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A Dynamic Price Formation System and Its Welfare Analysis in Quantity Space: An Application to Korean Fish Markets†

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I. Introduction

In the recent, policy makers are often concerned about the dynamic effects of demand behavior and its welfare analysis by quantity changes while most researches of cost-benefit analyses are concerned with the welfare effects of price changes. The current policy option of total allowable catch restrictions may be one example of those. Without demand estimates and welfare measures appropriate to those, the consumer and processor costs of policy regulations such as area closures, catch limits, and the future benefits of stock increases cannot be calculated accurately. Although recent studies by a non-negligible set of authors have made enormous progress on the role and nature of dynamics in the price formation systems, appropriate tools of their dynamic welfare measurement are hardly found in the existing literature.

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The welfare effects of quantity changes are associated with the inverse demand system in which prices play a role of marginal willingness-to-pay and depend upon their quantities demanded[1]. Quantity-based welfare measures are useful to the situations where there exist restrictions on commodity quantities such as quota systems, or transaction costs on adjustment to price changes, or production time lags, or nature of perishable and non-storable commodities. There are some limited empirical studies on consumer welfare changes in the static context, for example Rucker, Thurman, and Sumner (1995) for tobacco, Bailey and Liu (1995) for airline, Kim (1997), Park (1997), and Park et al. (2004) for fishes. To make it worse, there is no formal analysis of welfare measures pertinent to dynamic price formation systems for quantity changes.

The applications of price formation systems include studies of price formation of perishable goods, for which quantities cannot adjust in the short run. Because quantities are predetermined by production at the market level, price must adjust so that the available quantity is consumed. It has been argued that such is the case for perishable agricultural commodities and fish. The most recent advances in modeling price formation functions in a system include Barten and Bettendorf (1989) for fish, Moschini and Vissa (1993) for agriculture, Eales and Unnevehr (1994) for agricultural products, Park et al. (2004), Wong and McLauren (2005) for fish. Other applications of inverse demand include work by resource and environmental economists using inverse demands as marginal willingness-to-pay functions in order to evaluate the welfare changes from environmental quality changes (see Rosen [1974] for the seminal hedonic price model, Palmquist [1988] for recreation, Park [1997] for fish)[2].

The empirical literature on price formation systems for fish is growing and the examples include Tsoa, Schrank, and Roy (1982); Cheng and Capps (1988); Barten and Bettendorf (1989); Thurman and Easley (1992); Wessells and Wilen (1994); Wessells, Miller, and Brooks (1995); Eales, Durham, and Wessells (1997); Bishop and Holt (2002); Park et al.(2004) and more. The classical overviews of the systems are provided theoretically by Weymark (1980) and Anderson (1980).

1) Note that the ordinary demand approach inquires into the dependence of the quantities of commodities consumed on the marginal valuations of those commodities.

2) The terms "inverse demand functions" and "marginal willingness-to-pay functions" [Hicks (1956)] can be employed interchangeably. Note, however, that empirical inverse demand functions are marginal willingness-to-pay functions normalized by fixed income.

As well-established, the dynamic behavior of demand (not price formation) can be categorized into two approaches: (1) the state variable approach, (2) the intertemporal demand approach. In the state variable approach, the quantity demanded of ith good is hypothesized to be a function of physical stock or a psychological stock of habits, prices and income. Then, the dynamic demand systems are developed using the functional relation between the reference bundle and past consumption through the use of state variables. It was pioneered by Houthakker and Taylor (1970) and applied in various forms by Ray (1984, 1985), Peeters, Surry, and Cielen (1997), Holt and Goodwin (1997), Karagiannis, Katranidis, and Velentzas (2000). The second approach consists of generating rational dynamic demand systems as the solution of a constrained intertemporal utility maximization problem, where the consumer attempts to maximize a discounted utility function subject to wealth and stock constraints. It has been developed by Lluch (1974), and applied by Becker, and Murphy (1988), Becker et al. (1994), Park (2005), and Boonsaeng and Wohlgenant (2009). The differences stem from how to model the habit formation process.

The motivation of our interests in such models stem from the existence of goods for which the assumption of predetermined prices may not be viable and current supplies may be fixed because of biological, production lags or public good characteristics. Examples of such goods include nonstorable goods such as fish, recreational and environmental amenities, the existence of unique environments and endangered species, etc. Even the authors developing dynamic models did not dig into the dynamic welfare effects. This paper seeks to fill this gap in the literature and formulates a dynamic model of consumer behavior for fish, analyzing both static and dynamic welfare measures. Hence the purpose of this paper is naturally to focus on the dynamic welfare effects of fisheries regulations-those that are transmitted through changes in equilibrium ex vessel fish prices. We accomplish this by specifying a dynamic system of price formation functions for fish species in S. Korea. In a static sense, we conceive of regulations as movements along inverse demand curves, and measure their costs by surplus areas under the inverse curves.

In summary, this paper aims to propose a flexible dynamic price formation system, based on the framework advanced originally by Boonsaeng and Wohlgenant (2009) for meats. While the resulting model has a similar form of the error correction types of dynamic system, it will provide the rational dynamic behavior contrary to the myopic behavior of the latter. In addition, it is to develop analytic tools of welfare measurement appropriate for the dynamic price formation systems. A contribution of this paper, therefore, is to develop empirical methodology of specification of dynamic price formation system and static and dynamic welfare measures appropriate to the current fishery policy alternatives. Thus our research can provide the most valuable data and empirical methodology for regulatory policies to fishery managers and other related agricultural, environmental and resource managers.

The outline of this paper is as follows. In section II, we propose a dynamic price formation system from the intertemporal optimization of the consumer choice problem and provide the empirical model of a dynamic price formation system. Section III develops analytic tools of welfare measurement appropriate for the dynamic price formation systems. Section IV applies to S. Korea commercial fish demand. Section V concludes with some remark.

Ⅱ. The Model

The motivation to set up a dynamic price formation model in this section stems from the existence of nonstorable and perishable goods such as fish and some agricultural products. Many researchers report dynamic specification is needed to improve the forecasting ability and fit the data as well. Several attempts have been made to incorporate dynamics in the price formation models. Among those, one attempt is the error correction dynamic model. In this model, the adaptive adjustment mechanism has been rationalized as the optimal reaction of an agent to the adjustment costs of implementing a consumption and production plan. For a consumer, it suffices to interpret adaptive adjustment as a trade-off between the costs of not altering the utility maximizing solution and the costs of adjusting to the new position.

The error correction dynamic model is said to be a myopic model in contrast to a rational model fully consistent with a lifetime budget, in the sense that the consumer is aware of the endogenous process in which future tastes are formed[3]. The studies such as Becker and Murphy (1988), Becker et al. (1994), and Park (2005) follow the theoretical model that consumers are rational or farsighted in the sense that they anticipate the expected future consequences of their current actions. In this paper, it will be shown that the error correction dynamic demand systems from myopic utility optimization may not be worse than or distinguished from demand systems under rational habit formation, though the estimated coefficients would have different interpretations. We will see this point below.

