument is that international trade regulations limit the room for manoeuvring selective industrial policy. Demand-driven PPI policy is widely used in developed countries. Among developing counties, however, public procurement is often utilized as a form of domestic industry protection. But Government Procurement Agreement (GPA) rules make for a stringent procurement procedure – one that offers very limited discretion in the exceptional fields like national security, public morals, order and safety, etc. In order to adopt the GPA rules, many developing countries gradually stop trade protection, while trying to find a way out on the utilization of the exceptional rules of awarding process. However, the regulation on contract awarding process has strong impacts on the competition among suppliers.

As regards the influence of public procurement on the structure of competition, Office of Fair Trading the Office of Fair Trading (2004) revealed three types of impact: (1) Short-term effects on competition among potential suppliers – that is, on the intensity of competition among those participating in a particular tender. (2) Long-term effects on investment, innovation and competitiveness that lead to changes in market structure and technology – such changes are reflected in the level of competition at future tenders, among other things; (3) Knock-on effects on competition among other buyers, who are affected by changes in market competitiveness or technology – for example, they can benefit from or be harmed by public-sector attempts to use purchasing power to obtain better terms and conditions from suppliers.

In this empirical study, the author examined the correlations between the competition regulation on procurement contracts awarding, the structure of industrial competition and dominant design cultivation efficiency. In particular, two intermediate outcomes of the shaping of regulation by public procurement were analysed:

- The number of suppliers, which reflects the market barrier and dynamic relations between potential competitors. As Levin (1978) showed that innovation comes from the superior competitor's motivation to overcome the market barrier for late-comers.
- Market concentration, the degree of which is another widely used indicator of market structure. How market concentration influences innovation performance has been a constant major research theme (Caves & Uekusa, 1976; Shrieves, 1978; Geroski, 1990).

## METHODOLOGY

### Data

For the empirical part of this analysis, the US Federal Procurement Data System (FPDS), which provides a full range of data from federal procurement contracts, was used. In order to gain insights into how public procurement promotes the dominant design, the author particularly selected procurement contract data on automatic data processing (ADP) products – ADP is one of the most innovative fields driven by public procurement. Both the FPDS data and ADP industry are widely used in policy research. In total, 822,332 procurement contracts were selected that were concluded during the nine-year period from 2004 to 2012. From each of those contracts, The author extracted data on the following: procurement methods, contract value, product service code and supplier. Based on government agency and fiscal year, the contracts were divided into 1,113 research samples or segmented markets. In each segmented market, the following variables were calculated: competition regulation (independent variable), market structure (intermediate variable) and dominant design cultivation efficiency/innovation performance (dependent variable).

