Working Paper Series

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Working Paper 03-4

August 2003

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Abstract

The inflation rate in Japan has been decreasing since the beginning of the 1990s. Although weak domestic demand most probably explains a large part of the story of this deflationary trend, external factors such as the recent increase in the number of cheap imported goods, have played an important role. In fact, the import penetration ratio in Japan has been increasing since the beginning of the 1990s. This paper empirically analyses the dynamics of sectoral trade patterns and the aggregate import penetration ratio by considering both macroeconomic factors (expected changes in common technologies and unexpected changes in sector specific technologies) and sector-specific factors (changes in the levels of comparative advantage). The empirical analysis successfully explains the rise in the Japanese import penetration ratio during the 1990s.

Key Words: Deflation, Import penetration, Trade patterns, Technology changes.

JEL Classification: F14, F41.

*We would like to thank Anton Braun, Hijiri Matsubara, Tetsuji Sonobe, the seminar participants at Kansai University, Osaka University, Japan Economic Association 2003 Spring Meetings, and the staff of the Bank of Japan for their insightful comments. We would also like to thank Masahiro Kawai and Li-Gang Liu for helpful discussions. Views expressed in this paper are those of the authors and do not necessarily reflect those of the Bank of Japan or the Research and Statistics Department, Bank of Japan. We are responsible for all remaining errors.

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1 Introduction

The inflation rate in Japan has been decreasing since the beginning of the 1990s. Although weak domestic demand most probably explains a large part of the story of this deflationary trend, external factors such as the recent increase in the number of cheap imported goods, have played an important role.[1] In fact, the import penetration ratio in Japan has been increasing since the beginning of the 1990s (see Figure 1). This fact has called policy makers' attention to the analysis of an import penetration ratio. Also, a change in the import penetration ratio can represent a structural change in the coefficient on import prices in the traditional Phillips curve. It is, thus, important for policy makers to understand the dynamics of an import penetration ratio.

To analyse the dynamics of an import penetration ratio of an economy,

[1] This paper analyses the factors that contribute to the changes in the import penetration ratio, but it does not examine the link between the import penetration ratio and the inflation rate. Kamada and Hirakata (2002) investigate the relationship between an import penetration ratio and the deflationary pressure in Japan from 1980 to 2001 and show that changes in international competitiveness played a significant role in creating the deflationary pressure. Kamada and Hirakata (2002) construct the SVAR model which consists of 3 variables (an import penetration ratio, CPI, and real output) and break down Japan's inflation rate into three kinds of structural shocks: comparative advantage shcoks, global productivity shocks, and cyclical demand shocks.

One noticeable difference between Kamada and Hirakata (2002) and this paper lies in the way of measuring changes in comparative advantage. Kamada and Hirakata (2002) obtain the comparative advantage shocks that are implicitly derived from the fluctuations of the three variables (the import penetration ratio, CPI, and real output), but this paper directly calculates the comparative advantage changes by using the data on sectoral productivities across countries.

we need to understand how sectoral trade patterns change over time. Two factors should have effects on sectoral trade patterns over time: macroeconomic factors and sector-specific factors. However, these two types of factors have rarely been used together in order to analyse the dynamics of sectoral trade patterns. The macroeconomic factors have usually been used as a tool to analyse changes in an economy-wide trade pattern and the sector-specific factors used as a tool to analyse the cross-sectional behaviour of sectoral trade patterns.

A large literature uses an intertemporal approach to analyse the dynamics of an economy-wide trade balance.[2] Recently, Obstfeld and Rogoff (1997, Ch.2), Glick and Rogoff (1995), and İşcan (2000) have developed models that show the effects of macroeconomic technology shocks on the overall current account balance and investments. Their approach is attractive because the models are analytically tractable and empirically testable.

The essential concept in the cross-sectional analysis of trade patterns is comparative advantage. The most basic theory of comparative advantage is the Ricardian trade theory. The Ricardian models, e.g., Dornbush, Fischer, and Samuelson (1977) and Matsuyama (2000), focus on the role of technologies.[3] The basic prediction of the Ricardian trade theory is that countries

[2] For example, see Sachs (1981).

[3] Dornbush, Fisher and Samuelson (1977) and Matsuyama (2000) also consider demand

tend to export goods produced by those sectors with higher productivities (technologies) relative to other sectors. The Ricardian trade theory leads us to broadly expect that those sectors with higher productivities (technologies) relative to other sectors are likely to be a net exporter even if the overall trade balance is zero. The empirical evidence of the Ricardian theory of comparative advantage has been provided by many studies, which include MacDougall (1951), Stern (1962), Balassa (1963), Golub (1994), and Golub and Hsieh (2000).

In this paper, we combine the macroeconomic factors and the sector-specific factors and empirically analyse the dynamics of sectoral trade patterns and an aggregate import penetration ratio. We make a distinction between the technologies common to all sectors and the technologies specific to each sector. Common technologies represent the macroeconomic factors and the sector specific technologies represent the sector-specific factors. We also decompose the changes in common technologies into two parts: the expected changes in common technologies and the unexpected changes in common technologies.[4] These two types of changes in common technologies have different effects on the dynamics of sectoral trade patterns. The theoretical

effects on sectoral trade patterns, e.g., the effect of a sclae of an economy.

[4] We follow Glick and Rogoff (1995), and Obstfeld and Rogoff (1997, Ch.2) and use a simplified version of their models.

predictions are as follows: (i) the growth rates of sectoral export/import ratios are positively correlated with the growth rates of the levels of comparative advantage, (ii) the growth rates of sectoral export/import ratios are positively correlated with the expected growth rates of common technologies, and (iii) the growth rates of sectoral export/import ratios are negatively correlated with the unexpected growth rates of common technologies.

To test these theoretical predictions, we use the panel data on manufacturing industries and undertake the empirical analysis of the dynamics of Japanese sectoral trade patterns. All the coefficient estimates are significant and they enter as theoretically predicted. We also successfully explain the rise in the Japanese import penetration ratio during the 1990s.

Section 2 describes the specification for the regression analysis and section 3 shows the empirical results. Section 4 concludes the paper.

2 The Regression Specification

In this section, we explain our regression specification. We, then in the next section, perform the regression analysis of the dynamics of sectoral trade patterns and use the obtained estimates to analyse the dynamics of an import penetration ratio.

We argue that technology changes have significant effects on the dynamics of sectoral trade patterns. We make a distinction between the technologies common to all sectors and the technologies specific to each sector. Appendix A shows the theoretical details. In Appendix A, we develop a simple general equilibrium model and obtain the following specification which describes the relationship between the dynamics of sectoral trade patterns and technology changes (i and t denote the sector and time respectively):

$$\begin{aligned}\triangle \ln \left(\frac{Export}{Import}\right)^{JPN}_{i,t} &= cnt + \alpha_{1,i}\, \Delta \ln \left(\frac{A^{JPN}_{i\ SP}}{A^{World}_{i\ SP}}\right)_{t-1} + \alpha_{2,i}\, \Delta \ln A^{UN}_t \\ &\quad + \alpha_{3,i}\, \Delta \ln A^{E}_t + \alpha_{4,i}\, \Delta REXRT_t + e_{i,t}\ , \qquad (1)\end{aligned}$$

where $\left(\frac{Export}{Import}\right)^{JPN}_{i,t}$ is Japanese sectoral export/import ratio, $A^{JPN}_{i\ SP,t-1}$ is the Japanese sector specific technology, $A^{World}_{i\ SP,t-1}$ is the world sector specific technology (note that world here means all countries except Japan), $\Delta \ln A^{UN}_t$ is the unexpected part of growth rate of the Japanese common technology level A^{JPN}, $\Delta \ln A^{E}_t$ is the expected part of growth rate of the Japanese common technology level A^{JPN}, $\Delta REXRT_t$ is the change in the real effective exchange rate (measured in terms of the Japanese price level), cnt is the constant term and e is the error term.