In the intertemporal framework, the consumer choice is to find the time path q_t such that

3) In other words, it is myopic since past consumption stimulates current consumption but individuals ignore the future when making consumption decisions,

$$\text{Max.} \sum_{t=0}^{\infty} \beta^t U(q_t, s_t)$$
$$\text{s.t.} \quad \Delta s_{t+1} = F(q_t, s_t) - Ds_t$$
$$\Delta A_{t+1} = rA_t + m_t - p_t' q_t \tag{1}$$
$$s_0, A_0 \textit{ given},$$

where A is wealth, s is a stock of habits, and D is a diagonal matrix of memory loss rates (of habits). Letting F(·) $= q_t$ for simplicity, then the Hamiltonian would be:

$$H_t^* = U(q_t, s_t) + \mu_{t+1}(q_t - Ds_t) + \lambda_{t+1}(rA_t + m_t - p_t' q_t) \tag{2}$$

where μ_{t+1} is a Lagrangian multiplier for the stock constraint and λ_{t+1} is a Lagrangian multiplier for the wealth constraint. After normalizing the wealth constraint by current income (m_t), we have the following set of necessary conditions:

(a) $H_q = U_q(q_t, s_t) + \mu_{t+1} - \lambda_{t+1} v_t = 0$
(b) $\Delta\mu_{t+1} = (1 - \beta + \beta r)\lambda_{t+1} = 0$
(c) $\Delta\mu_{t+1} = -\beta U_s(q_t, s_t) + \mu_{t+1}(1 - \beta + \beta D) - \beta U_s(q_t, s_t) + \mu_{t+1}\alpha$
(d) $\Delta s_{t+1} = q_t - Ds_t$
(e) $\Delta A_{t+1}^* = rA_t^* + 1 - v_t' q_t$

where $\alpha = 1 - \beta + \text{D}$, v_t denotes a normalized price vector, and A_{t+1}^* and A_t^* are normalized wealth at time t + 1 and t, respectively.

By the mean value theorem, condition (a) may be written in the form:

$$U_{qq}\Delta q_t + U_{qs}\Delta s_t + \Delta\mu_{t+1} - \lambda_{t+1}\Delta v_t \tag{3}$$

Using conditions (c) and (d), and noting $\mu_{t+1} = \lambda v_t - U_q$ from (a), we may rewrite

$$\Delta v_t = a + \phi\Delta q_t + \phi q_{t-1} + \theta v_{t-1} + \xi s_{t-1} \tag{4}$$

where $\alpha = \dfrac{-\beta U_s - \alpha U_q}{\lambda(1-\alpha)}$, $\phi = \dfrac{U_{qq}}{\lambda(1-\alpha)}$, $\phi = \dfrac{U_{qs}}{\lambda(1-\alpha)}$, $\theta = \dfrac{\lambda\alpha}{\lambda(1-\alpha)}$, $\xi = \dfrac{-DU_{qs}}{\lambda(1-\alpha)}$

As seen in eq. (4), there is an unobservable variable, s. In order to eliminate s, we assume that the basic structural demand equation is

$$q_t = \text{K}_0 + \text{K}_1 v_t + \text{K}_2 s_t \tag{5}$$

Solving eq. (5) for s_t, we have

$$s_t = -K_2^{-1}K_0 - K_2^{-1}K_1 v_t + K_2^{-1} q_t \quad (6)$$

Lagging one period for (6) and substituting the result into (4) yields

$$\Delta v_t = \phi \Delta q_t + \theta^*[v_{t-1} - \alpha_0^* - \alpha_1^* - q_{t-1}] \quad (7)$$

where

$$\alpha_0^* = -[\alpha - \xi K_2^{-1}K_0] / [\theta - \xi K_2^{-1}K_1],\ \alpha_1^* = -[\phi + \xi K_2^{-1}] / [\theta - \xi K_2^{-1}K_1],\ \theta^* = \theta - \xi K_2^{-1}K_1.$$

When we look at (7), we may notice that it is similar to the error correction types of dynamic demand except that prices and quantities are exchanged in both sides in terms of a regression model[4]. However, there is a key difference between them. That is, all parameters in (7) include the marginal utility of wealth, λ, which subsumes all future information and acts as a summary of between-period allocation. Thus, all parameters may be reinterpreted as reflecting the behavior of a rational rather than a myopic consumer[5]. While the resulting model has a similar form of the error correction types of dynamic price formation system, it provides the rational demand behavior contrary to the myopic behavior of error correction demand models.

An empirical parameterization of the dynamic price formation system will be discussed below. There are several ways to derive the error correction form of dynamic price formation system. One way among those is to consider the behavioral equation as $v_{it} = f(q_{1t}, \ldots, q_{nt})$. Taking habit formation effects into account, we may express the behavioral equation as $v_{it} = g((q_{1t}, \ldots, q_{nt}, s_{1t}, \ldots, s_{nt})$. Assuming the following form of a structural demand function:[6]

$$v_t = F(q_t) + \alpha_s s_t \quad (8)$$

where $v_t = (v_{1t}, \ldots, v_{nt})'$, $q_t = (q_{1t}, \ldots, q_{nt})'$. Pre-multiplying (8) by q_t to obtain budget equations,

$$w_t = G(q_t) + \gamma s_t \quad (9)$$

4) Error-correction terms were used originally by Sargan (1964), Hendry and Anderson (1977), and Davidson et al. (1978).

5) Although they have different interpretations, it may be difficult to distinguish between the two models empirically. Deaton and Muellbauer (1980) notice that dynamic factor on consumer side may improve the estimates.

6) Note that this is different from the long-run equilibrium inverse demand function since it includes s_t. In the long-run, $\Delta s_t = 0$.

where $G=q'f$ and $\gamma=q'\alpha_s$. We further assume that the habit stock effects follow the first order autoregressive scheme:

$$s_t=\delta s_{t-1}+\varepsilon_t \tag{10}$$

where ε_t is a disturbance vector. Then from (9), s_t can be expressed as

$$s_t=\gamma^{-1}[w_t-G(q_t)] \tag{11}$$

Lagging one period and plugging into (10) with some manipulation, we obtain

$$\Delta w_t=\Delta G(q_t)+\theta[w_{t-1}-G(q_{t-1})]+\eta_t \tag{12}$$

where $\theta=\delta-1$ and $\eta=\gamma\varepsilon_t$. We let

$$G(q_t;A)=A_0+A_1\ln q_t+A_2\ln Q_t \tag{13}$$

where $\ln Q_t=\Sigma w_j\ln q_{jt}$, Stone′s quantity index showing scale effects analogous to income effects in the ordinary demand system and A_1 denotes the parameter matrix $[\alpha_{ij}](i,j=1,...n)$, A_2 parameter vector $(\alpha_1,..., \alpha_n)'$, A_0 constant vector $(\alpha_{01},..., \alpha_{0n})'$, A parameter matrix (A_0, A_1, A_2). Then we obtain the empirical price formation model:

$$\Delta w_t=B\Delta\ln q_t+C\Delta\ln Q_t+\theta[w_{t-1}-A_0-A_1\ln q_{t-1}-A_2\ln Q_{t-1}]+\eta_t \tag{14}$$

where B and C are some parameter matrix and vector. This is the form of an error-correction model used extensively throughout the recent time-series econometrics literature, where the bracketed terms play a role as an error correction term. For a single equation model, the error correction term has a natural interpretation even in the inverse demand context: if w_t rises above w_t^*(the desired level) by quantity changes, then the error correction term would be positive but $-A_1<0$ makes $\ln v_t$ lower toward its steady state path. A similar interpretation can be extended to the multi-equation model.