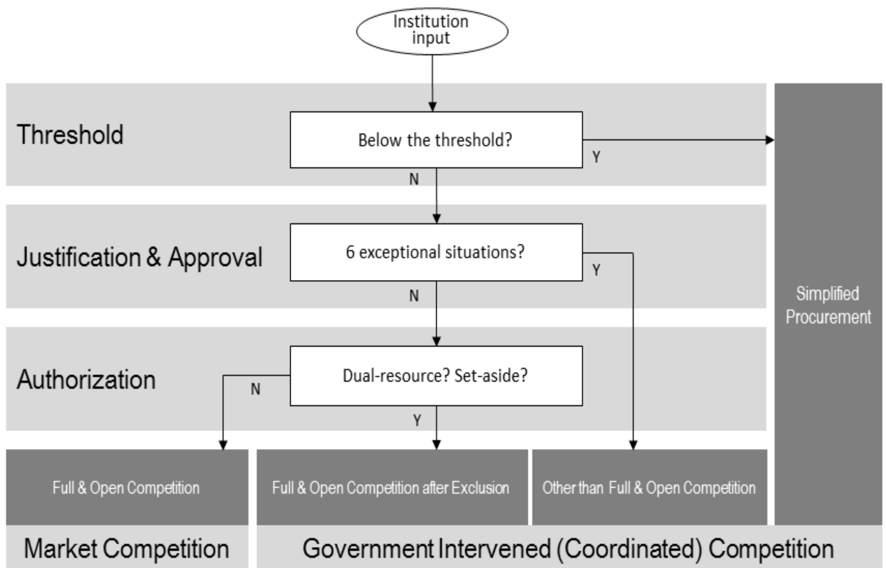
## Variables

### *Independent Variable*

Because this study was using data from US federal procurement contracts, the author analysed competition rules under the Federal Acquisition Regulation (FAR), which allows three types of competition: full and open competition; other than full and open competition; and full and open competition after exclusion of certain supplier sources. Only full and open competition is a model of market competition without any government intervention (41 U.S.C. § 403(7)); usually a sealed bidding process is used. Full and open competition after exclusion is shaped by government authorization, mainly in the form of dual-source and set-aside procurement, the latter of which is aimed at protecting small business – which is the main motor of innovation. The third type, other than full and open competition, allows procurers significant discretion in some exceptional situations, such as the mobilization of industrial resources, basic copyright protection of scientific research, sustained support for follow-up research (10 U.S.C. § 2304(d)(1)(A)-(B) & 41 U.S.C. § 253(d)(1)(A)-(B)) . Most of these exceptional uses could provide a strong boost to innovation (Figure 1).

The competitive bidding rules for public procurement constantly change in accordance with two separate institutional goals: (1) Maximizing market competition in the procurement contract bidding process to increase financial efficiency, which is known as the value for money principal, and to reduce corruption; (2) Making suitable use of the exceptional bidding rules to widely mobilize industrial resources and to safeguard public security and/or the interests of society. The ratio of three levels of competition under which procurement takes place was used in this analysis.

FIGURE 1
Federal Acquisition Regulation on Rules on Competition in Public Procurement




Source: Adopted from *Federal Acquisition Regulation* (FAR).[1]

## Intermediate Variable

As Cabral et al. (2006) have pointed out, procurement regulations are likely to have an impact on innovation through their influence on intermediate outcomes such as the intensity of competition, industrial structure and network effects. In this analysis, the intermediate outcome of competition levels was examined more closely via two intermediate variables.

### *Market Barrier*

The number of suppliers reflects the market barrier and dynamic relations between the potential competitors. As mentioned above, innovation originates from the superior competitor's motivation to build a market barrier for late comers. However, some researchers have argued that the market barrier results in a technological lock-in, which hinders sustainable innovation. In this analysis, the number of suppliers was to determine the level of market barrier.

### *Market Concentration*

The degree of market concentration is another widely used indicator of overall market structure. How market concentration impacts on innovation performance has been a constant major research theme (Caves & Uekusa, 1976; Shrieves, 1978; Geroski, 1990). For this study, the Herfindahl-Hirschman Index (HHI) was used to determine the degree of market concentration:

$$\mathrm{HHI} = \sum_{i=1}^{N} (a_i/A)^2$$

Where:
N = total number of suppliers
$a_i$ = market share of supplier i
A = overall market volume

### Dependent Variable

According to policy implication of the lead market strategy, the cultivation efficiency of the dominant design was used to determine the innovation policy performance. But it is very difficult to measure cultivation efficiency. The Gompertz curve is one of the most widely used indicators in dominant design research; it tracks the evolution of a certain product, as Figure 2 below shows (Curve III indicates the emergence of the dominant design at an earlier stage than does Curve I, while Curve II is an average trajectory). There are two possible approaches: calculate the integral value of the Gompertz curve in each 1,113 segmented procurement markets, or calculate the ratio of the first half of the Gompertz curve to the second half – namely $\alpha/\beta$ as a substitutive methods. The second substitution method was used to determine the cultivation efficiency of dominant design in the 1,113 segmented markets.

In order to calculate the ratio between the first and second halves of the Gompertz curve, one must calculate the product life cycle (PLC) distribution of the 1,113 segmented procurement markets. Among the ADP products selected for the purpose of this paper, nine are smaller classifications with the following codes: 7010, 7020, 7021, 7022, 7025, 7035, 7040, 7042 and 7050. Annual sales volumes, price and the number of suppliers were to calculate the nine PLC belongings (see Table 1 below for life cycles of the ADP products– for the author's calculation, see the Appendix).