The term $\frac{A^{JPN}_{i\ SP}}{A^{World}_{i\ SP}}$ measures Japanese sector i's relative productivity in terms of the world and thus shows the level of Japanese sector i's comparative advantage. An increase in $\frac{A_{i\ SP}^{JPN}}{A_{i\ SP}^{World}}$ implies an increase in the level of Japanese sector i's comparative advantage. As various empirical studies show, we expect $\alpha_{1,i}$ to be positive in equation (1).[5] The Ricardian theory of comparative advantage predicts that those sectors with higher productivities (technologies) relative to other sectors tend to be a net exporter even if the overall trade balance is zero. Strictly speaking, the Ricardian model predicts that countries specialize completely. We can, however, allow for incomplete specialization even in a Ricardian context by assuming that products are to some extent distinguished by place of production.[6] Note that we use the lags of the sector specific technologies to allow for the slow adjustment as Golub and Hsieh (2000).[7]

The terms $\Delta \ln A_t^{UN}$ and $\Delta \ln A_t^{E}$ capture macroeconomic effects on the dynamics of sectoral trade patterns. The intuitive explanation is as follows.[8] The unexpected increase in the common technology level (i.e., the unexpected increase in income) raises the expected value of permanent income so that consumption increases. Assuming that the unexpected increase

[5] See Appendix A for the details.

[6] This assumption was first suggested by Armington (1969).

[7] We chose one period lag by using the Schwarz information criterion (the maximum number of lags we take is four).

[8] See Appendix A for the details.

in the common technology level raises consumption more than output (see the specification of technological progress used in Appendix A), national savings decrease and the trade balance worsens. On the other hand, the expected increase in the common technology level (i.e., the expected increase in income) does not affect the expected value of permanent income so that consumption does not change. Since income increases but consumption stays at the same level, national savings increase and the trade balance improves. Thus, we expect $\alpha_{2,i}$ ($\alpha_{3,i,}$) to be negative (positive) in equation (1).

We include the changes in real effective exchange rates in equation (1) to allow for the possibility of imperfect flexibility of prices.[9] That is, the levels of prices are assumed not to adjust completely to the levels that ensure general equilibrium. When supply factors change, prices instantaneously change, by a large but not a full amount, to adjust to the new equilibrium levels. Since the prices do not adjust completely, they change over time to eliminate the still remaining gaps between the new equilibrium levels and the current levels. Thus, if prices are not perfectly flexible, the sectoral export intensity changes over time not only due to changes in supply factors, but also due to the changes in prices, i.e., the adjustments of prices which

[9] The model in Appendix A assumes that prices are perfectly flexible so that the economies are always in general equilibrium. Thus, prices do not have any effects on the changes in sectoral trade patterns.

are needed to eliminate the gap between the equilibrium price levels and the current price levels.[10] Since it is difficult to observe sectoral relative Japanese price levels in terms of the world, we use the real effective exchange rates and let the coefficient of $\Delta REXRT_t$ vary across sectors. We expect $\alpha_{4,i,} < 0$ since an increase in $\Delta REXRT_t$ implies the real appreciation.

We next explain some important points in obtaining the variables included in the estimated equation (1).[11] $\triangle \ln \left(\frac{Export}{Import}\right)_{i,t}^{JPN}$ and $\Delta REXRT_t$ are straightforward to measure. To find $\Delta \ln A_t^{UN}$ and $\Delta \ln A_t^{E}$, we first measured the (total) manufacturing sector's growth rates of technologies both in Japan and the world by constructing Solow residuals.[12] We then regressed the Japanese technology growth rate $\Delta \ln A_t^{JPN}$ on the world technology growth rate $\Delta \ln A_t^{World}$ and treated the residual as the Japan specific technology growth rate, $\Delta \ln A_t^{JPN\ SP}$. We then estimated $\Delta \ln A_t^{JPN\ SP}$ in the AR process and treated the residual as $\Delta \ln A_t^{UN}$ and the predicted value as $\Delta \ln A_t^{E}$.[13] To measure $\Delta \ln \left(\frac{A_{i\ SP}^{JPN}}{A_{i\ SP}^{World}}\right)_t$, we first calculated the Solow resid-

[10] We could also argue that the real effective exchange rate captures the effects of demand shocks. As to the justification of including the real effective exchange rate in our regression specification, we largely benefitted from discussions with Tetsuji Sonobe and Anton Braun.

[11] See Appendix C for details of the data.

[12] As in Glick and Rogoff (1995), we calculated the Solow residuals without adjusting for capacity utilization. Thus, to some extent, the residuals could reflect demand effects. Especially, the expected increase in the common technology level could largely represent a fluctuation of demand. Backus, Kehoe, and Kydland (1992), however, argue that adjusting for capital inputs does not produce radically different results based upon the U.S. data. They argue that this is because short-run fluctuations of capital are small relative to short-run fluctuations of labour.

[13] We chose one period lag by using the Schwarz information criterion (the maximum

ual for each manufacturing sector i both in Japan and the world, $\Delta \ln A_{i,t}^{JPN}$ and $\Delta \ln A_{i,t}^{World}$. Since $\Delta \ln A_{i\,SP,t}^{JPN}$ and $\Delta \ln A_{i\,SP,t}^{World}$ are the growth rates which are orthogonal to $\Delta \ln A_t^{JPN\ SP}$ and $\Delta \ln A_t^{World}$ respectively, we regressed $\Delta \ln A_{i,t}^{JPN}$ ($\Delta \ln A_{i,t}^{World}$) on $\Delta \ln A_t^{JPN\ SP}$ ($\Delta \ln A_t^{World}$) and treated the residual as $\Delta \ln A_{i\,SP,t}^{JPN}$ ($\Delta \ln A_{i\,SP,t}^{World}$).

3 The Regression Analysis

In this section we perform a panel regression analysis of the dynamics of Japanese sectoral trade patterns. Equation (1) is the base for our empirical analysis.

We use the panel data on manufacturing sectors. The details of the data descriptions are in Appendix C. We use the Trade and Production Database and OECD STAN (ISIC Rev.3). The sample period is from 1977 to 2000 (for the following regression analysis, we use the data only for the period between 1977 and 1997), and the time frequency is annual. The countries included in the sample for the period of 1976-1997 are: Austria, Canada, China, Denmark, Spain, Finland, U.K., Greece, Hong Kong, Indonesia, Ireland, Japan, South Korea, Malaysia, Netherlands, Norway, Philippines, Portugal,

number of lags we take is four). The estimation results are as follows: $\Delta \ln A_t^{JPN\ SP} = \underset{(0.010)}{-0.004} + \underset{(0.146)}{0.378} \Delta \ln A_{t-1}^{JPN\ SP}, DW = 2.05$ where parentheses show heteroscedasticity and autocorrelation consistent standard errors.