In order to derive the flexibilities, recall the behavioral equation with the expenditure share (w_{it}) expressed as a function of logarithmic quantities ($\ln q_{jt}$, $j=1,...,n$) in a market sense (see (13)). Totally differentiating (13), we obtain

$$\begin{aligned}\Delta w_{it}&=\sum_j\left(\frac{\partial w_i}{\partial\ln q_j}\right)\Delta\ln q_{ji}+\left(\frac{\partial w_i}{\partial\ln Q}\right)\Delta\ln Q_t\\&=\sum_j(\alpha_{ij}+\alpha_i w_j)\Delta\ln q_{jt}+\alpha_i\Delta\ln Q_t\end{aligned} \tag{15}$$

Using and differentiating definition of the budget shares and flexibilities and equating to (15)[7] we get the following relationships :

$$\frac{\Delta w_i}{\Delta \ln q_j} = \alpha_{ij} + \alpha_i w_j = f_{ij} w_i + w_i \delta_{ij} \tag{16}$$

$$\frac{\Delta w_i}{\Delta \ln Q} = \alpha_i = w_i f_i + w_i \tag{17}$$

where δ_{ij} is the kronecker delta ($\delta_{ij} = 1$ if $i = j$, $\delta_{ij} = 0$ otherwise). It follows that[8]

$$f_{ij} = -\delta_{ij} + \frac{\alpha_{ij} + \alpha_i w_j}{w_i} \tag{18}$$

$$f_{ij}^{*} = -\delta_{ij} + w_j + \frac{\alpha_{ij}}{w_i} \tag{19}$$

$$f_i = -1 + \frac{\alpha_i}{w_i} \tag{20}$$

There are two sets of restrictions on the parameters of (14). The first set of weak restrictions on consumer demand from the budget constraint is $\Sigma_i \alpha_{ij} = 0$(adding-up), $\Sigma_i \alpha_i = -1$(adding-up), $\Sigma_j \alpha_{ij} = 0$(homogeneity). The strong restrictions on consumer demand, following from the utility maximization, are $\alpha_{ij} = \alpha_{ji}$ (symmetry).

Ⅲ. Welfare Measurement of Dynamic Price Formation Systems in Quantity Space

1. Welfare Change Measures in Quantity Space

As Kim (1997) and Park (2004) state, the distance function is a natural tool to define welfare measures for quantity changes. As a normalized money metric utility function, we describe the consumer's preferences by $D(u,q) = 1$ where $D(u,q)$ is the distance function defined implicitly by

7) To obtain the required expression, we have used that $w_i = v_i q_i$ and $dw_i = w_i d\ln w_i$. The compensated price flexibility and the scale flexibility are defined, respectively, as:

$$f_{ij} \equiv \frac{\partial \ln v_i(q,s)}{\partial \ln q_j};\ f_i \equiv \frac{\partial \ln v_i(q,s)}{\partial \ln Q}$$

where s is the scale variable and lnQ = k implies all quantities increased by k. ,

8) The scale flexibility can be derived from the sum over j of f_{ij} in a different way. The uncompensated and compensated price flexibilities are related through the Antonelli equation analogous to the Slutsky equation.

$$D(q, u) = \text{Max}\{s|U(q/s) \geq u\} \quad (21)$$

where u is some reference utility level.

Since the consumers are presumed to face fixed quantities, the compensation required for consumers to be indifferent to arbitrary changes in their consumption bundle cannot take the form of money income. It leads to the different consideration from that in measuring welfare changes due to price changes. In the expression of distance function, we are only able to compensate consumers in the form of quantities, which are exogenous to them. Therefore, following Fare et al.(2008) and Deaton (1981), we consider scaling up the new consumption bundle until the consumer is indifferent between the compensated bundle and the initial bundle.

Using the direct utility function, the quantity-based compensating variation (QCV) may be defined implicitly by[9]

$$U\left[\frac{q^0}{D(q^0, u^*)}\right] = U\left[\frac{q^1}{D(q^1, u^1) - QCV}\right] \quad (22)$$

when $u^* = u^0$. The quantity-based compensating variation, QCV, equals how much scale to compensate to increase the new consumption bundle (q^1) until the consumer is indifferent between the compensated bundle and the initial bundle (q^0). As the inverses of indirect utility functions give expenditure functions, the inverses of direct utility functions give distance functions. Thus, setting the left-hand side of (22) to u^0, the explicit expression for QCV is given by

$$\begin{aligned} QCV &= W(q^0, q^1, u^0) = D(q^0, u^0) - D(q^1, u^0) \\ &= D(q^1, u^1) - D(q^1, u^0) \end{aligned} \quad (23)$$

Similarly, the quantity-based equivalent variation (QEV) may be defined implicitly by

$$U\left[\frac{q^0}{D(q^0, q^1) + QEV}\right] = U\left[\frac{q^1}{D(q^1, u^1)}\right] \equiv u^1 \quad (24)$$

and explicitly given by

9) The terms QCV and QEV employed in the analysis have been first used by Palmquist (1989). Hicks used compensating valuation and equivalent valuation for QCV and QEV, respectively. In the environmental economics literature, compensating surplus and equivalent surplus are frequently employed.

$$QEV = W(q^0, q^1, u^1) = D(q^0, u^1) - D(q^1, u^1)$$
$$= D(q^0, u^1) - D(q^0, u^0). \qquad (25)$$

The QEV is how much scale to take away from the consumer to reduce the initial consumption bundle (q^0) until the consumer is indifferent between the new consumption bundle and the compensated bundle. Both QEV and QCV measure the amount by which the degree of rescaling of q^0 exceeds the degree of rescaling of q^1, i.e., a quantity metric welfare affecting quantity change for q^0 to q^1. If QCV and QEV are positive, then q^0 is preferred to q^1.