FIGURE 2
The Gompertz Curve and a Substitution Calculation of Dominant Design Cultivation

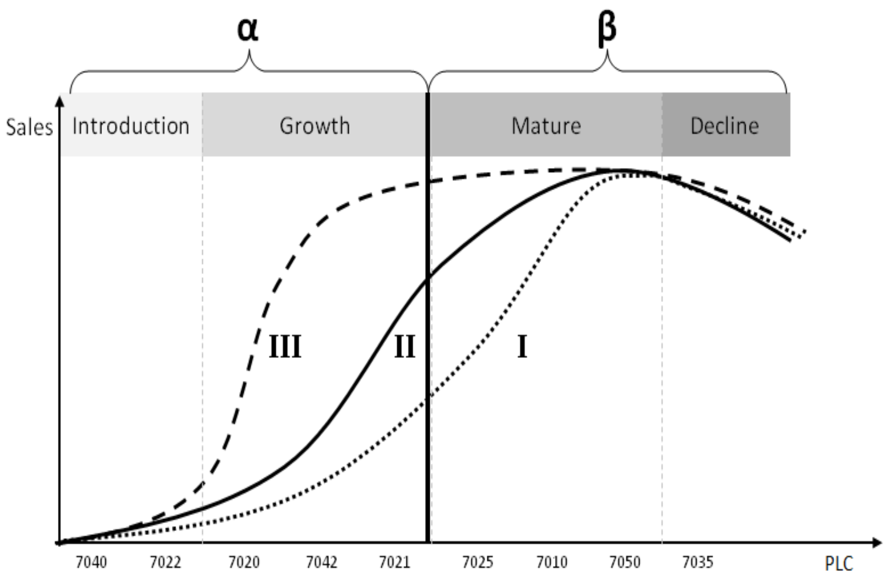



TABLE 1
Product Life Cycles of Nine ADP Products

| PLC | Product code | Annual sales* | Price* | Number of suppliers* |
|---|---|---|---|---|
| Introduction 1 | 7040 | 55 | 251291.50 | 3 |
| Introduction 2 | 7022 | 623 | 175160.38 | 6 |
| Growth 1 | 7020 | 2135 | 75666.50 | 11 |
| Growth 2 | 7042 | 2109 | 51311.83 | 11 |
| Growth 3 | 7021 | 6510 | 151243.88 | 14 |
| Mature 1 | 7025 | 9683 | 153822.74 | 29 |
| Mature 2 | 7010 | 15704 | 244562.58 | 25 |
| Mature 3 | 7050 | 9594 | 118490.74 | 29 |
| Decline 1 | 7035 | 13590 | 83265.36 | 38 |

The calculation results in Table 1 clearly show the evolution trends of the ADP products. During introduction stage, the annual sales total is very small as the new product is not well accepted by the market yet; the price is very high as the technology is still unstable and does support mass production; number of suppliers is also very small as very few producers have the production capacity. During the growth stage, annual sales climb a little as more consumers accept; price declines a little as the technology is gradually stable for mass production, the number of suppliers increases a little as the market feedback attracts some more manufacture and investors. During the mature stage, annual sales increase dramatically as the product prevails in the market; the price declines as the production scale expands quickly, the number of suppliers increases as this product has already claimed the market and been very profitable. During decline stage, technology is very mature. Thus, annual sales are still very high as the product is adopted by most consumers; the price starts to decline as oversupply; and the number of suppliers still increases as many late comers are attracted in.

### Descriptive Statistics

In our analysis, the median procurement market has 80 ADP suppliers – the maximum value is 4,532 and the minimum 1. The average HHI is 0.3349 (the HHI of the most monopolized market, with only one supplier, is 1.0 and of the most competitive market 0.03). According to our substitutive estimation method the dominant design cultivation efficiency has a wide range too – from 0.0 to 1.0 (see Table 2). Among the three levels of competition at which procurement takes place, full and open competition accounted for the largest share of total procurement contracts, followed by full and open competition after exclusion of certain supplier sources and other than full and open competition – in that order. To take into account any skewed distribution, the author used the logarithm of the number of suppliers in the regressions.

## RESULTS AND DISCUSSION

The analysis of how market structure influences dominant design cultivation efficiency (Table 3), which is an indicator of innovation policy performance proved that:

- Dominant design cultivation efficiency is positively correlated to HHI and the number of suppliers.
- The number of suppliers, which is an indicator of market barrier, has a more positive influence on dominant design cultivation efficiency than does market concentration (HHI).