Singapore, Sweden, and U.S.A. Due to availability of the data, China, Hong Kong, Indonesia, Malaysia, Philippines, and Singapore are excluded from the sample for the period of 1998-2000.

To estimate equation (1), we, as in İşcan (2000), use the Swamy random coefficient GLS estimator. That is, we treat the coefficients in equation (1) as random and different. The first reason we treat them as random and different is that we do not have any priori belief that the coefficients are systematically different across sectors. The second reason is purely for convenience. By applying the random and different coefficient specification, we can reduce the number of parameters to be estimated substantially compared with the fixed and different coefficient specification, but we can still allow the coefficients to vary.

Defining α_i as the coefficient vector (5×1) for the i th sector (including the constant term), the underlining assumptions of the random coefficient specification are:

$$\alpha_i = \overline{\alpha} + \nu_i \ , \ E(\nu_i) = 0, \ E(\nu_i \, \nu_i^{'}) = \Gamma \text{ and } E(e_i \ e_i^{'}) = \sigma_i^2 I_t$$

If Γ is small, the coefficients will be almost identical. We first estimate the group mean coefficients $\overline{\alpha}$ by using the Swamy random coefficient GLS estimator and then test whether the coefficients are the same across sectors.

The results are reported in Table 1.[14]

According to Table 1, all the coefficients enter as the model predicts (the model predicts that $\widehat{\alpha}_{1,i} > 0$, $\widehat{\alpha}_{2,i} < 0$, $\widehat{\alpha}_{3,i} > 0$, and $\widehat{\alpha}_{4,i} < 0$). The coefficient estimates for the change in the level of comparative advantage, the unexpected growth rate of the Japanese common technology level, and the real exchange rate change enter at the 5-percent significance level. The coefficient estimate for the expected growth rate of the Japanese common technology level enter at the 10-percent significance level. The Swamy statistic rejects the null hypothesis of coefficient homogeneity across sectors at the 5-percent significance level. Thus, it suggests that the Swamy random coefficient model is the appropriate way to estimate the group mean effects of the independent variables on the dependent variable. Since the null hypothesis of coefficient homogeneity across sectors is rejected, it is important to know the differences across sectors.[15] Table 2 reports the predicted coefficients for each sector. According to Table 2, there are large differences in the predicted coefficients across sectors. The interesting finding is that $\widehat{\alpha}_1$s

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[14] We exlcuded oil-intensive industries from the sample.

[15] Lee and Griffiths (1979) and Hsiao (1989) show that the predicted individual coefficients, α_i is given by:

$$\widehat{\alpha}_i = \widehat{\widehat{\alpha}} + \widehat{\Gamma} X_i^{'} (X_i \widehat{\Gamma} X_i^{'} + \widehat{\sigma}_i^2 I_t)^{-1} (Y_i - X_i \widehat{\widehat{\alpha}}),$$

where X_i is the matrix of the time-series observations of the ith individual's independent variables and Y_i is the vector of the time-series observations of the ith individual's dependent variable. $\widehat{\widehat{\alpha}}$, $\widehat{\Gamma}$, and $\widehat{\sigma}^2$ are the estimates obtained by the Swamy random coefficient model. Table 2 shows the predicted coefficients for each sector.

of the fabricated metal sector, non-electrical machinery sector, and electrical machinery sector are considerably larger than those of other sectors. That is, the comparative advantage effects on the export intensity are larger in the fabricated metal sector, non-electrical machinery sector, and electrical machinery sector.

Next, by using the previous empirical estimates, we decompose the changes in Japanese aggregate import penetration ratio into contributions from the changes in the levels of comparative advantage, the unexpected changes in the Japanese common technology level, the expected changes in the Japanese common technology level, and the changes in real effective exchange rates. Since the data for calculating the levels of comparative advantage are not available for the 1998-2000 period for several countries (including China), the decomposition for the period is, therefore, done by using the values forecasted by the time-series method.

Figures 2-5 show the contributions from each variable individually: the changes in the levels of comparative advantage, the unexpected changes in the Japanese common technology level, the expected changes in the Japanese common technology level, and the changes in real effective exchange rate. Figure 6 shows the contributions from all the variables together. Due to data availability, some Asian countries (including China) are not included to calculate the levels of comparative advantage across Japanese manufacturing sectors for the period of 1998-2000. Note that, to calculate the fitted values of the changes in the aggregate import penetration ratio, we weighted each sector's fitted import penetration ratio with the corresponding consumption goods share in total production. This is because policy makers are usually more concerned about the inflation rates measured by using the CPI. Appendix D shows how to calculate the fitted values of changes in the aggregate import penetration ratio.

Figure 6 reveals several points. First, the increases in the aggregate import penetration ratio from 1992 to 1995 are mainly due to the changes in real effective exchange rates, the changes in the levels of comparative advantage across sectors, and the expected changes in common technologies. Second, the increases in the aggregate import penetration ratio after 1998 are mainly due to the changes in real effective exchange rates, the changes in the levels of comparative advantage across sectors, and the unexpected changes in common technologies. Third, the effects of the changes in real effective exchange rates are larger after 1998 than in the period of 1992-1995.

Figures 7-18 show the factorization of changes in the trade pattern for each manufacturing sector on the basis of the predicted coefficients reported in Table 2.[16] By looking at Figures 7-18, we can find the following points. First, there are substantial decreases in the levels of comparative advantage in the food sector, paper & products sector, fabricated metal products sector, non-electrical machinery sector, and electrical machinery sector in the period of 1992-1995. The decreases in the levels of comparative advantage in those sectors generate large effects on the increases in the aggregate import penetration ratio in the period of 1992-1995 as shown in Figure 6.[17] Second, there are substantial decreases in the levels of comparative advantage in the non-electrical machinery sector and electrical machinery sector after 1998. The decreases in the levels of comparative advantage in those sectors generate large effects on the increases in the aggregate import penetration ratio after 1998 as shown in Figure 6. The reason that we do not observe the decreases in the levels of comparative advantage in the food sector and textile sector in 1999 and 2000 is likely to be due to the exclusion of China and other Asian countries from the 1998-2000 data set.

[16] We produced Figures 7-18 only for those sectors for which all of the data are available in the period of 1998-2000. For some sectors, some variables are omitted in Figures 7-18 since the predicted coefficieints on those variables give a wrong sign in Table 2. However, it turns out that the contribution of omitted variables is rather little to the changes in trade patterns for those sectors.

[17] This does not mean the disappearance of comparative advantage in the food sector, paper & products sector, fabricated metal products sector, non-electrical machinery sector, and electrical machinery sector in the period of 1992-1995. It only implies the decreases in the levels of comparative advantage in those sectors. For example, our calculation shows that the difference in the Japanese productivity growth rate and the world productivity growth rate in the electrical machinery sector is 1.503 in the period of 1977-1997.

