THE EFFECT OF HOUSE PRICE ON FERTILITY: EVIDENCE FROM HONG KONG

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This article extends a standard Beckerian model of fertility behavior to formulate the effect of house price (HP) on fertility. The simple model predicts a negative effect of HP on the number of children for a representative household not only through the income effect but also through the compensated substitution effect. The prediction is confirmed by a cointegration analysis applied to the annual data at the aggregate level covering the period from 1971 to 2005 in Hong Kong. It is found that a 1% increase in HP is significantly related to a 0.45% decrease in total fertility rates (TFRs), which is robust in sensitivity tests with an alternative model specification and alternative measures of TFRs. This implies that high HP inflation can account for about 65% of the fertility decrease in Hong Kong in the past four decades. (*JEL* J13, J11, C32)

I. INTRODUCTION

The mechanism underlying the demographic transition coinciding with industrialization still remains an unresolved debate in economics and demography. Early contributions to the New Family Economics formulated the choice of fertility into the Beckerian time allocation model and derived that the secular decline of fertility rates in developed countries over the past 50 yr was mainly attributed to the increase of the opportunity cost of childbearing and rearing, represented by the increase of female education levels, wage rates, and labor force participation rates (Becker 1960, 1991; Willis 1973). Although this negative relationship between fertility rates and female labor market activities has been verified by later empirical studies (Butz and Ward 1979; Heckman and Walker 1989, 1990), "it cannot fully explain the demographic transition pattern in Western Europe and elsewhere," as contended by Becker and Murphy (2000).

An illustration in point of the insufficiency of this female labor market story comes from the demographic transition pattern that has occurred with the East Asian Tigers during the past four decades. While these four economies, South Korea, Taiwan, Hong Kong, and Singapore, have experienced both economic "takeoff" and fertility decrease synchronously (Macunovich 2000), their female labor market behavior changed mildly and female labor force participation rates (FLFPRs) are still much lower than their western counterparts.[1] The typical

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1. For example, the TFR in the East Asian Tigers are all far below the replacement level of 2,100; 1,270 in South Korea, 1,570 in Taiwan, 950 in Hong Kong, and 1,060 in Singapore, and their FLFPRs are 52.1%, 46.6%, 52.0%, and 53.4%, respectively, in 2005, in contrast with 71.3% in the United States, 67.2% in the United Kingdom, and 69.4% in Canada (Central Intelligence Agency 2006).

ABBREVIATIONS

ADF: Augmented Dickey-Fuller
CBR: Crude Birth Rates
ECM: Error Correction Model
FDH: Foreign Domestic Helper
FLFPR: Female Labor Force Participation Rate
FW: Female Wage
GDP: Gross Domestic Product
HP: House Price
MW: Male Wage
OLS: Ordinary Least Squares
RTFR: Revised Total Fertility Rate
TFR: Total Fertility Rate
VAR: Vector Autoregression

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representation of this new demographic transition pattern happened in Hong Kong. On the one hand, the economy of Hong Kong has been booming and has experienced one of the fastest per capita gross domestic product (GDP) growth rates around the world in the past four decades. However, the total fertility rate (TFR) has sharply decreased by 75% at the same period, from 3,459 in 1971 downward to 966 in 2005, one of the lowest in the world and far below the required replacement level of 2,100.[2] On the other hand, however, the extent to which the female labor market behavior has responded to the economic prosperity has been very limited. For example, the FLFPRs just increased from 42.8% in 1971 to 52.0% in 2005.[3] Since it is unbelievable that a 9.2% increase of FLFPRs is the primary driving force for the almost 75% decrease of TFRs, other factors influencing the shadow price of childbearing and rearing should also be taken into account.[4]

The dominant factor responsible for the drastic decrease of fertility rates in Hong Kong suggested by the present article is the house price (HP). The justification of the HP into a fertility decrease story involves the standard income and substitution effects. First of all, the increase of HPs impoverishes parents and exerts a negative income effect on the demand for children in the standard economic theory of fertility (Becker 1991). Following the conventional practice in which the child is assumed to be a normal good, the negative income effect decreases the demand for children. Second, HP is a part of the shadow price for children. The increase of the HP should also decrease the demand for children in the Hicksian sense and this negative compensated substitution effect reinforces the pure negative income effect. Overall, both effects may cause many relatively young or poor households to be unable to afford to set up a household in a lifecycle context. Consequently, to the extent that owning house or renting house of a sufficient size may be a precondition for having children, many such households may be highly constrained to have any children at all. For relatively wealthy couples, rising housing prices would diminish the house size they could afford to buy or to rent and decrease the demand for children accordingly.

More importantly, the magnitude of the increase of HP may be large enough to trigger the sharp decrease of fertility rates in Hong Kong. In fact, the growth rates of HPs have dominated the growth rates of both real per capita GDP and real wage rates during the past four decades. From 1971 to 2005, HP has increased by almost 550% in Hong Kong, while real per capita GDP and real wage rates have increased by only 380% and 201%, respectively. Thus, high HP inflation has qualified itself as a reasonable candidate for the explanation of the sharp decrease of fertility rates in Hong Kong.[5]

However, empirical studies of fertility behavior at the aggregate level must contend with the fact that variables in the economic model of fertility are most likely to be nonstationary time series and the estimation of the fertility equation is also plagued with endogeneity problems (Cigno and Rosati 1996; Macunovich 1995; McNown and Rajbhandary 2003; Wang, Chong, and Scotese 1994). For example, variables entering the modified economic model of fertility when HP is included may reflect the joint outcomes of household decisions regarding work, childrearing, and house purchasing or renting by young spouses. Hence, the cointegration model of Johansen (1995) is applied to estimate and test the dynamic linkage between fertility rates and HPs in the long run in this article. The Johansen method is appropriate for analyzing relations between nonstationary time series, and the estimating results are asymptotically consistent and governed by the asymptotic normal distribution even in the presence of endogeneity problems. To capture the responses of fertility behavior to both labor market and real estate market variations,

2. The TFR is defined as the average number of children that would be born alive to 1,000 women during their lifetime if they were to pass their childbearing ages 15–49 yr experiencing the age-specific fertility rate prevailing in that year.