The remaining work is to obtain practical approximations to the welfare change measures, the QCV and QEV, that utilize only the observed data for the two periods, i.e., (v^1, v^0, q^1, q^0). Under the assumption of optimizing behavior by consumers, we have that D (q^0, u^0) = 1 = v^0q^0 and D (q^1, u^1) = 1 = v^1q^1. First-order approximations to the unobserved terms D (·) can be obtained using Taylor′s theorem. The resulting linear approximations to the QCV and QEV are as follows. Expanding around q^0,

$$QCV = D(q^0, u^0) - D(q^1, u^0)$$
$$\cong D(q^0, u^0) - [D(q^0, u^0) + \nabla_q D(q^0, u^0)\,(q^1 - q^0)]$$
$$= v^0(q^1 - q^0). \qquad (26)$$

and similarly expanding around q^1, we obtain

$$QCV = D(q^0, u^1) - D(q^1, u^1) \cong -v^1(q^1 - q^0) \qquad (27)$$

where ∇ indicates a gradient vector. Thus, the QCV is approximately equal to the sum of the quantity changes weighted by the base period prices v^0, while the QEV is approximately equal to the sum of the quantity changes weighted by the current period prices v^1.

2. Dynamic Welfare Change Measures in Quantity Space

Given a description of lifetime preferences, one can simply calculate the lifetime welfare change using a lifetime distance function instead of a single period distance function. In our dynamic price formation model, a consumer maximizes the discounted sum of instantaneous utility in a perfect capital market subject to a wealth constraint. This research develops dynamic welfare measures analogous to those analyzed by Keen (1990) in the ordinary demand context. Although his key insight is still valid, his results and formulas cannot be adopted directly in the inverse demand context. Thus we develop an intertemporal welfare measure in a primal space as a first attempt.

1) Relationship between single period and lifetime distance functions

Suppose that a single consumer lives in a perfectly certain world for S periods, in each of which two goods are available, money and q. It is assumed that lifetime utility (U) is additive in single-period utility (u_t, $t=1,...,S$). The consumer faces prices p with lifetime wealth $M>0$ while he/she faces prices p_t with income m_t in period t. Assuming further that the rate of interest is equal to the rate of time preference, then the maximized lifetime utility U is given by

$$U=\max_{\{\alpha_t\}_{t=1}^{S}}\{\sum_t\beta_t u(q_t)\mid\sum_t\beta_t m_t=M\} \tag{28}$$

where the discount factor for period t is $\beta_t=[1/(1+r)]^{t-1}$. Using single period indirect utility functions and prices normalized by lifetime wealth, U may be redefined as

$$U=\max_{\{\alpha_t\}_{t=1}^{S}}\{\sum_t\beta_t V_t(v_t/\alpha_t)\mid\sum_t\beta_t\alpha_t=1\} \tag{29}$$

where $\alpha_t=m_t/M$, $v_t=p_t/M$, and V_t is single period indirect utility functions.

Since the indirect utility functions can be implicitly written the single period expenditure functions $e^t(v_t, u_t)=\alpha_t$ and lifetime expenditure functions $E(v, U)=1$, the single period and the lifetime distance functions (d^t and D) can be defined by[10)]

$$d(q_t, u_t)=\min_{v_t}\{v_t\, q_t\mid e^t(v_t\, u_t)=\alpha_t\} \tag{30}$$

and

$$D(q, U)=\max_{\{u_t\}_{t=1}^{S}}\{\sum_t\beta_t d(q_t, u_t)\mid s.t.\ E(v, U)=1\} \tag{31}$$

As a more suitable form to our purpose, (31) can be rewritten

$$D(q, U)=\max_{\{u_t\}_{t=1}^{S}}\{\Sigma_t\beta_t d(q_t, u_t)\ s.t.\ \Sigma_t\beta_t u_t=U \tag{32}$$

Eq. (32) shows the relationship between the lifetime and the within-period distance functions: that the lifetime distance function can be minimized only if each within-period utility (u_t) is attained at minimum indirect expenditure (d^t)[12)].

The minimized function of the above problem will give the lifetime distance function:

$$d_u(q_t, u_t)=D_U(q, U),\ t=1,...\ S \tag{33}$$

12) Note that $e^t(v_t, u_t)=\alpha_t$ is equivalent to $V_t(v_t, \alpha_t)=u_t$.

13) When it denotes a lifetime function, the time superscript will be dropped throughout.

at the optimum by the envelope theorem. Inverting the above expression, we then have for the optimal choice of u_t:

$$u_t = d_u^{-1}[q_t, D_U(q, U)] = G[q_t, D_U(q, U)] \tag{34}$$

where $G = d_u^{-1}$. The equation implies that the optimal allocation of utility at time t is a function of the quantities at time t, the quantities in all other periods, and lifetime utility.

In order to develop an exact measure of intertemporal welfare changes, we examine the derivative properties of the function G(·):

$$G_u = {}^{1}/_{d_{uu}},$$
$$G_u = -{}^{d_{uq}}/_{d_{uu}}. \tag{35}$$

Note that since the discounted sum of G(·) over time will give lifetime utility, the derivative properties of the lifetime utility are the same as above except replacing d_U by D_U.

2) Lifetime Quantity-based Welfare Measures

Suppose that a quantity restriction changes the lifetime quantity from q^0 to q^1 and lifetime wealth is not changed. It follows from (34) that for the optimal allocations for U^0 under the old and new consumption bundles,

$$u_t^0 = d_u^{-1}[q_t^0, D_U(q^0, U^0)] = G[q_t^0, D_U(q^0, U^0)],\ t = 1, \dots, S,$$
$$u_t^a = d_u^{-1}[q_t^1, D_U(q^1, U^0)] = G[q_t^1, D_U(q^1, U^0)],\ t = 1, \dots, S. \tag{36}$$

In this case, a lifetime quantity-based compensating variation (QCV) is

$$QCV = D(q^0, U^0) - D(q^1, U^0)$$
$$= \sum_t \beta_t\, [d(q_t^0, u_t^0) - d(q_t^1, u_t^a)], \tag{37}$$

where u_t^0 and u_t^a (t = 1,..., S) are the optimal allocations for U^0 defined in (36). Thus, the lifetime QCV can be related to each period QCV, QCV_t, by adding and subtracting $\Sigma_t d(q_t^1, u_t^0)$ as follows:

$$QCV = \sum_t \beta_t\, [d(q_t^0, u_t^0) - d(q_t^1, u_t^0)] + \sum_t \beta_t\, [d(q_t^1, u_t^0) - d(q_t^1, u_t^a)] \tag{38}$$

The first term is the discounted sum of QCV_t (call SQCV) and the second term comes from intertemporal substitution effects, which is the discounted sum of intertemporal (quantity-based) variation of substitution (call IQSV). Thus, the lifetime QCV is not the sum of static

QCV (QCV_t). The intertemporal variation of substitution measures the payment per dollar for reallocating utility over time in response to restriction.