4 Conclusion

The analysis of the dynamics of the import penetration ratio can give an important implication to policy makers since the import penetration ratio is one of the factors that have significant effects on the price movement. We empirically analysed the dynamics of sectoral trade patterns and the aggregate import penetration ratio.

The theoretical distinction between the common-technology effects and the sector-specific technology effects made it possible to use a panel data approach to empirically identify the two kinds of effects on the changes in the sectoral trade patterns. The empirical tests based on the panel data on Japanese manufacturing industries show that the changes in sectoral trade patterns are significantly explained by macro-economic factors (both the expected and unexpected changes in common technologies) and sector-specific factors (changes in the levels of comparative advantage). We also successfully explained the rise in the Japanese import penetration ratio during the 1990s: (i) the increases in the aggregate import penetration ratio from 1992 to 1995 are mainly due to changes in real effective exchange rates, changes in the levels of comparative advantage across sectors, and the expected changes in common technologies, and (ii) the increases in the aggregate import penetration ratio after 1998 are mainly due to changes in real effective exchange rates, changes in the levels of comparative advantage across sectors, and the unexpected changes in common technologies.

There are several important aspects to be investigated for future research. Firstly, this paper considers the effects of imperfect flexibility of prices empirically but not theoretically. One might be able to construct the model which can endogenously show the effects of imperfect flexibility of prices on the dynamics of sectoral trade patterns and the aggregate import penetration ratio. Secondly, it might be more desirable to use the technology variables described in this paper to capture the structural changes in the coefficient on import prices in the Phillips curve. It could give more reliable estimates of the Phillips curve. Third, as for the data, the recent increases in imports from China are thought to have played an significant role in the changes in the import penetration ratio. Further availability of the data for China would help us measure the levels of comparative advantage across Japanese manufacturing sectors more precisely.

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Appendix A: The Model

In this section we develop a simple tractable general equilibrium model in which the dynamics of sectoral trade patterns depends on changes in technologies. In order to analyse the technological effects on the dynamics of sectoral trade patterns, we categorize technologies into two types: technologies common to all sectors and technologies specific to each sector.

Section A1 follows Obstfeld and Rogoff (1997, Ch.4). Section A3 is based on Obstfeld and Rogoff (1997, Ch.2) and introduces population growth into their model. Section A4 uses a simplified version of Glick and Rogoff (1995). Based upon the analysis done in sections A1-A4, section A5 explains the dynamics of sectoral trade patterns by considering both technologies common to all sectors and technologies specific to each sector.

In the following model, we assume that firms produce a continuum of goods, indexed by $i \in [0, 1]$ and all the goods are tradable. We also assume zero transportation costs and identical international tastes.

A1: Optimal allocation of consumption expenditure

We first look at how households allocate their income across goods at a given point of time and then derive the consumption-based price index.

A consumption index C depends on consumption of every good $i \in [0, 1]$.

The consumption index at time t is defined by:

$$C_t = \exp\left[\int_0^1 \ln C_{i,\,t}\, di\right] \ . \tag{A1}$$

We suppress time scripts in the followings. Taking good 1 as the numeraire, commodity prices P_i are expressed in units of good 1. The consumption-based price index in terms of the numeraire is defined as the lowest possible cost, measured in units of good 1, of purchasing a unit of C. The expenditure allocation problem at a given point of time is, thus, given by:

$$\min_{\{C_i | i \in [0,1]\}} \int_0^1 P_i C_i \, di$$

subject to the constraint:

$$C = \exp\left[\int_0^1 \ln C_i \, di\right] = 1 \ . \tag{A2}$$

Solving this problem yields:

$$P_i C_i = L \ , \tag{A3}$$

where L is the shadow price of the constraint (A2). Equation (A3) implies that every good receives an equal weight in expenditure. Substituting equation (A3) into equation (A2) can yield the consumption-based price index:[18]

$$P = \exp \int_0^1 \ln P_i \, di \ . \tag{A4}$$

A2: Firms' Optimization

We next consider the firm's optimization problem. We assume that firms are homogeneous and perfectly competitive in each sector. That is, firms producing good i can access to the following production function at time t:

$$Y_{i,\,t} = A_{i,\,t} \, N_{i,\,t} = A_t e^{a_{i,t}} N_{i,\,t} \ , \tag{A5}$$

where $Y_{i,\,t}$ and $N_{i,,\,t}$ are output and labour at time t, respectively. We ignore capital stock for simplicity. In equation (A5), we assume that sectoral technologies $A_{i,\,t}$ consist of two types of technologies: technologies specific to each sector and technologies common to all sectors. The term $e^{a_{i,\,t}}$ represents the sector specific technology level and A_t represents the level of technologies common to all sectors. We assume that a_i is randomly distributed across sectors and $\int_0^1 a_{i,\,t} \, di = 0$ holds. a_i is also assumed to follow the random

[18] For details, see Obstfeld and Rogoff (1997, Ch.4).

walk process, i.e., $a_{i,t} = a_{i,t-1} + v_{i,t}$ where v_{it} is a white noise.

Equation (A5) implies that the sector with the higher value of a_i holds the higher level of technologies. Since we assume no adjustment cost, the representative firm's profit maximization problem becomes a static one and the usual equation between the marginal product and the factor price gives:

$$A_t e^{a_{i,t}} = \frac{W_{i,t}}{P_{i,t}} ,$$

where $W_{i,t}$ is the nominal wage of labour in sector i. We assume that labour is homogeneous and inelastically supplied. The labour market clearing condition is, thus, given by:

$$P_{i,t} A_t e^{a_{i,t}} = W_t , \tag{A6}$$

where W_t is the equilibrium nominal wage that is common to all sectors. Equation (A6) can then be rewritten as:

$$A_t \, \mu_t = W_t , \tag{A7}$$

where

$$\mu_t = P_{i,t} \, e^{a_{i,t}}. \tag{A8}$$

Total output in units of good 1 is given by:

$$Y_t = \int_0^1 P_{i,\,t} A_t e^{a_{i,\,t}} N_{i,\,t} \; di \; . \tag{A9}$$

Substituting equation (A6) into equation (A9) yields:

$$Y_t = W_t N_t \; ,$$

where $N_t = \int_0^1 N_{i,\,t}\, di$ so that N_t is total labour force. Total real output is then given by:

$$\frac{Y_t}{P_t} = w_t N_t \; , \tag{A10}$$

where P_t is the consumption-based price index, which is given by equation (A4) and w_t is the real wage W_t/P_t . Using equations (A7), (A4) and the assumption $\int_0^1 a_{i,\,t}\, di = 0$, we can rewrite equation (A10) as:

$$\frac{Y_t}{P_t} = \widehat{Y}_t = A_t N_t \, , \tag{A11}$$

where $\widehat{Y}_t$ denotes the aggregate real output. Rewriting equation (A11) in an intensive form gives:

$$\widehat{y}_t = A_t \,, \tag{A12}$$

where $\widehat{y}_t$ is the aggregate real output per labor. Equation (A12) shows that the aggregate real output per labour grows at the same rate as common technology A_t. Thus, equation (A12) is a reasonable description of the economy if we assume that the economy is in or near the steady state.