3. In contrast to the inertia of the female labor market behavior responding to the economic prosperity in Hong Kong, the female labor market participation rate in the United States for the age cohort of 25–34 yr increased from 40.3% in 1963 to 76.1% in 1989 (Macunovich 1995).

4. The definitions and data sources of the variables in this paragraph are given in Table A1.

5. In fact, the importance of HPs in the explanation of different fertility rates between farm households and urban ones was noted by Becker as early as 1960 (Becker 1991). Another related study is Ermisch (1988) in which the HP is coupled with other economic variables to explain the birth rate dynamics in the United Kingdom in the period of 1952–1983.

variables entering the fertility equation are HPs, FLFPRs, and female wage (FW) and male wage (MW) rates.

Consistent with the theoretical prediction, the empirical results suggest, based on Hong Kong annual data at the aggregate level covering the period from 1971 to 2005, that a 1% increase of HPs is significantly related to a 0.45% decrease in fertility rates, which is robust to sensitivity tests with an alternative model specification and alternative measures of TFR. This implies that high HP inflation can account for about 65% of the fertility decrease in Hong Kong in the past four decades.

This article proceeds in the following manner. Section II presents a simple model to formulate the mechanism by which HP inflation decreases fertility rates. Section III specifies the empirical strategy. Section IV describes the data and variables. Section V reports the empirical evidence of unit root tests and cointegration analysis. Section VI conducts robust tests and Section VII concludes.

II. A SIMPLE MODEL OF THE EFFECT OF HP ON FERTILITY

This section presents a simple model to formulate the mechanism by which HP inflation decreases the fertility rate. Consider a representative household with a husband h and a wife w. The household derives utility from the number of children N, the husband's leisure L_{h}, and the wife's leisure L_{w}. Denote W_{h} and W_{w} to be the wage rates for the husband and wife, respectively, and the individual's time endowment is normalized to 1. In addition, the housing requirement for N children is represented by a function $H(N)$ with the market price p_h. Thus, the maximization program for the household is:[6]

$$\text{(1)} \quad \begin{aligned} &\operatorname{Max} U = U(N, L_{\mathrm{h}}, L_{\mathrm{w}}) \\ &\text{s.t. } p_n N + p_h H(N) = I + \sum_{i=h,w} W_i(1 - L_i). \end{aligned}$$

The demand function of $H(N)$ in the budget constraint of the maximization program above is to capture the fact that a house is a necessary good for the child. Hence, the house H should be an increasing function of the number of children $N(H'(N) > 0)$. To illustrate the relationship between the size of the house and the number of children clearly, the demand function for the house can be specified as $H(N) = a + bN^{\alpha}$ $(0 < \alpha < 1)$, where a can be treated as the necessary part of the house for parents and it is constant, b is the necessary size of the house for only one child, and bN^{α} is the part of the house for all children. Considering the scale effect in the house demand function, that is, the children can partly share the space, α is less than 1. However, the scale effect is not perfect, especially in the case that the children are of different genders, hence $\alpha > 0$.

Assuming that the utility function $U(\cdot)$ is well behaved, for an interior maximum, the first-order condition with respect to N is:

$$\text{(2)} \qquad U_1 - \lambda(p_n + p_h H'(N)) = 0,$$

where λ is the Lagrange multiplier. Since the shadow price for the child U_1/λ in this model setting equals $p_n + p_h H'$ HP$(p_h)(N)$, it is an increasing function of the HP(p_h) at the optimum. By manipulating the first-order conditions of the maximization problem (1), we can derive the comparative statistics of the fertility rate N with respect to the price of the house as:

$$\text{(3)} \qquad \frac{\partial N}{\partial p_h} = -H\frac{\partial N}{\partial I} + \lambda H'(N)\frac{|F_{22}|}{|F|} < 0,$$

where $\partial N/\partial I$ is the income effect on the demand for children. Since the child is assumed to be a normal good in the altruistic household model, $\partial N/\partial I$ is positive. In addition, $|F|$ is the determinant of the bordered Hessian matrix and it is negative; $|F_{22}|$ is the subdeterminant of the bordered Hessian matrix after the deletion of its second row and second column and it is positive.

The economic intuition of Equation (3) is straightforward. In fact, Equation (3) is a transformation of the Slutsky decomposition of the

6. The price of children would normally include childbearing and rearing costs and thus mother's opportunity cost of time. For simplicity, however, we ignore mother's opportunity cost in p_n. Thus, the mother's wage effect would work through substitutability/complementarity of children and leisure in the utility function. Complementarity between mother's leisure and children could produce a negative substitution effect on the demand for children. Moreover, the quality of children and the consumption of other goods and services are ignored in the utility function as well.

effect of HP on the demand for children through the derived demand for the house. Specifically, the first term on the right-hand side of Equation (3) is the pure income effect, that is, HP inflation tightens up the household's budget constraint and generates a negative income effect; the second term is the compensated substitution effect since the HP is also a part of the shadow price of the child as expressed in Equation (2). To sum up, we can conclude from Equation (3) that the total effect of HP on fertility is negative.

Before proceeding, one thing should be noted. The unambiguously negative effect of HP on fertility in Equation (3) is derived under the assumption that the house is a necessary good for the family, that is, the house does not directly enter the utility function. The scenario becomes a little more complicated when the house is directly included in the utility function. Besides the negative income and compensated substitution effects presented in Equation (3), the effect of HP on fertility also depends on whether the house and the child are substitutes or complements to each other. However, treating housing as a necessary consumption good is appropriate in Hong Kong.[7] In addition, the house would likely be a necessary good for a majority of households. Hence, the total effect of HP on fertility could still be assumed to be negative at the aggregate level.