Consider the approximations to IQSV to measure welfare effects empirically. Using the Taylor expansion of $d(q_t^1, u_t^0)$ around $d(q_t^1, u_t^a)$ and substituting into the second term of (38) gives a second-order approximation:[12)]

$$
\begin{aligned}
IQSV &= \sum_t \beta_t \cdot IQSV_t \\
&\cong \sum_t \beta_t d_u(q_t^1, \bar{u})\Delta u_t + 1/2, \sum_t \beta_t d_{uu}(q_t^1, \bar{u}_t)[\Delta u_t]^2 \\
&= 1/2, \sum_t \beta_t d_{uu}(q_t^1, \bar{u}_t)[\Delta u_t]^2
\end{aligned} \tag{39}
$$

where $\Delta u_t = u_t^0 - u_t^a$ and $\bar{u}_t$ lies between u_t^0 and u_t^a.

As seen above, the $IQSV_t$ has only second-order importance. However, it may be important in certain cases. Thus, it is useful to have an expression of approximation of $IQSV_t$ using solely short-run (single period) information and multi-good cases. We expand $d(q_t^1,u_t^0) = d(q_t^1, G(q_t^0, q^0, U^0))$ around $q^1 = \{q_t^1\}_{t=1,\ldots,S}$ and substitute the result into the second term inside the bracket (call $IQSV_t$) of (38) to obtain:

$$IQSV_t \cong d_u \sum_t \sum_s \left[\frac{\partial G_t}{\partial q_{is}}\right]\Delta q_{is} \tag{40}$$

where $\Delta q_t = q_t^0 - q_t^1$. Differentiating (34) with respect to q_{is} and substituting the result into (40), we obtain the following expression:

$$IQSV_t = d_u \sum_t [d_{uq_{is}}/d_{uu}]\, \Delta q_{is} + d_u/d_{uu} \sum_t \sum_s [d_{uq_{is}}]\, \Delta q_{is} \tag{41}$$

The definitions that $f_{it} = (\partial q_{it}/\partial d_t)(d_t/q_{it}) = d \cdot d_{uq_{is}}/d_u$, $(\Sigma_t k_t \sigma_t)$ $F_{is} = \sigma_s f_{is}$ (where $k = e/E$ and $F_{is} = (\partial q_{it}/\partial D)(D/q_{it})$), and the definition of the elasticity of intertemporal substitution (σ_t) lead to the following expression for one good case:[13)]

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12) Note that $D_u^t = \lambda$ (Lagrangian multiplier) and $\Sigma\beta_t\Delta u_t = 0$.

13) The elasticity of intertemporal substitution between consumption at two points in time t and s (denoted f_t) is defined as the inverse of the negative of the elasticity of marginal utility of period-t expenditure (e_t). Algebraically, it is given by

$$\phi_t(e_t) \equiv -\frac{u'(e_s)/u'(e_t)}{e_s/e_t} \quad \frac{\partial(e_s/e_t)}{\partial[u'(e_s)\ /u'(e_t)]}$$

where primes imply derivatives. Taking the limit as s converges to t gives $\phi = -u_e/u_{ee}\, e_t$ where u_e is the derivative of u with respect to e. Since marginal utility is just $1/e_u$, it can be expressed as $\phi = -[e_u]^2 / e \cdot e_{uu}$. The analogue of this denoted by σ_t is defined in a similar fashion as $\sigma = -[D_u]^2 / D \cdot D_{uu}$. It is an inverse measure of a pure scale measure of the elasticity of the marginal utility. Note that the convexity assumption implies $\sigma_t > 0$. When utility is nearly linear, the elasticity of intertemporal substitution is very large, thereby giving the large value of σ_t.

$$IQSV_t \cong \sigma_t d^t \,[f_t \Delta \log q_t - \sum_t \pi_t (f_t \Delta \log q_t)] \tag{42}$$

where $\pi_t = d^t \sigma_t / \sum_t d^t \sigma_t$ and f_t denotes a scale flexibility at time t. If we have more than one good, the expression can be extended as

$$IQSV_t \cong \sigma_t d^t \,[\, \sum_t f_{it} w_{it} \Delta \log q_t - \sum_t \pi_t (\sum_t f_{it} w_{it} \Delta \log q_{it})] \tag{43}$$

where w_i is the expenditure share for good i.

Since the sum of $IQSV_t$ (i.e., IQSV) is identically zero, we may need the second-order approximation to the lifetime IQSV. Substituting the first-order approximation of $IQSV_t$ for Δu_t ($IQSV_t[1] = d_u(\cdot)\Delta u_t$) into the second-order approximation of $IQSV_t$ yields [see the second line equation of (39) and consider its single period counterpart][14)]

$$IQSV_t[2] = IQSV_t[1] - (IQSV_t[1])^2 / 2d^t\sigma_t \tag{44}$$

and

$$IQSV = \Sigma_t \beta_t IQSV_t[2] = -\Sigma_t \beta_t (IQSV_t[1])^2 / 2d^t\sigma_t \tag{45}$$

where the numbers in the brackets indicate orders of approximation and we use Σ_t $IQSV_t[1] = 0$. Thus, the relationship shown in this section is summarized as

$$\begin{aligned} QSV &= SQCV + IQSV \\ &\cong \sum_t \beta_t [d(q_t^0, u_t^0)] - \Sigma_t \beta_t \,[IQSV_t]^2 / 2d^t\sigma_t, \end{aligned} \tag{46}$$

where $IQSV_t$ is defined in (43).

IV. An Application to Korean Fish Market Demand

1. Data Structure

In this section, the dynamic price formation system is applied to the demand for fisheries markets in S. Korea. Aggregate annual sales price and per capita consumption data were collected for six fish product categories in Korea, which are Mackerel, Jack Mackerel, Sardine, Alaska Pollack, Hair Tail, and Croaker. These data were compiled from various

14) Note that it is not an elegant second-order approximation, but a truncated second-order approximation of $IQSV_t(q_t^1, u(q^0, U^0), u(q^1, U^0))$ around q^1, omitting second derivatives of $u(q,U)$.

〈Table 1〉 The consumption ratio and consumption of sample fishes

Type of Fishes	Sample Average Share (%)	Sample Average Consumption (ton per thousand)	Total Consumption Average (ton)	Total Export Average (ton)	Total Import Average (ton)
Mackerel	10.4 %	1.205	127,804	8,172	9,831
Jack Mackerel	1.0 %	0.318	17,500	4,442	4,054
Sardine	1.6 %	1.394	48,752	2,971	2,428
Alaska Pollack	48.7 %	2.370	316,937	126,809	56,629
Hair Tail	19.1 %	0.688	108,880	9,966	1,436
Croaker	19.2 %	0.531	50,793	13,354	170

Source: Korea Rural Economic Institute 'Food Balance Sheet', annual reports, and National Federation of Fisheries Cooperatives 'Annual Statistics on Cooperative Sales of Fishery Products', annual reports.

published *'Food Balance Sheet'* (Korea Rural Economic Institute) and *'Annual Statistics on Cooperative Sales of Fishery Products'* (National Federation of Fisheries Cooperatives), which cover the period 1969 – 2006[15]. The Amount of consumption is computed by adjusting exports and imports to the total domestic amounts, i.e. the total production-export + import from Food Balance Sheet, whereas the prices are calculated by the values of sales divided by sales quantity from Annual statistics on cooperative Sales of Fishery Products. Table 1 summarizes sample average budget shares and average consumption per capita for the selected fishes[16]. As seen in Table, main fish species such as Alaska Pollack, Hair Tail, and Croaker have much higher consumption shares than those of TAC fish species, Mackerel, Jack Mackerel and Sardine. Except for Alaska Pollack, the exports and imports of other species are very mild.