A3: Consumers' intertemporal optimization

Next we consider consumers' intertemporal optimization problem. We follow Obstfeld and Rogoff (1997, Ch.2).

The representative household maximizes the following utility function (we normalize the number of total labour at the beginning of the time period to unity):

$$U_t = E_t \sum_{s=t}^{\infty} \beta^{s-t}(1+n)^{s-t}u(c_s) \;, \tag{A13}$$

where c is consumption per labour, and β and $1+n$ are the discount factor and growth rate of labour, respectively.

The current account identity is given by :

$$CA_t = B_{t+1} - B_t = \widehat{Y}_t + rB_t - C_t \ , \tag{A14}$$

where r is the world real interest rate and B_t are net foreign assets. We assume that the world real interest rate is fixed for simplicity. Note that since we ignore capital stock by assumption, investment does not enter the current account identity. Rewriting the above expression in per labour terms gives:

$$(1+n)b_{t+1} - b_t = \widehat{y}_t + rb_t - c_t \ , \tag{A15}$$

where $b_{t+1} = B_{t+1}/N_{t+1}$ and $b_t = B_t/N_t$. Equation (A15) is the flow budget constraint for the household.

A representative household maximizes the utility function (A13) subject to the budget constraint (A15). Assuming the linear-quadratic utility function: $u(c) = c - (h/2)c^2, h > 0$ and $\beta = 1/(1+r)$, we can obtain Hall's (1978) well-known result:

$$E_t c_{t+1} = c_t \ . \tag{A16}$$

Using equation (A15), we can also show consumption per labour at time t as in the following equation:

$$c_t = (r-n)b_t + \frac{r-n}{1+r}\sum_{s=t}^{\infty}\left(\frac{1+n}{1+r}\right)^{s-t} E_t\widehat{y}_s \ . \tag{A17}$$

Equation (A17) states that the current consumption per labour depends on the expected value of permanent income per labour.

A4: Common technologies and the aggregate trade pattern

In this section we look at the effects of changes in the levels of common technologies on an aggregate trade balance. The method taken here is similar to those of Glick and Rogoff (1995).

We first make an assumption concerning technologies common to all sectors. We assume ΔA takes the following $AR(1)$ process:

$$A_{t+1} - A_t = \rho\,(A_t - A_{t-1}) + \varepsilon_{t+1}, \quad -1 < \rho < 1. \tag{A18}$$

Since from equation (A12) $\widehat{y}_t = A_t$,

$$\widehat{y}_{t+1} - \widehat{y}_t = \rho\,(\widehat{y}_t - \widehat{y}_{t-1}) + \varepsilon_{t+1}. \tag{A19}$$

Thus, the changes in A and $\widehat{y}$ that are expected at time t are given by:

$$E_t\,\Delta A_{t+1} = \rho\,\Delta A_t$$

and

$$E_t\,\Delta\widehat{y}_{t+1} = \rho\Delta\widehat{y}_t.$$

Here, note that ε_{t+1} is an unexpected change in A (also $\widehat{y}$) at time $t+1$.

Next, we consider a change in consumption per labour. By using equations (A15) and (A17), we can obtain the following expression for the change in per labour consumption:[19]

$$c_{t+1} - c_t = \left(\frac{1+r}{1+r-\rho-n\rho}\right)(\widehat{y}_{t+1} - E_t\widehat{y}_{t+1}),\ \left(\frac{1+r}{1+r-\rho-n\rho}\right) > 1. \tag{A20}$$

Note that the term $(\widehat{y}_{t+1} - E_t\widehat{y}_{t+1})$ represents ε_{t+1}, which is an unexpected change in A (also $\widehat{y}$) at time $t+1$. Equation (A20) states that the change in per labour consumption is more volatile than per labour output innovation. Therefore, the unexpected positive change in the common technology level worsens the current account per labour and the trade balance per labour since the unexpected change increases consumption per labour more than output per labour. On the other hand, the expected positive change in the common technology level improves the current account per labour and the

[19] See Obstfeld and Rogoff (1997, Ch.2) for the details.

trade balance per labour since the expected change raises output per labour but not consumption per labour.

Next, we show the above statement formally. From the current account identity (A14), the trade balance per labour tb can be given by:

$$\triangle tb_{t+1} = \triangle \widehat{y}_{t+1} - \triangle c_{t+1} \ .$$

Using equations (A12) and (A20), we can rewrite the above expression as:

$$\triangle tb_{t+1} = \Delta x_{t+1} - \Delta m_{t+1} = -\frac{(1+n)\rho}{1+r-\rho-n\rho}\varepsilon_{t+1} + \rho\triangle A_t \ , \qquad \text{(A21)}$$

where x is the level of exports per labour and m is the level of imports per labour. Remember that term $\rho\triangle A_t$ represents the change in A (also $\widehat{y}$) that is expected at time t. As already mentioned, equation (A21) shows that the positive unexpected change in A worsens the trade balance per labour, but the positive expected change in A improves it.

For the latter use, we arrange equation (A21) as in the following equation:[20]

[20] See Appendix B for the derivation.

$$\Delta \ln x_{t+1} - \Delta \ln m_{t+1} \approx \frac{1}{z_0\,\mu}\left(-\frac{(1+n)\rho}{1+r-\rho-n\rho}\varepsilon'_{t+1} + \rho\triangle \ln A_t\right) \ . \quad \text{(A22)}$$

Note that $\rho\triangle \ln A_t$ represents the expected rate of change in $A:\ E_t(\Delta \ln A_{t+1})$ and ε'_{t+1} represents the unexpected part of growth rate of A: $\Delta \ln A_{t+1} - E_t(\Delta \ln A_{t+1})$.

A5: Sector specific technologies and the sectoral trade patterns

Finally, we look at the trade patterns across sectors. We try to find out what affects the dynamics of sectoral trade patterns.

The assumption we take here is that products are to some extent distinguished by place of production. This is called the Armington (1969) assumption. This assumption implies that even if two countries produce the same type of products, goods produced by country A are an imperfect substitute for goods produced by country B.

Assume that there are two economies: “Home” and “Foreign.” According to the Armington assumption, there is at least a certain amount of demand for Home good i and Foreign good i in each of the economies. Home demand and Foreign demand for good i (in an intensive form) are given by (we suppress time scripts in the followings):

$$d_i = d_i^H + d_i^F = d_i^H + m_i^H \tag{A23}$$

and

$$d_i^* = d_i^{*H} + d_i^{*F} = x_i^H + d_i^{*F}. \tag{A24}$$

Equations (A23) and (A24) show a demand for good i per labour in Home economy and a demand for good i per labour in Foreign economy, respectively. d_i is Home demand for good i per labour, d_i^* is Foreign demand for good i per labour, d_i^H is Home demand for Home-produced good i per labour, d_i^F is Home demand for Foreign-produced good i per labour, d_i^{*H} is Foreign demand for Home-produced good i per labour, d_i^{*F} is Foreign demand for Foreign-produced good i per labour, m_i^H is Home imports per labour, and x_i^H is Home exports per labour. Since we assume that there are only two economies Home and Foreign, $d_i^F = m_i^H$ and $d_i^{*H} = x_i^H$ hold. The Armington assumption assures that d_i^H, d_i^F, d_i^{*H}, d_i^{*F}, m_i^H , and x_i^H are all greater than zero.