III. METHODOLOGY

To implement the cointegration analysis of the effect of HP inflation on fertility discussed in the preceding section, we incorporate HP into the traditional fertility equation and specify the empirical strategy to deal with the problems of endogeneity and nonstationary. The simple model in the preceding section gives the following children demand function in the reduced form:

$$N = N(p_h, W_{\mathrm{h}}, W_{\mathrm{w}}, R), \tag{4}$$

where R denotes the FLFPR, capturing the probability whether wives are active in the labor market at the macrolevel. The theoretical model in Section II shows that $\partial N/\partial p_h < 0$. Following Willis (1973) and Butz and Ward (1979), it is expected that $\partial N/\partial W_{\mathrm{w}} < 0$, $\partial N/\partial W_{\mathrm{h}} > 0$, and $\partial N/\partial R < 0$.[8]

Before directly implementing this fertility equation with the aggregate data, two problems with the estimation of Equation (4) should be addressed. First, the behavior of childbearing, work, and house purchase may be determined jointly and influenced by one another simultaneously. Thus, all the variables entering the fertility equation are quite plausibly endogenous, which may bias the ordinary least squares (OLS) estimation. We will apply the Johansen (1995) method that accommodates endogeneity problems. Second, as discussed in Ermisch (1988), Macunovich (1995), Wang, Chong, and Scotese (1994), Cigno and Rosati (1996), and McNown and Rajbhandary (2003), variables common to models of fertility and labor market behavior are most likely to be nonstationary time series. Hence, unit root tests should be applied to determine whether these time series are difference stationary or trend stationary.

A by-product of the unit root test for fertility rates is to examine the snowball or cascade hypothesis proposed by Wachter (1991). Easterlin (1978) hypothesized that the emergence of pressure for fertility limitation could bring pressure for the change of fertility attitude among young adults and result in cognitive dissonance between younger and older cohorts. With the negatively socioeconomic shocks on fertility, which may be accompanied by the industrialization process, the decrease of fertility could increase the social acceptance of the family regulation concept and thus decrease fertility rates further. This process would be repeated and the effects of those negative shocks on fertility would be accumulated. Wachter (1991) formulated this feedback effect into a snowball or cascade model to explain the cyclic fertility movements in the United States. In addition, Kohler (2001) suggested a social interaction mechanism such as learning in social networks, which may underlie this cumulative effect of the fertility decline, to explain the demographic change in a population. In terms of

7. In 1996, for example, 51.10% of the whole population older than 18 yr were living in rented houses, and the share of renters was as high as 71.06% for the young cohort aged from 18 to 30 yr (the calculation is based on the 5% sample of the 1996 Hong Kong Population By-census).

8. We will estimate an alternative model specification with two equations, one for the fertility and the other for the FLFPR in the following robust analysis section.

the econometrics of time series, if the above fertility transition process is valid and the fertility rate itself has no ability to revert to its previous levels after exogenous shocks, the fertility rate should follow a unit root process. Hence, this "snowball" hypothesis can be well examined by the implementation of a unit root test.

If any two or more variables in the fertility equation exhibit a same order of unit root, cointegrating tests should be applied to determine the number of cointegrating vectors in this system. If at least one cointegrating vector is found, the fertility equation can then be identified by the cointegrating vector and viewed as the stationary long-run relationship among those variables in the fertility function.[9] Following the standard method of cointegration analysis of Johansen (1995) and Enders (2004), the dynamic representation of the regression of Equation (4) is given by the following error correction model (ECM)

$$(5)\quad \Delta \boldsymbol{X}_t = a + \sum_{j=1}^{p} \Gamma_j \Delta \boldsymbol{X}_{t-j} + \boldsymbol{\delta\beta}' \boldsymbol{X}_{t-1} + \boldsymbol{e}_t,$$

where $\boldsymbol{X}_t$ is a 5 × 1 vector including TFR, HPs, FLFPRs, FW rates, and MW rates and $\boldsymbol{e}_t$ is the vector of error terms and is assumed to be serially uncorrelated after the appropriate selection of the lag length p.[10] The parts in Equation (5) which are of interest to us are the two $5 \times r$ matrices $\boldsymbol{\delta}$ and $\boldsymbol{\beta}$, where $\boldsymbol{\beta}$ is the cointegrating vector representing the long-run relationship among the five variables, $\boldsymbol{\delta}$ is the adjustment parameter vectors representing the speed of convergence to the equilibrium path, and r is the number of cointegrating vectors.

The critical step in the Johansen procedure is to determine the significance rank of the 5 × 5 matrix $\boldsymbol{\delta\beta}'$. If this matrix is fully ranked, that is, $r = 5$, on the one extreme case, directly applying a vector autoregression (VAR) model is appropriate since it indicates that all the five series are stationary. On the other extreme case, if $r = 0$, all the five series should be detrended or differenced first according to the results of unit root tests. A VAR model can then be applied to derive the dynamic relationship among these variables in the short run. While if $0 < r < 5$, steady states or equilibria may exist in the system and ECM is appropriate (Enders 2004). The estimation and testing procedure implemented in this article are the Cointegration Analysis of Time Series module (Hansen and Juselius 1995) of the Regression Analysis of Time Series program; and both the maximum eigenvalue statistics and trace statistics are jointly employed to determine the number of cointegrating vectors.

IV. DATA DESCRIPTION

The series used in this article are constructed from annual aggregate data in Hong Kong covering the period from 1971 to 2005, namely, TFR, HPs, FLFPRs, FW rates, and MW rates. Table 1 gives the variables, definitions, and summary statistics; Table A1 lists the data sources. All five variables entering the model are in logarithmic form, and the parameters should be interpreted as elasticities. Following common practice, fertility rate here is measured by the TFR, which is designed to match the comprehensive definitions of other series. Considering the economic and social integration between Hong Kong and mainland China and the highly frequent migration in Hong Kong, two alternative measures of birth rates, that is, revised total fertility rate (RTFR) and crude birth rates (CBRs), have been employed as robust tests to control for both the number of live births born outside Hong Kong to Hong Kong residents and the number of live births born in Hong Kong to women from mainland China whose spouses are Hong Kong residents.

Figure 1 illustrates the decrease of TFR in contrast to the increase of HPs, which is normalized at 1 in the year of 2000. On the one hand, the TFR has declined dramatically by almost 75% in the past four decades, from

9. Cointegrating relationship refers to the stationary linear combination of two or more nonstationary time series and signifies an equilibrium relationship or stationary relationship among those originally nonstationary time series in the long run.

10. In the original model of Willis (1973) and empirical implementation of Butz and Ward (1979), the FLFPR is interacted with both MW and FW rates to distinguish families with participating wives from those with nonparticipating wives. However, we do not make such classification here. The reasons are as follows. First, given the relatively short time series, the ECM of Equation (8) could only be treated as a linear approximation. Second, because the nonlinear combination of two $I(1)$ processes can result in integrated process of higher orders, this would greatly complicate the cointegration analysis (Escribano and Mira 2002).