TABLE 2
Descriptive Statistics of 1,113 Segmented Procurement Markets with 822,332 Contracts

| Variables | Mean | Standard deviation | Range | Minimum | Maximum |
|---|---|---|---|---|---|
| Number of suppliers | 79.84 | 333.97 | 4531 | 1 | 4532 |
| HHI | 0.3349 | 0.28222 | 0.97 | 0.03 | 1 |
| Dominant design cultivation Efficiency | 6.3107 | 12.17738 | 100 | 0 | 100 |
| FOC* (%) | 0.6447 | 0.32729 | 1 | 0 | 1 |
| Other than FOC* (%) | 0.1684 | 0.24246 | 1 | 0 | 1 |
| FOC after exc.* (%) | 0.187 | 0.26436 | 1 | 0 | 1 |

Notes: * FOC = full and open competition; Other than FOC = other than full and open competition; FOC after exc. = full and open competition after exclusion of certain supplier sources.

TABLE 3
Influence of Market Structure on Dominant Design Cultivation Efficiency

| Variables | Dominant design cultivation efficiency |
|---|---|
| HHI | .072*(.046) |
| Number of suppliers | .154**(.172) |
| Constant | .832*** |
| $R^2$ | .032 |
| Adj. $R^2$ | .024 |
| F | 3.997 |
| Number of samples | 1113 |

Notes: * Significance level of 10%; **Significance level of 5%; ***Significance level of 1%.

The first finding supports the policy approach proposed in this paper, while the second finding refers a further implication for policy implementation. A dominant design incorporates a set of key features derived from various technological innovations that have been introduced independently of one another in prior product variants, the low-entry barrier tends to attract more manufacturers as well as lead to increased knowledge about the prior products' variants. In practice, many ambitious government sectors have tried all means at their disposal to mobilize industry resources in order to enter/capture the market for a certain strategic innovation. Indeed, a procurement contract is one of the most attractive baits for capturing that market. As for market concentration, just as dominant design is the one that wins the allegiance of the marketplace, so market concentration means that the marketplace is well suited for the emergence of such a product.

The analysis of how competition regulation influences market structure (Table 4) proved that:

- HHI is negatively correlated to full and open competition but is positively correlated to the other regulation (procurement methods) shaped to a greater and lesser by the government. Furthermore, the exclusion of certain supplier sources – in itself

TABLE 4
Influence of Competition Regulation on Market Structure

| Variables | HHI | Number of suppliers |
|---|---|---|
| FOC* (%) | -.225****(-.206) | -.384***(-.144) |
| Other than FOC* (%) | .012**(.020) | .067**(.047) |
| FOC after exc.* (%) | .054**(.094) | -.178***(-.127) |
| Constant | -2.034**** | 2.513**** |
| $R^2$ | .081 | .018 |
| Adj. $R^2$ | .075 | .012 |
| F | 13.456 | 2.862 |
| Number of samples | 1113 | 1113 |

Notes: * FOC = full and open competition; Other than FOC = other than full and open competition; FOC after exc. = full and open competition after exclusion of certain supplier sources.
**Significance level of 10%; ***Significance level of 5%; ****Significance level of 1%

a strong market barrier – has a stronger influence on increasing market concentration than do the six exceptional situations;

- The number of suppliers – which is an indicator of the market barrier level – is negatively correlated to both full and open competition and the exclusion of certain supplier sources but is positively correlated to the six exceptional situations.

Based on the combined two sets of regression results, the general probability function of the "competition regulation – market structure – dominant design efficiency" model is as follows:

Dominant Design Cultivation Efficiency = 0.046 HHI + 0.172 Supplier Number + 0.832 (1)

HHI = 0.012 Other than FOC + 0.054 FOC after exc. – 0.206 FOC - 2.034 (2)

Supplier Number = -0.144 FC + 0.047 Other than FOC - 0.127 FOC after exc. + 2.513 (3)

Market competition pursues the "value for money" principle, which prioritizes expenditure efficiency and thus tends to avoid innovation because of the risks it poses. Full and open competition – as an indicator of market competition – is negatively correlated to HHI and the number of suppliers, both of which are positively correlated to dominant design cultivation. From this is the obvious inference: market competition downplays PPI policy and well-designed competition regulation helps create market structure that is crucial for dominant design cultivation. Well-designed competition regulation includes (1) Certain supplier exclusion rules, such as set-aside and dual-source procurement; (2) Certain exceptions to full and open competition to accommodate PPI policy.