We next look at Home aggregate demand and Foreign aggregate demand. They are given by:

$$d = \sum_i (d_i^H + d_i^F) = d^H + d^F = d^H + m^H \tag{A25}$$

and

$$d^* = \sum_i (d_i^H + d_i^F) = d^{*H} + d^{*F} = x^H + d^{*F} \ , \tag{A26}$$

where d is Home aggregate demand per labour, d^* is Foreign aggregate demand per labour, d^H is Home aggregate demand for Home-produced goods per labour, d^F is Home aggregate demand for Foreign-produced goods per labour, d^{*H} is Foreign aggregate demand for Home-produced good per labour, d^{*F} is Foreign aggregate demand for Foreign-produced good per labour, m^H is Home aggregate imports per labour, and x^H is Home aggregate exports per labour.

Since the total supply of Home(Foreign)-produced good i must be equal to the demand for Home(Foreign)-produced good i both in Home and Foreign, we obtain the following equilibrium conditions:

$$y_i^H = d_i^H + d_i^{*H} = d_i^H + x_i^H \tag{A27}$$

and

$$y_i^F = d_i^F + d_i^{*F} = m_i^H + d_i^{*F} , \tag{A28}$$

where y_i^H is the amount of Home-produced good i per labour and y_i^F is the amount of Foreign-produced good i per labour. $d_i^H + d_i^{*H}$ and $d_i^F + d_i^{*F}$ represent world demand for Home-produced good i per labour and world demand for Foreign-produced good i per labour.

Similarly, we can obtain the following equilibrium conditions for the aggregate markets:

$$y^H = d^H + d^{*H} = d^H + x^H \tag{A29}$$

and

$$y^F = d^F + d^{*F} = m^H + d^{*F} , \tag{A30}$$

where y^H is the aggregate Home-produced output per labour and y^F is the aggregate Foreign-produced output per labour. $d^H + d^{*H}$ and $d^F + d^{*F}$ represent the world aggregate demand for Home-produced goods per labour and the world aggregate demand for Foreign-produced goods per labour.

Letting $s_i^H = \frac{d_i^{*H}}{d_i^H} = \frac{x_i^H}{d_i^H}$, $s_i^F = \frac{d_i^F}{d_i^{*F}} = \frac{m_i^H}{d_i^{*F}}$, $s^H = \frac{d^{*H}}{d^H} = \frac{x^H}{d^H}$, $s^F = \frac{d^F}{d^{*F}} = \frac{m^H}{d^{*F}}$, and substituting them into equations (A27), (A28), (A29), (A30) yield:

$$y_i^H = \frac{s_i^H + 1}{s_i^H} x_i^H,\ y_i^F = \frac{s_i^F + 1}{s_i^F} m_i^H,\ y^H = \frac{s^H + 1}{s^H} x^H \ and\ y^F = \frac{s^F + 1}{s^F} m^H.$$

According to equation (A5), the sectoral real output per labour is equal to the sectoral technology level that is decomposed into common and sector-specific components technology by $A_i = Ae^{a_i}$,(A represents the common technology level and e^{a_i} represents the sector-specific technology level). Equation (A11) states that the real aggregate output per labour is equal to the common technology level. Thus, we can rewrite the above expressions as:

$$\begin{aligned} A^H (e^{a_i})^H &= \frac{s_i^H + 1}{s_i^H} x_i^H,\ A^F (e^{a_i})^F = \frac{s_i^F + 1}{s_i^F} m_i^H,\ A^H = \frac{s^H + 1}{s^H} x^H \\ and\ A^F &= \frac{s^F + 1}{s^F} m^H, \end{aligned}$$

where A^H and A^F are the Home common technology level and the Foreign common technology level, respectively, and $(e^{a_i})^H$ and $(e^{a_i})^F$ are the Home sector-specific technology level and the Foreign sector-specific technology level, respectively.

Using the above expressions, we can obtain:

$$\frac{x_i^H/m_i^H}{x^H/m^H} = \frac{(e^{a_i})^H}{(e^{a_i})^F}\left[1/\frac{(d_i^H+d_i^{*H})/(d^H+d^{*H})}{(d_i^F+d_i^{*F})/(d^F+d^{*F})}\right]\frac{d_i^{*H}/d^{*H}}{d_i^F/d^F}\ . \tag{A31}$$

Equation (A31) holds in equilibrium. $\frac{x_i^H/m_i^H}{x^H/m^H}$ is Home sector i's export/import ratio relative to Home aggregate export/import ratio, $\frac{(e^{a_i})^H}{(e^{a_i})^F}$ is Home sector i's sector-specific technology level relative to Foreign sector i's sector-specific technology level, $(d_i^H+d_i^{*H})/(d^H+d^{*H})$ is a relative world-demand for Home-produced good i , and $(d_i^F+d_i^{*F})/(d^F+d^{*F})$ is a relative world-demand for Foreign-produced good i . As in the previous section, we implicitly assume that prices adjust instantaneously so that there is no demand effect on the equilibrium level of output. In the following, we explain how a change in $\frac{(e^{a_i})^H}{(e^{a_i})^F}$ affects the equilibrium level of $\frac{x_i^H/m_i^H}{x^H/m^H}$.

We first define the price level of Home-produced good i by p_i^H, the price level of Foreign-produced good i by p_i^F, Home aggregate price level by p^H, and Foreign aggregate price level by p^F. Assume that $\frac{p_i^H/p^H}{p_i^F/p^F}$ is initially at an equilibrium level so that equation (A31) holds. At the initial level of $\frac{p_i^H/p^H}{p_i^F/p^F}$, an increase in $\frac{(e^{a_i})^H}{(e^{a_i})^F}$ leads to an excessively high level of $\frac{y_i^H/y^H}{y_i^F/y^F}$ (the fraction of Home good i's supply in the total Home goods supply relative to the fraction of World good i's supply in the total World goods supply). Thus,

$\frac{p_i^H/p^H}{p_i^F/p^F}$ decreases until the excess is completely eliminated. This implies that $\frac{(d_i^H+d_i^{*H})/(d^H+d^{*H})}{(d_i^F+d_i^{*F})/(d^F+d^{*F})}$ increases by the same amount as the increase in $\frac{(e^{a_i})^H}{(e^{a_i})^F}$. Thus, in equation (A31), the term $\frac{(e^{a_i})^H}{(e^{a_i})^F}\left[1/\frac{(d_i^H+d_i^{*H})/(d^H+d^{*H})}{(d_i^F+d_i^{*F})/(d^F+d^{*F})}\right]$ does not change. Assuming that Home and Foreign consumers have identical preferences over a choice between Home-produced good i and Foreign-produced good i, the term $\frac{d_i^{*H}/d^{*H}}{d_i^F/d^F}$ in equation (A31) should now be higher than before since the level of $\frac{p_i^H/p^H}{p_i^F/p^F}$ is lower in the new equilibrium. Above all, the increase in $\frac{(e^{a_i})^H}{(e^{a_i})^F}$ results in the increase in $\frac{x_i^H/m_i^H}{x^H/m^H}$.