TABLE 1
Summary Statistics of Fertility Rate, HPs, FLFPRs, and FW and MW rates

Variable	Definition	N	Mean	SD	Minimum	Maximum
TFR	Total fertility rate	35	1,676.20	740.86	927	3,459
RTFR	Revised total fertility rate	35	1,677.91	739.71	901	3,459
CBR	Crude birth rate	35	13.17	4.14	6.90	19.70
HP	House price index	35	0.54	0.32	0.13	1.10
FLFPR	Female labor force participation rate	35	0.47	0.03	0.43	0.52
FW	Female daily wages	35	357.94	140.58	186.75	622.49
MW	Male daily wages	35	536.26	187.73	295.76	898.46

Notes: Data sources and variable constructions are given in Table A1.

a peak of 3,459 in 1971 to 927 in 2004, before rising slightly to 966 in 2005. On the other hand, HPs have been increasing from 0.13 in 1971, reaching a peak at 1.10 in 1998, which have been inflated by almost nine times. Due to the shock of the East Asian Financial Crisis in 1997, HP lowered to 0.84 in 2005. Even then, HPs in Hong Kong still remain one of the highest in the world.

Figures 2 and 3 depict the dynamic change of the labor market in Hong Kong. From Figure 2, the FLFPRs increased from 42.8% in 1997 to 52.0% in 2001 and then halted around this level in the next 4 yr. Although the FLFPR has increased 10 percentage points, it is still much lower relative to its counterparts in the United States and other western countries. From Figure 3, although the relative wage disparity between male and female, measured by $(W_m - W_f)/W_f$, decreased slightly from 64.55% in 1971 to 45.98% in 2005, the absolute wage gap has increased from 122.27 to 273.12 during the same period. Summarizing from Figure 1 to Figure 3, we can conclude that female labor market behavior has mildly changed in response to the economic prosperity in Hong Kong, though the fertility behavior of households has experienced a fundamental transition during the past four decades. Hence, in contrast to the hypothesis advanced by the New Family Economics that the change of female labor market behavior is the primary driving force underlying the decline of fertility rates, we postulate that the drastic increase of HPs has played an essential role in the demographic transition in Hong Kong.

Before proceeding to a formal time series analysis, we conduct two traditional regressions. From Figure 1, it is suspected that the negative relationship between HP and fertility may be primarily driven by a time trend (or its negative trend). Hence, we carry out the OLS estimations of the effect of the HP on the TFR with and without a time trend in Table A2, respectively. Comparing column 2 to column 1 in Table A2, we find that the inclusion of the time trend has little influence on the magnitude of the estimated coefficient on the HP. Indeed, the time trend itself is not even statistically significant. In addition, the R^2

FIGURE 1
TFR and HP Index

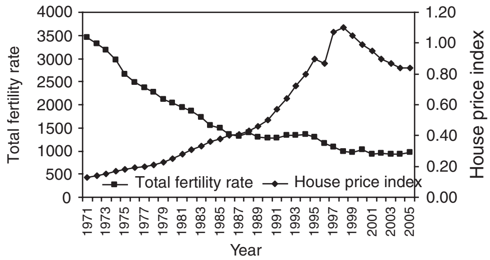


FIGURE 2
Female Labor Force Participation Rate

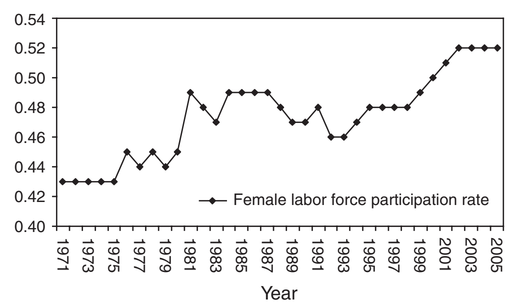


FIGURE 3
FW and MW Rates

remains the same after the inclusion of the time trend. Therefore, we can safely exclude the time trend story, and the modern time series techniques will be employed to analyze the relationship between HP and fertility in the following sections.

V. EMPIRICAL RESULTS

A. Unit Root Tests

Before implementing the cointegration test, the first step of the Johansen (1995) procedure is to determine the integrated order of the series by appropriately employing unit root tests. Following the rule from a general model with both a time trend and a constant to the specific model without them (Dolado, Jenkinson, and Sosvilla-Rivero 1990), Table 2 reports the results of the augmented Dickey-Fuller (ADF) tests for the five series (Enders 2004). The lag length selection criteria are based on the Schwartz Bayesian Criterion statistics with the lowest value to ensure the residual is white noise. Table 2 shows that all five series are nonstationary, and they are integrated of an order greater than 0. To further investigate the dynamic property of the five variables, respectively, the Dickey and Pantula (1987) test for higher order of unit roots has also been implemented. Since no higher order of unit roots has been detected, the results are left out in this table.

Therefore, the cointegration test is necessary prior to further explore the dynamic relationship among the five nonstationary series in the fertility equation. In addition, the result of the ADF tests for the TFR series is consistent with the snowball hypothesis. It confirms that

TABLE 2
ADF Tests for TFRs, HPs, FLFPRs, and FW and MW rates

Model	H_0	Statistics	TFR	HP	FLFPR	FW	MW
$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t$	$\gamma = 0$	τ_τ	−1.36	−2.06	−2.82	−3.12	−2.99
	$\gamma = a_2 = 0$	ϕ_3	2.22	2.37	4.00	5.54	6.21
	$a_0 = \gamma = a_2 = 0$	ϕ_2	2.15	1.94	2.98	5.04	4.89
$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t$	$\gamma = 0$	τ_μ	−1.91	−1.23	−1.21	−2.38	−1.97
	$a_0 = \gamma = 0$	ϕ_1	2.82	1.26	1.12	4.12	3.98
$\Delta y_t = \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t$	$\gamma = 0$	τ	−1.49	0.15	−1.30	−1.89	−1.30

Notes: The test procedure follows Dolado, Jenkinson, and Sosvilla-Rivero (1990); the Monte Carlo experiments suggest that the critical values for τ_3, ϕ_3, ϕ_2, τ_μ, ϕ_1, and τ at the significance level of 5% are −3.50, 6.73, 5.13, −2.93, 4.86, and −1.95, respectively; hence, all the statistics are insignificant at the level of 5%. The lag length selection criterion is Schwartz Bayesian Criterion with the lowest value to ensure the residual, ε_t, is white noise.

the dynamics of the fertility behavior has followed a random walk process and may not be able to return to its former levels after exogenous shocks. The fact that the TFR possesses the property of random walk may have important policy implications. For example, if the negatively exogenous shocks accompanied by the industrialization had decreased the fertility rate, these effects would be permanent.