## CONCLUSION

This study was conducted to analyse the effects of PPI policy – a recently revived demand-side innovation policy instrument. The effect of this instrument was judged not from the perspective of sophisticated and pioneering demand drive but from that of the influence of market structure. The goal of this study is to provide policymakers with empirical evidence on two major research questions:

- Is market structure a crucial factor in lead market strategy?
- Is public procurement an effective instrument for shaping the market structure that is necessary for the lead market strategy?

This paper will introduce the concepts of dominant design and lead market strategy, the latter of which is widely discussed in demand-side innovation policy research, and identifying two policy approaches: procurement as a demand-driving instrument and procurement as a market structure-shaping instrument. This led the author to research competition regulation on public procurement. Later an empirical analysis of 822,332 US federal procurement contracts for ADP products was conducted to examine the correlation between competition regulation and market structure, market structure and dominant design cultivation performance. The regression analysis shows that the market barrier (the number of suppliers) and market concentration (HHI) have a positive influence on dominant design cultivation. This result shows the market structure is a crucial factor of dominant design cultivation process. As regards policy, how to shape the necessary market structure should not be neglected in the policy toolbox of PPI.

Afterwards, the author examined the correlation between three different regulations on contracts awarding (procurement method) and market structure, and found that the full and open competition (FOC) method decreases both structure indicators. As regards policy, the adoption of market competition without any government intervention pursues the "value for money" principle, which prioritizes expenditure efficiency and thus tends to avoid innovation because of the risks it poses. In this way, PPI policy is downplayed in FOC method. However, two other procurement methods show the positive impact on market structure. As implied, the author suggests that well-designed competition regulation helps create the market structure that is crucial for dominant design cultivation. Such regulation includes: (1) certain supplier exclusion rules, such as set-aside and dual-source procurement; (2) certain exceptions to full and open competition to accommodate PPI policy.

As for future research, the author has at his disposal the extensive database of US federal procurement contracts, which may provide opportunities for further (fruitful) investigation. One constraint of this current analysis is that the author does not know if the various competition regulations have explicit innovation objectives since the author has no information about which exceptional situations are enforced or which supplier sources excluded under any given procurement method. For this reason, it is difficult to make specific recommendations about improving competition regulation. Furthermore, the author used a substitution method to calculate dominant design cultivation efficiency because ADP product is difficult to classify and cannot fully reflect the evolution of a certain technology. An in-depth case study of how public procurement can generate an ADP dominant design would strongly support the argument put forward in this paper. Another constraint is that the results of this current analysis are limited to the US context; comparative country studies could provide valuable new insights.

## NOTES

1. More detailed introduction can be found in Wan (2013).

## REFERENCES

Aho, E., Cornu, J., Georghiou, L., & Subira, A. (2006). *Creating an Innovative Europe* (Report by the Independent Expert Group on R&D and Innovation). Brussels, Belgium: European Commission.

Beise, M. (2004). "Lead Markets: Country-Specific Success Factors of the Global Diffusion of Innovations", *Research Policy,* 33(6–7): 997–1018.

Beise, M., Blazejczak, J., Edler, D., & Jacob, K. (2003). *The Emergence of Lead Markets for Environmental Innovations*. Berlin, Germany: Forschungsstelle für.

BMBF (German Federal Ministry of Education and Research) (2010). *Ideas, Innovation, Prosperity. High-Tech Strategy 2020 for Germany: Report*. Berlin, Germany: Author.

Cabral, L., Cozzi, G., Denicolo, V., Spagnolo, G., & Zanza, M. (2006). "Procuring Innovations." In N. Dimitri, G. Piga, & G. Spagnolo (Eds.), *Handbook of Procurement*. (pp. 483-528). Cambridge, UK: Cambridge University Press.