We use the following equation to capture the above relationship between $\frac{(e^{a_i})^H}{(e^{a_i})^F}$ and $\frac{x_i^H/m_i^H}{x^H/m^H}$:

$$\frac{(x_{i,t}^H/m_{i,t}^H)^{\frac{1}{\omega_i}}}{x_t^H/m_t^H} = \left(\frac{(e^{a_{i,t}})^H}{(e^{a_{i,t}})^F}\right)^{\gamma}, \ \gamma > 0 \ and \ \omega_i > 0 \ . \tag{A32}$$

The term $\frac{(x_i^H/m_i^H)^{\frac{1}{\omega_i}}}{x^H/m^H}$ is Home sector i's relative export intensity, which is adjusted for an individual effect. $(1/\omega_i)$ captures the unknown individual effect. Leaving the individual effect aside, equation (A32) says that an increase in Home sector i's relative sector-specific technology level in terms of Foreign raises Home sector i's relative export intensity. Hereafter, we call $\frac{(e^{a_{i,t}})^H}{(e^{a_{i,t}})^F}$ as the level of comparative advantage since it measures Home's relative productivity in sector i in terms of Foreign.

Taking logs and the first differences of equation (A32) and rearranging it yield:

$$\triangle \ln \left(\frac{x}{m}\right)_{i,t}^{H} = \omega_i \triangle \ln \left(\frac{x}{m}\right)_{t}^{H} + \omega_i \gamma \triangle \ln \left(\frac{e^{a_{i,t}^{H}}}{e^{a_{i,t}^{W}}}\right), \tag{A33}$$

where $\left(\frac{x}{m}\right)_{i,t}^{H}$ and $\left(\frac{x}{m}\right)_{t}^{H}$ are Home sector i's export intensity and Home aggregate export intensity, respectively. Substituting equation (A22) into equation (A33) yields:

$$\triangle \ln \left(\frac{x}{m}\right)_{i,t}^{H} \approx \omega_i \gamma \triangle \ln \left(\frac{e^{a_{i,t}^{H}}}{e^{a_{i,t}^{W}}}\right) - \omega_i \frac{\lambda(1+n)\rho}{1+r-\rho-n\rho} \varepsilon_t^{\prime H} + \omega_i \lambda\rho \triangle \ln A_{t-1}^{H}, \tag{A34}$$

where $\lambda = \frac{1}{z_0 \mu}$. This is a key equation for our empirical analysis.

Equation (A34) states that the growth rate of the sectoral export-import ratio depends on the growth rate of the level of comparative advantage $\triangle \ln \left(\frac{e^{a_{i,t}^{H}}}{e^{a_{i,t}^{W}}}\right)$, the unexpected growth of the common technology $\varepsilon_t^{\prime H}$, and the expected growth of the common technology $\rho \triangle \ln A_{t-1}^{H}$. The first term $\omega_i \gamma \triangle \ln \left(\frac{e^{a_{i,t-1}^{H}}}{e^{a_{i,t-1}^{W}}}\right)$ captures the positive relationship between the growth rate of the level of comparative advantage and the growth rate of the sectoral export-import ratio. The second term $-\omega_i \frac{\lambda(1+n)\rho}{1+r-\rho-n\rho} \varepsilon_t^{H}$ captures the negative relationship between the unexpected growth of common technology and the growth rate of the sectoral export-import ratio. The third term $\omega_i\,\lambda\rho\triangle\ln A^H_{t-1}$ captures the positive relationship between the expected growth of common technology and the growth rate of the sectoral export-import ratio (remember that $\rho\triangle\ln A^H_{t-1}$ represents the growth rate of the common technology that is expected at time $t-1$). The unexpected and expected growth rates of common technology affect the growth rate of the sectoral export-import ratio because their effects on the aggregate trade pattern (as shown in the previous sub-section) must become visible in individual sectors.

We set the following specification for the model described above:

$$\triangle\ln\left(\frac{Export}{Import}\right)^{JPN}_{i,t} = cnt + \alpha_{1,i}\,\Delta\ln\left(\frac{A^{JPN}_{i\ SP}}{A^{World}_{i\ SP}}\right)_{t-1} + \alpha_{2,i}\,\Delta\ln A^{UN}_t + \alpha_{3,i}\,\Delta\ln A^E_t + \alpha_{4,i}\,\Delta REXRT_t + e_{i,t}\ , \quad \text{(A35)}$$

where $\left(\frac{Export}{Import}\right)^{JPN}_{i,t}$ is Japanese sectoral export/import ratio, $A^{JPN}_{i\ SP,t-1}$ is Japanese sector specific technology $e^{a^{JPN}_{i,t-1}}$, $A^{World}_{i\ SP,t-1}$ is the world sector specific technology $e^{a^{World}_{i,t-1}}$ (note that world here means all countries except Japan), $\Delta\ln A^{UN}_t$ is the unexpected part of growth rate of the Japanese common technology level A^{JPN}, $\Delta\ln A^E_t$ is the expected part of growth rate of the Japanese common technology level A^{JPN}, $\Delta REXRT_t$ is the change in the real effective exchange rate (measured in terms of the Japanese price level), cnt is the constant term and e is the error term. Note that we use the lags of the sector specific technologies to allow for the slow adjustment as in Golub and Hsieh (2000). $\alpha_{1,i,}$, $\alpha_{2,i}$ and $\alpha_{3,i}$ correspond to $\omega_i\,\gamma$, $-\omega_i\frac{\lambda(1-n)\rho}{1+r-\rho-n\rho}$ and $\omega_i\,\lambda\rho$ in equation (A34), respectively and thus $\alpha_{1,i,} > 0$, $\alpha_{2,i,} < 0$ and $\alpha_{3,i} > 0$.

We include the changes in real effective exchange rates in equation (A35) to take into account the possibility of an imperfect flexibility of prices. The model assumes that prices are perfectly flexible so that the economies are always in general equilibrium. Although it is not consistent with the model, mainly for empirical purposes, we consider the possibility that price levels do not adjust completely to the levels that ensure general equilibrium. When supply factors change, prices instantaneously change, by a large but not a full amount, to adjust to the new equilibrium levels. Since the prices do not adjust completely, they change over time to eliminate the still remaining gaps between the new equilibrium levels and the current levels. Thus, if prices are not perfectly flexible, the sectoral export intensity changes not only due to changes in supply factors that determine the equilibrium levels of various variables, but also due to changes in prices that are the adjustments of prices needed to eliminate the gap between the equilibrium price levels and the current price levels. Since it is difficult to observe sectoral relative Japanese price levels in terms of the world (measured in terms of the Japanese price level), we use the real effective exchange rates and let the coefficient of $\Delta REXRT_t$ vary across sectors. We expect $\alpha_{4,i} < 0$ since an increase in $\Delta REXRT_t$ implies the real appreciation.