B. Cointegration Analysis

Table 3 presents the results of the cointegration analysis and the diagnostic checks for the Johansen test. Due to the short time span of 35 yr, the ECM of Equation (5) remains only one lagged difference for all the five variables. The results of the diagnostic checks nevertheless indicate that one lagged difference is proper. The results of the maximum eigenvalue test and trace test, in which both tests are based on likelihood ratio statistics, are reported in the top panel of Table 3. Although the maximum eigenvalue statistics indicate the existence of two integrating vectors at the significance level of 10%, the trace statistics suggest only one at the same significance level.[11] Based on the following two additional considerations, however, we conclude that the identification of one cointegrating vector is preferred by inferring from the Johansen test: (1) the maximum eigenvalue statistics are insignificant for two cointegrating vectors at the 5% significance level (the critical value is 22.00) and (2) the fact that four roots of the companion matrix (unrestricted model) are near to 1 indicates only one cointegrating vector in this model because one cointegrating vector reduces one unit root in this system which began with a total of five unit roots for those five integrated variables. Nonetheless, since the maximum eigenvalue test indicates two cointegrating vectors at the 10% significance level, an alternative model specification with two cointegrating vectors will be estimated in the next section as a robust test.[12]

The diagnostic tests for serial correlation, heteroskedasticity, and nonnormality of the residuals in all the five equations are reported at the bottom panel of Table 3. First, the hypothesis that all the residuals in the five equations, $\boldsymbol{e}_t$ in Equation (5), are serially uncorrelated is checked by the Lagrange multiplier test, and the chi-square statistic with 10 *df* is insignificant at the conventional level of 5% (the critical value is 18.31). Second, the combined Jarque-Bera test is the joint test for normality of each residual in the five equations with an asymptotic chi-square distribution with 10 *df*. The lower panel of Table 3 states that the Jarque-Bera statistic is also insignificant at the 5% level. Finally, the equation-specific diagnostic tests for autoregressive conditional heteroscedasticity (ARCH) effect and nonnormality are listed at the bottom of Table 3 in which none of the statistics are significant at the 5% level except the MW equation (the critical value is 5.99). To sum up, the results of the three diagnostic tests for serial correlation, heterogeneity, and nonnormality indicate that the model is well fitted.

In the case of only one cointegrating vector, the fertility equation is then identified by normalizing the estimated coefficient on TFR to 1. The estimated parameters and the asymptotic SE of the integrating equation are reported in the upper panel of Table 4 in which the sign of each estimated coefficient is consistent with the prediction in the theoretical model presented in the previous section. Note that a positive (negative) estimated coefficient implies a negative (positive) relationship between the fertility and the variable under consideration (Enders 2004, 365).

First, as expected from the theoretical model, the TFR is negatively related to HP. The estimated coefficient on HP indicates that a 1% increase in HP will decrease the TFR by 0.45% in the long run. This result is consistent with Ermisch's (1988) study of the birth rate dynamics in the United Kingdom in which it is found that a high HP would deter female entry into motherhood. To gauge the importance of the impact of HP inflation on the fertility decline in Hong Kong, it is interesting to calculate the total effect of HP on fertility from 1971 to 2005. A simple calculation shows that 65.82% of the fertility decline can be

11. One cointegrating vector means that the equilibrium relationship among the nonstationary series can be uniquely identified.

12. However, the interpretation for the multiple cointegrating vectors is not straightforward since any linear combination of these vectors is also a cointegrating vector. Therefore, other structural restrictions should be imposed in this case. We will discuss this matter further in the next section of robust analysis.

TABLE 3
The Cointegration Analysis among TFRs, HPs, FLFPRs, and FW and MW Rates

Cointegration Test Statistics							
	Maximum Eigenvalue				Trace		
H_0	H_1	Statistics	10% CV	H_0	H_1	Statistics	10% CV
$r = 0$	$r > 0$	27.08*	20.90	$r = 0$	$r = 1$	66.54*	64.74
$r \leq 1$	$r > 1$	21.33*	17.14	$r = 1$	$r = 2$	40.76	43.84
$r \leq 2$	$r > 2$	12.32	13.39	$r = 2$	$r = 3$	21.33	26.7
$r \leq 3$	$r > 3$	4.06	10.60	$r = 3$	$r = 4$	6.82	13.31
$r \leq 4$	$r > 4$	1.99	2.71	$r = 4$	$r = 5$	1.99	2.71
Roots of the companion matrix (unrestricted model)							
0.9615, 0.8764, 0.8386, 0.8137, 0.5240, 0.4143, 0.3256, 0.3007, 0.2013, 0.1757							
Residual diagnostics (unrestricted model)							
Lagrange multiplier tests for autocorrelation							
1st order :			$\chi^2_{[10]} = 12.42,\ p = 0.28$				
Jarque-Bera test for normality			$\chi^2_{[10]} = 17.73,\ p = 0.12$				
Equation-Specific Diagnostics							
			ARCH(1)				**Jarque-Bera Test**
			ARCH(1)				**Jarque-Bera test**
TFR			6.456				0.697
HP			3.329				5.455
FLFPR			2.828				0.109
FW			4.076				3.851
MW			7.096				6.474

*Significant at the 10% level. CV = critical value.

TABLE 4
Estimates of Cointegration Equation and Adjustment Parameters

TFR	HP	FLFPR	FW	MW
Cointegrating equation				
1.000	0.449* (0.143)	0.520* (0.102)	0.322 (0.286)	−0.338* (0.065)
Adjustment parameters				
−0.117* (0.066)	−0.145* (0.079)	−0.049 (0.034)	0.009 (0.089)	−0.141* (0.070)

Notes: Values given are coefficients (SE).
*Significant at the 10% level.

accounted for by the HP inflation in Hong Kong in the past four decades.[13] Furthermore, the crucial role that the HP has played in the fertility decline story is also evident in Figure 4, in which we have shown actual fertility rates, the fitted values of TFRs with actual housing prices, and the fitted values when the HP is held constant at 1971. From this figure, we can see that the actual fertility rates and fitted values with rising housing prices are very close and that the decrease of TFRs would be rather modest in the absence of HP inflation.