Dalpe R., De Bresson, C., & Hu, X. (1992). "The Public Sector as First User of Innovations." *Research Policy, 21*(3): 251–263.

Department for Innovation, Universities and Skills, (2008). "Innovation Nation White Paper" (CM7345). London, UK: Author.

Edler, J. (2006). "Demand-oriented Innovation Policy." Paper Presented at the ProACT Conference, March, Tampere, Finland.

Edler, J. & Georghiou L. (2007). "Public Procurement and Innovation — Resurrecting the Demand Side." *Research Policy, 36*: 949–963.

Edler, J., Ruhland, S., & Hafner, S. (2005). *Innovation and Public Procurement. Review of Issues at Stake, Study for the European Commission* (Final Report). Brussels, Belgium: European Commission.

Edquist, C., Hommen, L., & Tsipouri, L., J. (2000). *Public Technology Procurement and Innovation*. Paris, France: Springer Science & Business Media.

European Commission (2006). *Pre-commercial Procurement of Innovation:* Report. Brussels, Belgium: Author.

European Commission (2007). *A Lead Market Initiative for Europe*. (Research Paper). Brussels, Belgium: Author.

Frynas, J. G., Mellahi, K., & Pigman, G. A. (2006). "First-mover Advantages in International Business and Firms – Specific Political Resources." *Strategic Management* 27(4): 321–345.

Geroski, P., A. (1990), "Procurement Policy as a Tool of Industrial Policy." *International Review of Applied Economics*. *4* (2): 182–98.

Lember, V., Kalvet, T., Kattel, R., Penna, C., & Suurna, M. (2007). "Public Procurement for Innovation in the Baltic Metropolises – Case Studies." [Online]. Available at http://www.tallinn.ee/est/g2420s335192007.

Magee, J. C., & Galinsky, A. D. (2007). "Power, Propensity to Negotiate, and Moving First in Competitive Interaction", *Personality and Social Psychology Bulletin*, *33*(2): 200–212.

Nesta Policy & Research Unit (2007). "Driving Innovation Through Public Procurement." [Online]. Available at www.nesta.org.uk/l ibrary /documents/Driving-innovation-public-procurement-pb.pdf.

Office of Fair Trading (2004), *Assessing the Impact of Public Sector Procurement on Competition*: *Report*. London, UK: Author.

Organisation for Economic and Cooperation Development (2011). *Demand-Side Innovation Policy* (Research Paper). Paris, France: Author.

Rigby, J., Boekholt, P., Semple, A., Deuten, J., Apostol, R., & Corvers, S., Edler, J. (2012). *Feasibility Study on Future EU Support to Public Procurement of Innovative Solutions* (Final Report). Brussels, Belgium: European Commission. [Online]. Available at http://ec.europa.eu/enterprise/policies/innovation/policy/lead-market-initiative/files/meeting-procurement-feb2012/study-eu-support-public- procurement-innovative-solutions_en.pdf.

Rolfstam, M. (2006). "Public Procurement and Formal Institutions as External Limiting Factors of Design for Innovation: The Case of Innovative Procurement of Maritime Radio Technology." Paper Presented at the DRUID – DIME Academy Ph.D. Student Conference, January, Skørping, Denmark.

Rothwell, R. (1984), "Technology-based Small Firms and Regional Innovation Potential: The role of Public Procurement." *Journal of Public Policy, 4* (2): 307–32.

Stern, P., Hellman, J., Rignders-Nagle, M., Terrell, M., & Astrom, T., (2011). *How Public Procurement Can Stimulate Innovative Services*. [Online]. Available at www.technopolis-group.com/resources/downloads/nl/2011_Report_Public_Procurement_NICE.pdf.

Utterback, J. M. (1994). *Mastering the Dynamics of Innovation*. Cambridge MA: Harvard Business School Press.

Uyarra, E., & Flanagan, K. (2010). "Understanding the Innovation Impacts of Public Procurement." *European Planning Studies*, *18*(1): 123–43.

Wan, R. (2013). "The Competition Regulation and Exemption Rules in U.S. Federal Procurement System." *China Government Procurement Journal*, *3*: 53-59.