2. Estimation and Results of a Dynamic Price Formation Model

In order to estimate the parameters, we modify the model in some respects. First, we add the disturbance terms to estimate (14). Second, the finite differences are used for the differentials as an approximation. The resulting equation would then be in the scalar form:

$$\Delta w_{it} = \Sigma_j b_{ij} \Delta \ln q_{jt} + c_i \Delta \ln Q_t + \lambda_i [w_{it-1} - a_{0i} - \Sigma_j a_{ij} \ln q_{jt-1} - a_i \ln Q_{t-1}] + e_{it}$$

where e_{it} is a disturbance term for ith equation at time t.

It can be estimated using a seemingly unrelated regression (SUR) procedure, which adjusts

15) Since the data was compiled from 1969 and annual data is used, we have chosen sample period from 1969 to 2006 to make as many observations as possible.

16) The basis of selection is to include TAC and main fish species from the viewpoint of consumers and our customs and culture.

for cross equation contemporaneous correlation. A budget share equation should be excluded by adding-up property. Since SUR is sensitive to the excluded equation, the procedure should be iterated. The restrictions of symmetry and homogeneity are imposed on the long-run parameters of the dynamic model, leaving non-symmetric and non-homogeneous responses in the short-run[17]. These procedures provide the one asymptotic to maximum likelihood estimation that is invariant to the equation chosen for deletion[18].

The time series properties of data should be investigated to yield reliable estimates of the demand parameters. The number of unit roots should be identified for each time series to see

⟨Table 2⟩ Tests for Unit roots and Cointegration

Variable	ADF statistic (H_0:$\gamma_i=0$)	PP statistic (H_0:$\gamma_i=0$)
w_1	3.28**	−4.31**
w_2	−2.47*	−2.55*
w_3	−3.65**	−4.00**
w_4	−2.62**	−2.63**
w_5	−3.48**	−4.00**
w_6	−4.85**	−6.03**
ln q_1	−3.54**	−5.05**
ln q_2	−2.65**	−2.40*
ln q_3	−4.42**	−5.94**
ln q_4	−3.69**	−3.48**
ln q_5	−2.57**	−2.40*
ln q_6	−4.95**	−5.31**
ln Q	−3.76**	−3.92**
Commodity	**ADF statistic (H_0:$\gamma_i=0$)**	**PP statistic (H_0:$\gamma_i=0$)**
Mackerel	−3.50**	−6.14**
Sardine	−5.60**	−4.31**
Alaska Pollak	−5.61**	−6.50**
Hair Tail	−4.44**	−4.28**
Croaker	−3.66**	−4.93**

Note : 1) Lag order for augmented DF test chosen by using the Akaike Information Criterion Test (AIC); Lag order 1 used for all the variables; Critical values of 1%, 5%, 10%: proposed by MacKinnon (1991) are −2.57, −1.94, −1.62.

2) ADF and PP regressions are in the following form: $\Delta y_t=\gamma_1 y_{t-1}+\sum_{j=1}^{p}\delta_j\Delta y_{t-1}+\mu_t$ and $\Delta y_t=\gamma_1 y_{t-1}+\mu_t$ while cointegration regressions replace y_t by ε_t for ADF and PP tests.

3) Since Jack Mackerel is dropped in estimation by singularity, it is not shown in the table.

4) *indicates the significance at 5% level and ** the significance at 1% level.

17) See Peeters, Surry, and Cielen (1997).

18) See Hayes, Wahl, and Williams (1990).

the stationarity of the dynamic process[19]. The test for cointegration consists of two steps: (1) unit root test for the variables and (2) unit root test for the residuals of the levels regressions estimated using the nonstationary variables. We tested the stationarity of all the variables such as quantities and budget shares for unit roots using the augmented Dickey-Fuller (ADF) tests and Phillips-Perron (PP) tests[20]. As in Table 2, the tests rejected the existence of unit roots in all variables at 5% significance level. Furthermore, consistency of the dynamic specification requires that all of its terms are integrated of order zero. So we tested the residuals of the estimated long-run relationships. The test results shown in the bottom part of Table 2 also rejected unit roots hypothesis at 5% significance level.

1) Estimation Results

The model is estimated by iterative SUR estimator dropping one of the equations-Jack Mackerel. The reason to drop one equation is that adding up conditions cause the contemporaneous covariance matrix to be singular and that maximum likelihood estimates are invariant to the equation dropped.

⟨Table 3⟩ The estimated quantity adjustment parameters

Adjustment parameters	Coefficients of error-correction
λ_1	-0.826 (0.085)**
λ_2	-0.878 (0.102)**
λ_3	-0.832 (0.083)**
λ_4	-0.835 (0.085)**
λ_5	-0.844 (0.083)**

Note. values in parentheses are standard deviations.
** indicates 5% significance level.

The estimates of the error correction terms are shown in Table 3. It shows that all of six coefficients are statistically different from zero and thus the system may not be expressed in terms of differenced variables alone. The estimated values of λ suggest that all fish species are quickly adjusting current consumption to the steady state. The coefficients of error correction types of AIDS model can not be interpreted directly. Thus, instead of reporting the coefficient estimates, price flexibilities and scale flexibilities analogous to demand and income elasticities in the ordinary demand are derived using (18) – (20) and presented in Table 4.

19) If not cointegrated, the first difference regressions are misspecified because they omits the relevant variable, dynamic element. Deaton and Muellbauer (1980) explained the reason for autocorrelation found in the residuals of the demand equations by the exclusion of dynamic element, i.e. habit formation.

20) I am thankful to anonymous referee to suggest the robust PP tests in addition to ADF tests.