The regression equations above are in quasi-reduced form, and thus, the estimated effect of HP on fertility may have picked up other neglected factors. For example, Kohler (2001) has formulized a "social interaction" model, and Montgomery and Casterline (1993) and Montgomery and Chung (1998) have tried to explain the fertility transition by a social interaction mechanism in Taiwan and South Korea. However, in the social interaction story, some economic shocks are needed to decrease the fertility rate to pass a "threshold" before the social interaction mechanism to reinforce this fertility decrease process. Thus, the HP inflation could be regarded as a triggering force underlying the fertility decrease in Hong Kong, and the estimated effect of HP may have subsumed the social interaction effect.

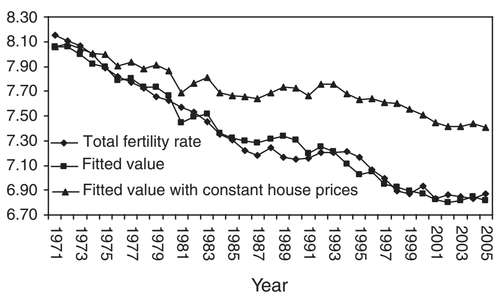
Second, as expected, TFR is inversely correlated to FLFPRs, and a 1% increase in FLFPRs reduces the TFR by 0.52%. Although the elasticity of TFR with respect to FLFPRs is marginally larger than its elasticity with respect to HPs, the total effect of HP inflation on fertility behavior is much larger than the effect of the increase of FLFPRs because HP has increased by almost 550% in the past four decades, while the FLFPRs have increased by only 20.93%. In fact, in contrast to the dominant effect of HP on fertility, the increase of FLFPRs can account for only 7.74% of the fertility decline in Hong Kong.[14]

Third, Table 4 shows a negative effect of FW rates on fertility, though it is statistically insignificant at the 10% level. In fact, while it is often believed that the substitution effect of the FW dominates its income effect and there should thus be a negative wage effect on fertility, empirical evidence is inconclusive (Arroyo and Zhang 1997). For example, Tasiran's (1995) empirical study on Swedish women's fertility behavior has shown an insignificant FW effect. When Macunovich (1995) reestimates the Butz and Ward's (1979) fertility model extending the data coverage to 1989, she also finds an insignificant FW effect. Macunovich (1996, 1998) has even found a significantly positive FW effect on fertility during the period of 1974–1993 in the United States. She proposes that the institutional changes in the labor market, such as the availability of childcare and the rising education and employment opportunities for women, has disconnected the direct relationship between the wife's time and childrearing to a certain extent. Thus, the substitution effect of FWs on fertility could be dampened to be insignificant by its income effect. Essentially, the

13. Since the TFR is 3,459 and 966 and the HP index is 0.13 and 0.84 in 1971 and 2005, respectively, and the elasticity of TFR with respect to HP is −0.45, we can calculate the part of the fertility decline that can be accounted for by the HP inflation as −0.45[ln(0.84) − ln(0.13)]/[ln(966) − ln(3,459)], which equals 65.82%.

14. Following the same method as in Footnote (13), the part of the fertility decline accounted for by the increase of FLFPRs can be easily derived as −0.52[ln (0.52) − ln(0.43)]/[ln(966) − ln(3,459)], which equals 7.74%.

FIGURE 4
The Simulation of TFR
Note: All series are in logarithmic form.



behavior of women is becoming more like that of men.

This hypothesis seems especially appropriate in the Hong Kong context where there is a highly developed foreign domestic helper (FDH) market. On the one hand, because the labor cost of the Indonesians, the Philippines, and other FDHs is much lower than the average wage in Hong Kong, a significant proportion of families can afford a domestic helper.[15] On the other hand, because the minimum allowable wage for FDHs is much higher in Hong Kong than in neighboring countries, the "endless" supply of FDHs has resulted in an effectively pegged minimum wage system for them. Thus, the large number of FDHs has really constituted a segmented labor market in Hong Kong where wages of FDHs do not follow changes in FWs in the local labor market. Finally, column 5 in the upper panel of Table 4 indicates fertility rates are positively related to MW rates, which is mainly attributed to the dominant income effect of the MW rate.

The estimated adjustment parameters, that is, the vector of $\boldsymbol{\delta}$ in Equation (5), with their asymptotic SE, are reported at the bottom panel of Table 4. These parameters indicate how their corresponding variables respond to the disequilibrium of the cointegrating relation. First, the significant adjustment coefficients on TFR and HPs imply that both variables are sensitive to the disequilibrium of the cointegrating relation. Second, the insignificant adjustment coefficients on both the FLFPRs and the FW rates suggest that these two variables form their own stochastic trends, respectively, and can be treated as weakly exogenous variables in this equation. Finally, considering that the FLFPR is unusually low in Hong Kong and that males take the primary responsibility in providing financial support for the households, the significant adjustment coefficient on MW rates indicates that it is sensitive to the disequilibrium of the cointegrating relation in the long run.

15. The total number of FDH, for example, was 237,104 in Hong Kong in 2002, accounting for about 7% of the total labor supply and 16% of female labor supply (Hong Kong Task Force on Population Policy 2003).

VI. ROBUST TESTS

A. An Alternative Model Specification

Since the maximum eigenvalue statistics in Table 3 indicate the existence of two cointegrating vectors at a significance level of 10%, we also conduct a cointegration analysis under an alternative model specification with two cointegrating vectors as a robust test. The result is reported in Table 5. To satisfy the identification condition arising from more than one cointegrating equation, as in McNown and Rajbhandary (2003), we exclude FLFPRs in the fertility equation and exclude fertility rates in the female labor supply equation. These two restrictions are sufficient in identifying both the fertility and the female labor supply equations simultaneously (Enders 2004).