## APPENDIX

TABLE 5
ADP Product Distribution in 1,113 Segmented Procurement Markets

| Product code | Sample with purchase record | Sample without purchase record | Frequency |
|---|---|---|---|
| 7010 | 826 | 167 | 83.18% |
| 7020 | 501 | 492 | 50.45% |
| 7021 | 700 | 293 | 70.49% |
| 7022 | 292 | 701 | 29.41% |
| 7025 | 829 | 164 | 83.48% |
| 7035 | 960 | 33 | 96.68% |
| 7040 | 109 | 884 | 10.98% |
| 7042 | 631 | 362 | 63.54% |
| 7050 | 841 | 152 | 84.69% |

Taking the indicator "a" (annual sales) as an example, Table 6 below shows the fuzzy sets for this indicator and the corresponding membership function. The same method can be applied to the other indicators – namely, the average price and the number of suppliers.

TABLE 6
Fuzzy Sets and Membership Function of the Indicator "a" (Annual Sales)

| Fuzzy sets | Membership function of $s_i$ | | | | |
|---|---|---|---|---|---|
| $s_1$: small | $0 < x_1 \leq a_1$<br>1 | $a_1 < x_1 \leq a_2$<br>$\frac{a2 - x1}{a2 - a1}$ | $x_1 > a_2$<br>0 | | |
| $s_2$: Relatively small | $0 < x_1 \leq a_3$<br>0 | $a_3 < x_1 \leq a_4$<br>$\frac{x1 - a3}{a4 - a3}$ | $a_4 < x_1 \leq a_5$<br>1 | $a_5 < x_1 \leq a_6$<br>$\frac{a6 - x1}{a6 - a5}$ | $x_1 > a_6$<br>0 |
| $s_3$: big | $0 < x_1 \leq a_7$<br>0 | $a_7 < x_1 \leq a_8$<br>$\frac{x1 - a7}{a8 - a7}$ | $a_8 < x_1 \leq a_9$<br>1 | $a_9 < x_1 \leq a_{10}$<br>$\frac{a10 - x1}{a10 - a9}$ | $x_1 > a_{10}$<br>0 |

TABLE 6 (Continued)

| Fuzzy sets | Membership function of $s_i$ | | | | |
|---|---|---|---|---|---|
| $s_4$: very big | $0 < x_1 \leq a_{11}$<br>0 | $a_{11} < x_1 \leq a_{12}$<br>$\frac{x1 - a11}{a12 - a11}$ | $x_1 > a_{12}$<br>1 | | |

In Figure 3 below, which shows the membership interval of the indicator "a" ($a_1a_3=a_2a_3=a_2a_4=0.5*a_4a_5$, $a_{12}=7.5*a_1$), we calculate each interval as follows: $a_1=2132$, $a_2=4264$, $a_3=3198$, $a_4=5330$, $a_5=7562$, $a_6=9594$, $a_7=8528$, $a_8=10660$, $a_9=12792$, $a_{10}=14924$, $a_{11}=13858$, $a_{12}=15990$.

FIGURE 3
Membership Interval of the Indicator "a" (Annual Sales)

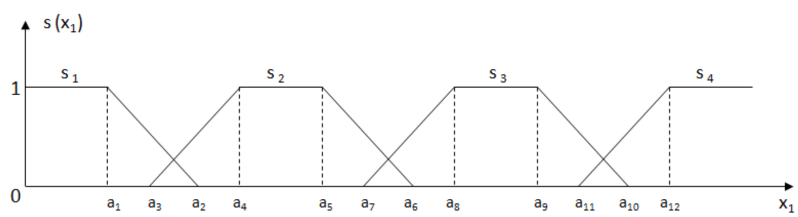



Table 7 below shows the parameter ("a" for annual sales, "b" for price, "c" for number of suppliers) and value for the each interval point of a certain parameter.