⟨Table 4⟩ The estimated long-run flexibilities of the dynamic model

Item	Price flexibility					Scale flexibility	R^2 /DW
	Mackerel	Sardine	A.Pollack	Hair Tail	Croaker		
1	−0.964**	−0.066*	0.874**	0.234	−0.016	−2.007**	0.69/2.1
	(0.138)	(0.039)	(0.195)	(0.156)	(0.052)	(0.254)	
2	0.165	−0.827**	0.987**	0.697**	−0.991**	−2.407**	0.84/1.7
	(0.279)	(0.078)	(0.394)	(0.314)	(0.194)	(0.514)	
3	0.225**	0.024	−0.605**	0.065	0.205**	−0.397**	0.84/2.1
	(0.074)	(0.020)	(0.104)	(0.083)	(0.051)	(0.136)	
4	−0.059	0.009	0.488**	−0.393**	−0.006	−1.462**	0.86/1.7
	(0.079)	(0.022)	(0.111)	(0.089)	(0.055)	(0.145)	
5	0.018	0.040	0.447**	0.035	−0.428**	−1.376**	0.76/1.8
	(0.103)	(0.029)	(0.145)	(0.116)	(0.072)	(0.190)	

Note. Item 1 = Mackerel; item 2 = Sardine; item 3 = Alaska Pollack; item 4 = Hair Tails; item 5 = Croaker; values in parentheses are standard deviations; the D-W statistics for the equations have ranged from 1.7 to 2.1.

Looking at the results shown in the last two column of Table 4, it appears that all the estimates of the scale flexibilities are negative and relatively large with respect to their standard errors, thus giving high t-ratios. Since the normalized price goes down as all quantities increase proportionately, this is what we expect. We also note that the estimated scale coefficients are rather larger than minus one (for example, Mackerel −2.007) except Alaska Pollack(−0.397). It implies most fishes are very responsive to the scale changes of consumption.

For the estimated elasticity form of the Antonelli substitution matrix in Table 4, all diagonal elements, i.e. the own-price flexibilities, have been estimated negatively with a high degree of precision. For the off-diagonal elements of the Antonelli matrix, representing cross substitution in the long-run, only five of the twenty cross effects are negative and nine among twenty are significantly different from zero. It implies that many types of fish are not mutual q-substitutes[21]. his demonstrates the complementarity bias in the inverse demand system. Among those, Mackerel and Alaska Pollack show strong q-substitutes and Croaker with Alaska Pollack and Sardine shows q-substitutes as well.

The estimated result of the short-run flexibilities is summarized in Table 5. According to the table, all own price flexibilities are estimated negatively with a high degree of precision. For the off-diagonal elements, only eight of twenty are significantly different from zero and

21) Q-substitutes imply that marginal rate of substitution between i and numeraire goes up as the quantity of good j goes down. The quantity of numeraire will be adjusted to keep utility constant.[Madden (1991)]

⟨Table 5⟩ The estimation result of the short-run flexibilities of the dynamic model

Item	Price flexibility					Scale flexibility	R^2 /DW
	Mackerel	Sardine	A.Pollack	Hair Tail	Croaker		
1	−0.751**	0.034	0.453**	0.169	0.147	−1.527**	0.46/1.7
	(0.127)	(0.048)	(0.214)	(0.204)	(0.116)	(0.323)	
2	0.201	−0.948**	0.756*	0.851**	−0.829**	−2.333**	0.58/1.7
	(0.242)	(0.094)	(0.417)	(0.397)	(0.224)	(0.616)	
3	0.133**	0.018*	−0.377**	0.032	0.100	−0.714**	0.54/1.8
	(0.075)	(0.029)	(0.127)	(0.121)	(0.069)	(0.191)	
4	−0.001	0.007	0.408**	−0.384**	0.030	−1.421**	0.54/1.7
	(0.075)	(0.029)	(0.127)	(0.122)	(0.070)	(0.192)	
5	0.064	0.003	0.231*	0.135	−0.314**	−0.926**	0.79/1.9
	(0.078)	(0.030)	(0.132)	(0.127)	(0.073)	(0.199)	

Note: 1) Item 1 = Mackerel; item 2 = Sardine; item 3 = Alaska Pollack; item 4 = Hair Tails; item 5 = Croaker.
2) The values in parentheses are standard deviations.

two among twenty are q-substitutes, which shows more complementarity bias than that of the long-run flexibilities. Especially, Mackerel and Alaska Pollack show strong q-substitutes either in the long-run or in the short-run. One of the reason may be that the consumers usually do not eat them together by customs. For the scale flexibilities, Mackerel(−1.527), Sardine(−2.333), and Hair Tail(−1.421) have greater than minus one, which implies they are very responsive to scale changes. Alaska Pollack has the scale flexibility less than minus one (−0.714) while Croaker has almost minus one (−0.926). Further, we normally expect that since past consumption stimulates current consumption by habit effects, the long-run responses should be greater than the short-run counterparts[22]. Given that the magnitudes of the short-run response of prices are smaller than those of the long-run response except for Sardine in absolute values (−0.827 for long-run; −0.948 for short-run), the LeChatelier principle holds[23].

2) Intertemporal Welfare Evaluation

To compute welfare measures using our data set and formula, we assume the regulatory imposition of a 10 % catch restriction on each type of fish. We compute the welfare effects based on short-run elasticities and the estimated welfare measures at the sample mean are presented in Table 6. It shows the annual welfare loss resulting from a 10 % catch restriction

22) In this paper, we do not focus much on the relationship between short-run responses and long-run counterparts empirically. Instead, we want to find how important dynamic factors are in dynamic models.

23) The principle states that long-run demand functions are more price and expenditures sensitive than their short-run ones (Silberberg, 1992, pp. 216−222).

⟨Table 6⟩ The estimated static welfare measures (current dollars)

Types of fish	Total dollar value (per year)			Proportion of QCV on total expenditure
	QCV	QCS	QEV	%
Mackerel	11,564,239	11,652,741	11,741,242	0.85
Sardine	2,515,484	2,519,938	2,524,393	0.19
A.Pollack	75,472,409	76,760,817	78,049,225	5.60
Hair Tail	22,773,855	23,077,246	23,380,636	1.68
Croaker	24,577,724	24,792,385	25,007,046	1.81

Note: The QEV, QCV, and QCS are calculated from the approximated fomula for QEV, QCV, and QCS and multiplied by total expenditure, which is computed as [average of (mt/CPI_t^{2005})] times ($CPI_t^{2006}/CPI_t^{2005}$) for current dollars 2006 of its real purchasing power, where CPI implies consumer price index.

on each type of fish. For example, the valued *quantity-based compensating variation* attained after the 10 % catch restriction on Mackerel is a $11,564,239 loss per year. Similar interpretation is applied for the other types of fish. The values in the last column show welfare measurement divided by total expenditure on fish and total population. For example, the welfare level attained after the 10 % catch restriction on Alaska Pollack is equivalent to a 5.6 cents loss per dollar spent on fish, which can be interpreted as percentage of total value spent on fish. As seen in Table 6, the welfare estimates are generally small except for Alaska Pollack.

In order to obtain some intertemporal welfare measures, we consider the following hypothetical situation in addition to the static scenario: a temporary harvest restriction decreases period-t quantity by 10 % while leaving all others unaffected, and the lifetime consists of only two periods. Further, we assume that the value of distance function is initially the same in each period i.e., $\pi_t = 1/2$ in (43)[24].