The upper panel of Table 5 presents the coefficients in the two cointegrating equations with SE in parentheses. In the fertility equation (row 1 in the upper panel), first, it is reassuring to find that the HP is still negatively correlated with fertility rates, which is statistically significant at a high level. In addition, the magnitude of the estimated effect of HPs on fertility rates remains largely the same compared to its counterpart in Table 4. Hence, we conclude that our estimated effect of HPs on fertility rates is robust to this alternative model specification. Second, note that the estimated coefficient on FW rates in the fertility equation is still statistically insignificant when the FLFPR is excluded. This may give us more confidence on the vitality of a segmented FDH market discussed above. Finally, the MW rate is positively correlated with fertility rates, though its coefficient is only marginally significant at the 10% level.

TABLE 5
Estimates of Cointegration Equations and Adjustment Parameters with Two Cointegrating Relations

TFR	FLFPR	HP	FW	MW
Cointegrating equations				
1.000		0.461* (0.168)	0.203 (0.179)	−0.263* (0.160)
	1.000	−0.101* (0.051)	−1.335* (0.442)	1.352* (0.397)
Adjustment parameters				
−0.208* (0.068)	−0.038 (0.041)	−0.082* (0.042)	0.008 (0.104)	−0.113 (0.081)
−0.398* (0.236)	−0.165* (0.107)	−0.812* (0.354)	−0.128* (0.397)	−0.657* (0.343)

Notes: Values given are coefficients (SE).
*Significant at the 10% level.

As for the female labor supply equation (row 2 in the upper panel), the HP is positively correlated with the FLFPR. Higher HPs decrease fertility rates and thus induce more females into the labor market. As expected, the estimated coefficients on FW and MW rates indicate that the former is positively correlated with female labor supply and the latter is negatively correlated with it.

B. Alternative Measures of Fertility Rates

As a highly open urban city, one distinct feature of Hong Kong is its voluminous migration, which may underestimate the data coverage in compiling fertility statistics in Hong Kong. For example, with the economic and social integration between Hong Kong and its neighboring regions in mainland China, Hong Kong has "exported" a large scale of marriages and births to mainland China.[16] Before 2005, these live births born outside Hong Kong to Hong Kong residents were not included in the compilation of its fertility statistics. Thus, to better reflect the actual fertility situation of Hong Kong and for the purpose of projections and planning, the Census and Statistics Department of Hong Kong enhanced the compiling approach of fertility statistics in 2005. Compared to the previously released TFR, the RTFR covers three additional classes of live births: those born in Hong Kong to mainland women whose spouses are Hong Kong residents, born in Hong Kong with both parents being Chinese nationals but not Hong Kong residents, and born outside Hong Kong to Hong Kong residents.

The fertility rate for our purpose could be constrained to those live births to women living in Hong Kong because they are the ones experiencing the housing and labor market changes in Hong Kong. However, most of the children born outside Hong Kong whose mothers or fathers are permanent residents of Hong Kong have immigrated to Hong Kong before entering primary schools because of the superiority of the Hong Kong education and welfare systems. Hence, the HP inflation will also affect their parents' fertility behavior, and the TFR should include these children as well. Based on this enhanced approach, the fertility statistics have been revised from 1996 by the Census and Statistic Department of Hong Kong. Table 6 presents the number of births of these three classes and compares the RTFR with the previously released TFR. It is demonstrated in Table 6 that the number of live births born in Hong Kong to mainland women exhibited an increasing trend, while the number of live births born outside Hong Kong to Hong Kong residents decreased steadily, which is consistent with the trend in the number of applications for the Certificate of Absence of Marriage Records.

To test the robustness of the results of the cointegration analysis in the previous section, we conduct a sensitivity analysis by employing the RTFR and the CBR as alternative measures for TFR.[17] The selection of CBR is based on the

16. Although we lack the exact statistics of this kind of marriages and births taking place in the Mainland, the number of successful applications for the Certificate of Absence of Marriage Records for marriage purposes are 21,655, 23,901, 27,864, 17,729, 15,028, and 14,847 from 1995 to 2001 (Hong Kong Task Force on Population Policy 2003). However, these numbers only account for part of legal crossboundary marriages; we still cannot reveal the extent of illegal crossboundary marriages and births.

17. The CBR refers to the number of live births in a calendar year to the midyear population.

TABLE 6
Enhancement of Data Coverage and RTFRs, 1996–2004

Year	Class 1	Class 2	Class 3	TFR	RTFR
1996	6,494	3,653	—	1,166	1,191
1997	5,830	3,619	—	1,095	1,127
1998	6,015	2,981	—	990	1,017
1999	7,081	2,359	—	965	982
2000	8,032	2,208	—	1,024	1,035
2001	7,539	2,034	169	927	932
2002	7,433	1,694	876	939	959
2003	8,240	1,553	1,622	901	941
2004	9,285	1,588	3,630	927	927

Notes: Data source: The fertility trend in Hong Kong, 1975–2004. Hong Kong Monthly Digest of Statistics, April 2005. Class 1 refers to the number of live births born in Hong Kong to Mainland women whose spouses are Hong Kong residents; Class 2 refers to the number of births born outside Hong Kong to Hong Kong residents; and Class 3 refers to the number of live births born in Hong Kong with both parents being Chinese nationals but not Hong Kong residents. The Court of Final Appeal ruled in July 2001 that babies born in Hong Kong to Chinese nationals have the right of abode in Hong Kong, so Class 3 begins in 2001.

following two considerations: (1) the CBR is also a measure of fertility behavior in common practice and (2) the extent to which CBR is affected by the enhancements made to the compilation of fertility statistics is less severe than TFR by definition. Table 7 reports the results of the robust test of alternative measures of fertility rates in which the methodology employed is the same as in previous sections. The upper panel of Table 7 presents the results of the cointegration test, cointegrating vector, and adjustment parameters by using RTFR. Comparing to Tables 3 and 4, these results have exhibited little change. Intuitively, this conclusion can be expected in the comparison between column 5 and column 6 in Table 6 in which the enhancement of data coverage does not change the previously released TFR too much. Even in 1997, the year when the gap between TFR and RTFR is the biggest, the difference between these two measures is only 32, which is about 3.08% of the TFR in 1997.