TABLE 7
Parameter and Value for Membership Function

| | | | | | | |
|---|---|---|---|---|---|---|
| Parameter | a1 | a2 | a3 | a4 | a5 | a6 |
| Value | 2132 | 4264 | 3198 | 5330 | 7462 | 9594 |
| Parameter | b1 | b2 | b3 | b4 | b5 | b6 |
| Value | 3.4 | 6.8 | 5.1 | 8.5 | 11.9 | 15.3 |
| Parameter | c1 | c2 | c3 | c4 | c5 | c6 |
| Value | 5.34 | 10.68 | 8.01 | 13.35 | 18.69 | 24.03 |
| Parameter | a7 | a8 | a9 | a10 | a11 | a12 |
| Value | 8528 | 10660 | 12792 | 14924 | 13858 | 15990 |

TABLE 7 (Continued)

| Parameter | b7 | b8 | b9 | b10 | b11 | b12 |
|---|---|---|---|---|---|---|
| Value | 13.6 | 17 | 20.4 | 23.8 | 22.1 | 25.5 |
| Parameter | c7 | c8 | c9 | c10 | c11 | c12 |
| Value | 21.36 | 26.7 | 32.04 | 37.38 | 34.71 | 40.05 |

Table 8 below shows the fuzzy result (s for annual sales, g for price, e for number of suppliers) and the value of each fuzzy sets of nine ADP classification.

TABLE 8
Fuzzy Results for the Nine ADP Classifications

| Fuzzy set | 7010 | 7020 | 7021 | 7022 | 7025 | 7035 | 7040 | 7042 | 7050 |
|---|---|---|---|---|---|---|---|---|---|
| s1 | 0 | 0.998 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| s2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| s3 | 0 | 0 | 0 | 0 | 0.542 | 0.626 | 0 | 0 | 0.500 |
| s4 | 0.866 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| g1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.500 | 0 |
| g2 | 0 | 0.735 | 0 | 0 | 0 | 0.941 | 0 | 0 | 1 |
| g3 | 0 | 0 | 0.441 | 1 | 0.529 | 0 | 0 | 0 | 0 |
| g4 | 0.706 | 0 | 0 | 0 | 0 | 0 | 0.882 | 0 | 0 |
| e1 | 0 | 0 | 0 | 0.876 | 0 | 0 | 1 | 0 | 0 |
| e2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0.562 | 0 |
| e3 | 0 | 0 | 0.075 | 0 | 1 | 0 | 0 | 0 | 1 |
| e4 | 0.682 | 0 | 0 | 0 | 0 | 0.382 | 0 | 0 | 0 |

As regards product life cycle (PLC), we define each stage as follows: (1) Introduction: annual sales small, price low or relatively low, supplier number small; (2) Growth: annual sales small or relatively small, price low or relatively low or high, supplier number relatively small or large; (3) Mature: annual sales large or very large, price relatively low or high or very high, supplier number large or very large; (4) Decline: annual sales relatively small or high, price low or relatively low, supplier number very large. The corresponding fuzzy function is shown in Table 9 below.

TABLE 9
Fuzzy Set and Membership Degree for Each PLC stage

| PLC stage | Fuzzy set | Membership degree |
|---|---|---|
| Introduction | s1 ∩ (g4 U g3) ∩ e1 | $U_{T1}$ (y) |
| Growth | (s1 U s2) ∩ (g1 U g2 U g3) ∩ (e2 U e3) | $U_{T2}$ (y) |
| Mature | (s3 U s4) ∩ (g2 U g3 U g4) ∩ (e3 U e4) | $U_{T3}$ (y) |
| Decline | (s2 U s3) ∩ (g1 U g2) ∩ e4 | $U_{T4}$ (y) |

TABLE 10
Membership Degree and Corresponding PLC Stage

| $U_T$ (y) | 7010 | 7020 | 7021 | 7022 | 7025 | 7035 | 7040 | 7042 | 7050 |
|---|---|---|---|---|---|---|---|---|---|
| Introduction | 0 | 0 | 0 | 0.876 | 0 | 0 | 0.882 | 0 | 0 |
| Growth | 0 | 0.734 | 0.033 | 0 | 0 | 0 | 0 | 0.281 | 0 |
| Mature | 0.234 | 0 | 0 | 0 | 0.287 | 0 | 0 | 0 | 0.211 |
| Decline | 0 | 0 | 0 | 0 | 0 | 0.363 | 0 | 0 | 0 |
| PLC stage | M2 | G1 | G3 | I2 | M1 | D1 | I1 | G2 | M3 |

Legends: I: introduction; G: growth; M: mature; D: decline.