Table 7 presents the estimated results of welfare measurement of the sample fishes under regulation. Calculations are based on the short-run information solely to compare with the static welfare measures and reported for a rather wide range of the value of the intertemporal substitution from -0.2 and -2.0[25]. As in the static welfare measure, the table shows that the welfare estimates are generally small except Alaska Pollack. Comparison of the second and third columns shows the extent to which the welfare loss from the temporary quantity restriction is mitigated by substituting away from the period t. As seen in the table, the larger

24) The effect of temporary restrictions ignores the long-run effects of permanent restrictions which may be more useful to policymakers. It is the limitation of this research and further study can be made in another paper.

25) Note that Browning (1989) and Hall (1988) suggest around -0.2 and Attanasio and Weber (1989) report -2.0.

⟨Table 7⟩ The lifetime welfare effects of a temporary quantity restriction(current dollars)[a]

Intertemporal elasticity of substitution ($-\sigma$)	Intertemporal QSV[b] (IQSV)	Static QCV (SQCV)	Lifetime QCV[c]
Mackerel (q=0.1)			
−0.2	−17,119	11,564,239	11,547,120
	(0.001)	(0.85)	(0.849)
−1	−85,596	11,564,239	11,478,643
	(0.006)	(0.85)	(0.844)
−2	−171,191	11,564,239	11,393,048
	(0.013)	(0.85)	(0.837)
Sardine (q=0.1)			
−0.2	−934	2,515,484	2,514,550
	(0.0006)	(0.19)	(0.189)
−1	−4,670	2,515,484	2,510,814
	(0.003)	(0.19)	(0.187)
−2	−9,340	2,515,484	2,506,144
	(0.006)	(0.19)	(0.184)
A.Pollack (q=0.1)			
−0.2	−82,139	75,472,409	75,390,270
	(0.006)	(5.6)	(5.594)
−1	−410,693	75,472,409	75,061,716
	(0.03)	(5.6)	(5.57)
−2	−821,386	75,472,409	74,651,023
	(0.06)	(5.6)	(5.54)
Hair Tail (q=0.1)			
−0.2	50,055	22,773,855	22,723,800
	(0.004)	(1.68)	(1.676)
−1	250,274	22,773,855	22,523581
	(0.018)	(1.68)	(1.662)
−2	500,548	22,773,855	22,273,307
	(0.037)	(1.68)	(1.643)
Croaker (q=0.1)			
−0.2	−21,367	24,577,724	24,556,357
	(0.002)	(1.81)	(1.808)
−1	−106,836	24,577,724	24,470,888
	(0.008)	(1.81)	(1.802)
−2	−213,673	24,577,724	24,364,051
	(0.016)	(1.81)	(1.794)

Note: a. The values in parenthesis indicate a percentage of total expenditure.

b. This is a monetary measure of IQSV, calculated from (45).

c. This is the sum of static QCV and intertemporal variation of substitution (IQSV), calculated by adding columns 1 and 2.

the value of the intertemporal elasticity, the bigger the loss in welfare for the case of welfare improvement or vice versa. The first column shows the discrepancy between the second and third columns, i.e., the significance of the second-order approximation of the intertemporal QSV (=IQSV), and the largest discrepancy at $\sigma=2$, which implies the magnitude of the aggregate intertemporal QSV (=IQSV) becomes substantial. Thus, good approximation depends on the magnitude of the intertemporal elasticity of substitution.

V. Concluding Remark

The paper has considered three issues: (1) demonstrating the feasibility of incorporating plausible dynamic effects through habit formation parameters into an inverse demand system. The paper has developed the flexible dynamic price formation based on the intertemporal optimization. While the resulting model has a similar form of the error correction types of dynamic system, it will provide the rational dynamic behavior contrary to the myopic behavior of the latter. (2) developing analytic tools of welfare measurement appropriate for the dynamic price formation systems as a first attempt in the literature. (3) applying empirical methodology of specification of dynamic price formation system and static and dynamic welfare measures appropriate to the current fishery policy alternatives into S. Korea fish markets.

The paper proposed a specification of dynamic price formation functions in a complete system. Using the inverse AIDS system as a static differential price formation model, the paper generalized it dynamically incorporating habit formation. The structure of the model is similar to that of Holt and Goodwin (1997). However, it is different from theirs in some respects. This paper derives dynamic price formation functions from the intertemporal optimization of consumers' utility while they use autoregressive schemes. On the other hand, this study develops a dynamic welfare measures for quantity changes while they take the IAIDS system without full rationality and welfare analysis.

The empirical results for the model show that it fits the data well and gives plausible signs and magnitudes of scale and price flexibilities. In addition, the results show strong evidence of importance of dynamic factor on empirical consumer allocation models. For dynamic welfare measures, it shows that the larger the value of the intertemporal elasticity, the bigger the loss in welfare if the situation is in welfare improvement. It also shows that the welfare loss from the temporary quantity restriction is mitigated by substitution away from the period

t. Thus, good approximation of static welfare measures depends on the magnitude of the intertemporal elasticity of substitution.

Our framework and approach should give an interest to policymakers because environmental quality change or natural resource regulation is done by change in quantity, which is exogenous in our model and now a policy variable. Thus, change in consumer welfare can be easily measured and analyzed by policymakers. In this regard, this research can provide the most valuable data and empirical methodology for regulatory policies to fishery managers and other related agricultural, environmental and resource managers.

Finally, we suggest some future research. Although a dynamic generalization of the price formation system and its welfare analysis in the quantity space should contribute to the general methodology of applied economics, the current paper has not treated problems of aggregation across species, actual policy analysis, long-run effects of permanent harvest restrictions, and forecasting performance of the model, leaving it to the future agenda.

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A Dynamic Price Formation System and Its Welfare Analysis in Quantity Space: An Application to Korean Fish Markets

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Abstract

As policy makers are often concerned about dynamic effects of demand behavior and its welfare analysis by quantity changes, the paper shows how dynamic price formation systems can be built up to analyze the effect of policy options to the markets dynamically. The paper develops dynamic model of price formation for fish from the intertemporal optimization of the consumer choice problem. While the resulting model has a similar form of the error correction types of dynamic price formation system, it provides the rational demand behavior contrary to the myopic behavior of error correction demand models. The paper also develops appropriate tools of dynamic welfare analysis in quantity space using only short-run demand estimates both theoretically and empirically as a first attempt in the literature of price formation and fisheries. The empirical results of Korean fish markets show that the dynamic model and the welfare measures are reasonably plausible. The methodology and theory of this research can be applied and extended to the commodity aggregation, dynamic demand estimation, and dynamic welfare effects of regulation in the similar framework. Thus, it is hoped that this will enhance its applications to the demand-side economics.

Key words : Price Formation System, Intertemporal Optimization, Price Flexibility, Scale Flexibility, Intertemporal Substitution.
JEL Classification : Q11, Q22, Q28, D60, D11, D12