The lower panel of Table 7 presents the results of cointegration analysis by using CBR as an alternative measure. Three points are worth noting. First, although the magnitude of the estimated coefficient on the HP in the equation for CBR has decreased to 0.26, it is still significance at the conventional level of 10%. Second, both the maximum eigenvalue test and the trace test unequivocally indicate the existence of only one cointegrating vector at the significance level of 10%, which confirms the judgment we have made in Section V. Third, both the estimated coefficient and the adjustment parameters on the FLFPRs are insignificant. One possible explanation is the tardiness of FLFPRs responding to the economic boom, which can be detected from Figure 2.

To sum up, the results of cointegration analysis in the previous section are robust to an alternative model specification with two cointegrating equations and to alternative measures of TFRs. Consistent with the theoretical prediction, our cointegration analysis shows that the HP inflation has played a crucial role in the drastic decrease of fertility rates in Hong Kong during the past four decades.

VII. CONCLUSIONS

This article extends a standard Beckerian model of fertility behavior to formulate the effect of HP inflation on fertility. The simple model predicts not only a negative income effect of HPs on the number of children born in a representative household but also a negative compensated substitution effect, which reinforces the negative income effect. Considering the nonstationarity and endogeneity of the variables in the fertility equation, the cointegration analysis is applied to annual data at the aggregate level covering the period from 1971 to 2005 in Hong Kong to empirically examine the negative effect of HPs on fertility in the long run. Consistent with the theoretical prediction, one cointegrating vector has been found and identified as the fertility equation in the equilibrium path in which a 1% increase of HPs significantly decreases the TFRs by 0.45%. It implies that high HP inflation can account for about 65% of the drastic fertility decrease in Hong Kong for the past four decades. This finding is robust in the sensitivity tests with an alternative model specification and alternative measures of TFRs.

The most interesting and valuable insight of this article is the perception of the crucial role played by the HP in the drastic decrease of fertility rates in a highly open economy, Hong Kong. The incorporation of HPs into the fertility equation may extend our understanding

TABLE 7
Sensitivity Analysis of Alternative Measures of Fertility Rates

H_0	Maximum Eigenvalue	Trace	Cointegrating equation				
r	**Statistics**	**Statistics**	**RTFR**	**HP**	**FLFPR**	**FW**	**MW**
0	26.61*	68.35*	1.000	0.450* (0.156)	0.513* (0.079)	0.314 (0.267)	−0.341* (0.075)
1	20.91*	41.74		(0.156)	(0.079)	(0.267)	(0.075)
2	12.63	20.83	Adjustment parameters				
3	4.46	6.2	−0.120* (0.071)	−0.137* (0.063)	−0.051 (0.034)	0.016 (0.091)	−0.132* (0.081)
4	1.74	1.74	(0.071)	(0.063)	(0.034)	(0.091)	(0.081)
H_0	**Maximum Eigenvalue**	**Trace**	**Cointegrating equation**				
r	**Statistics**	**Statistics**	**CBR**	**HP**	**FLFPR**	**FW**	**MW**
0	21.43*	66.07*	1.000	0.264* (0.103)	0.472 (0.358)	0.153 (0.317)	−0.511* (0.009)
1	16.98	39.87		(0.103)	(0.358)	(0.317)	(0.009)
2	11.06	19.25	Adjustment parameters				
3	5.13	5.92	−0.073* (0.029)	−0.069* (0.036)	−0.031 (0.027)	0.108 (0.425)	−0.088* (0.023)
4	1.09	1.09	(0.029)	(0.036)	(0.027)	(0.425)	(0.023)

Notes: SE are presented in parentheses. The null hypothesis and the critical value at the significance level of 10% are the same as in Table 3. The definition and construction for the alternative measures of fertility rate are given in Table A1.

*Significant at the 10% level.

of the mechanism underlying the demographic transition coinciding with industrialization. The main results of this article may also shed new light on the reconsideration of continuing the "one child policy" in mainland China, which, enacted in 1979, has drawn strong criticism (Chow 2002). Since HPs have been soaring beginning from the late 1990s, especially in the urban and coastal areas in China, the high inflation of HPs will change the household's budget constraint and may spontaneously induce a demographic transition. The remaining question is whether the results derived from a metropolis such as Hong Kong could be extended to a country with a vast territory and with the largest population in the world.

APPENDIX

TABLE A1

Data Sources

TFR	Total fertility rate
	1971–2005: http://www.censtatd.gov.hk/hong_kong_statistics
RTFR	Revised total fertility rate
	1971–1996: http://www.censtatd.gov.hk/hong_kong_statistics
	1996–2004: Hong Kong, Census and Statistics Department (2005), The fertility trend in Hong Kong, 1975–2004
	Hong Kong Monthly Digest of Statistics, 2005
	2005: Hong Kong, Census and Statistics Department, Hong Kong Monthly Digest of Statistics, 2005
CBR	Crude birth rate
	1971–2005: http://www.censtatd.gov.hk/hong_kong_statistics
HP	House price index, base year is 2000
	Composite of consumer prices index (CPI) A: house price indices
	1971–2004: http://www.censtatd.gov.hk/hong_kong_statistics
	2005: Hong Kong, Census and Statistics Department (2005), Hong Kong Monthly Digest of Statistics, 2005
FLFPR	Female labor force participation rate
	1971–1981: EconDB in the Department of Economic, Chinese University of Hong Kong
	1982–2005: http://www.censtatd.gov.hk/hong_kong_statistics
FW	Average real daily wages of female workers engaged in government building and construction projects, base year is 2000
MW	Average real daily wages of male workers engaged in government building and construction projects, base year is 2000
	1971–2004: http://www.censtatd.gov.hk/hong_kong_statistics
	2005: Hong Kong, Census and Statistics Department (2005), Hong Kong Monthly Digest of Statistics, 2005

TABLE A2

OLS Estimates of the Effect of the HP on the TFR

	Dependent Variable: TFR	
HP index	−0.365* (6.26)	−0.314* (3.85)
FLFPR	−2.397* (5.57)	−2.150* (3.55)
FW rate	−0.618 (1.55)	−0.57 (1.42)
MW rate	0.620 (1.35)	0.687 (1.60)
Time trend		−0.009 (0.66)
Constant	4.971* (4.81)	21.737 (0.85)
Observations	35	35
R^2	.97	.97

Notes: Robust *t* statistics are in parentheses; both the dependent and independent variables are transformed into logarithmic form; hence, the coefficients should be interpreted as elasticities.

*Significant at the 1% level.

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