Appendix B: Changes in Export-Import Ratio: Derivation of Equation (A22)

The trade balance per labour at time t can be written as:

$$tb_t = x_t - m_t = \exp(\ln x_t) - \exp(\ln m_t) \ .$$

We take the first order Taylor approximation of tb_t around a point tb_0 where $x_0/m_0 = 1$ (that is, the trade is balanced). It gives:

$$x_t - m_t \approx \exp(\ln x_0) - \exp(\ln m_0) + x_0(\ln x_t - \ln x_0) - m_0(\ln m_t - \ln m_0) \ .$$

Since $x_0/m_0 = 1$ holds, defining z_0 as the value satisfying $x_0 = m_0 = z_0$ and substituting z_0 for x_0 and m_0 yields:

$$x_t - m_t \approx z_0(\ln x_t - \ln z_0) - z_0(\ln m_t - \ln z_0) \ . \tag{B1}$$

Taking the first differences in both sides of the above expression gives[21]:

$$\Delta x_{t+1} - \Delta m_{t+1} \approx z_0(\Delta \ln x_{t+1} - \Delta \ln m_{t+1}) \ .$$

[21] Since x and m are exports per labour and imports per labour respectively, x and m do not change so much in the long-run. Thus, treating z as a fixed value z_0 and taking the first differences in (B1) can be a reasonable approximation method.

Thus, equation (A21) can be rewritten as:

$$\Delta \ln x_{t+1} - \Delta \ln m_{t+1} \approx \frac{1}{z_0} \left(-\frac{(1+n)\rho}{1+r-\rho-n\rho} \varepsilon_{t+1} + \rho \triangle A_t \right) . \qquad \text{(B2)}$$

Remember that $\triangle A_t$ is assumed to follow the AR(1) process given by equation (A18): $\Delta A_{t+1} = \rho \, \Delta A_t + \varepsilon_{t+1}$. If A is rather large relative to ΔA, i.e., the growth rate of A is small (this seems to be a reasonable assumption), most of variations in $\Delta \ln A_t$ come from variations in ΔA_t. Thus, $\Delta \ln A_{t+1} \approx \rho \, \Delta \ln A_t + \varepsilon'_{t+1}$ should hold in approximation where $\varepsilon'_{t+1} = \mu \varepsilon_{t+1}$ with $0 < \mu < 1$. Thus, equation (B2) can be rewritten as:

$$\Delta \ln x_{t+1} - \Delta \ln m_{t+1} \approx \frac{1}{z_0 \, \mu} \left(-\frac{(1+n)\rho}{1+r-\rho-n\rho} \varepsilon'_{t+1} + \rho \triangle \ln A_t \right) . \qquad \text{(A22)}$$

Note that $\rho \triangle \ln A_t$ represents the expected rate of change in $A:$ $E_t(\Delta \ln A_{t+1})$ and ε'_{t+1} represents the unexpected part of growth rate of A: $\Delta \ln A_{t+1} - E_t(\Delta \ln A_{t+1})$.

Appendix C: Data Description

(a) Japanese sectoral export and imports: We obtain the data from the 3-digit ISIC section of the Trade and Production Database (we can download the data from www.worldbank.org/research/trade). The codes for exports and imports are 'expTOTALTOT' and 'impTOTALTOT,' respectively. Since the database only covers the period between 1976-1997 for the countries we chose, for the period between 1998 and 2000, we use the data from OECD STAN (ISIC Rev.3). The codes for exports and imports are 'EXPO' and 'IMPO,' respectively.

(b) Japanese real effective exchange rate: We obtain the data from the CEIC Database. The code is 'JMDAF.'

(c) Technology growth rates: First, for each sector in each country, we obtain the data for the nominal value added output and the number of workers from the 3-digit ISIC sector of the Trade and Production Database (www.worldbank.org/research/trade). The codes are 'vlVADD' and 'vlLABOR,' respectively. (Note that the Trade and Production Database does not provide the real value added output and that we obtain, for the period between 1998 and 2000, the real value added output from OECD STAN (ISIC Rev.3), code 'VALUK' and the number of workers from OECD STAN (ISIC Rev.3), code 'EMPN'). Next, to create the real value added output, we obtain the US sectoral value added deflator from OECD STAN (ISIC Rev.3), code 'VALU,' and the real exchange rate (against US \$) from Penn World Table 6.0, code 'P.' Using these variables, we calculated the total manufacturing sector's growth rates of technologies and the sectoral growth rates of technologies across countries by applying a growth accounting method.

(d) Japanese sectoral consumption goods share in the production (1995 base): The data are taken from the Ministry of Economy, Trade and Industry's, *Indices of Industrial Production 2001.*

(e) Japanese import penetration ratio: The variable are calculated as (Imports of consumption goods / total domestic supply of consumption goods) by using the data from the Ministry of Economy, Trade and Industry's, *Indices of Industrial Production* (various years).

(f) Japanese inflation rate (CPI base): The data are taken from the Ministry of Public Management, Home Affairs, Posts and Telecommunications', *Consumer Price Index* (various years).

Appendix D: An Approximation of Import Penetration Ratio

This appendix shows that we can approximately measure the changes in the aggregate import penetration ratio by using the changes in sectoral export-import ratios. We first define the aggregate import penetration ratio at time t as:

$$IP_t = \frac{M_t}{Y_t - (X_t - M_t)} \ , \tag{D1}$$

where M, X, and Y are imports, exports, and output respectively. Assuming $M_t = 0$, equation (D1) can be rewritten as:

$$IP_t = 1/\left(\frac{Y_t}{X_t}\frac{X_t}{M_t} - \frac{X_t}{M_t} + 1\right). \tag{D2}$$

Taking the first order linear approximation around IP_0 where IP_0 is the average level of IP_t over the sample periods, we can obtain:

$$
\begin{aligned}
IP_t &= IP_0 + \left(1/\left(\frac{X_0}{M_0}\left(\frac{Y_0}{X_0}-1\right)+1\right)^2\right)\frac{X_0}{M_0}\left(2\frac{Y_0}{X_0}-1\right) \\
&\quad -\left(1/\left(\frac{X_0}{M_0}\left(\frac{Y_0}{X_0}-1\right)+1\right)^2\right)\left(\frac{Y_0}{X_0}-1\right)\frac{X_t}{M_t} \\
&\quad -\left(1/\left(\frac{X_0}{M_0}\left(\frac{Y_0}{X_0}-1\right)+1\right)^2\right)\frac{X_0}{M_0}\frac{Y_t}{X_t},
\end{aligned}
$$

where $\frac{X_0}{M_0}$ and $\frac{Y_0}{M_0}$ are the levels of $\frac{X}{M}$ and $\frac{Y}{M}$ that correspond to IP_0. The first differencing both sides of the above equation yields:

$$
\Delta IP_t = -\beta_1 \Delta\frac{X_t}{M_t} - \beta_2 \Delta\frac{Y_t}{X_t}\ ,\ \beta_1 > \beta_2 > 0. \tag{D3}
$$

We use equation (D3) to obtain the estimates for β_1 and β_2.The OLS estimates by using the Japanese data are 0.044 and 0.007 for β_1 and β_2, respectively. We can thus decompose ΔIP_t in the following way:

$$
\Delta IP_t = -0.044\left(\Delta\frac{X_t}{M_t}\right)^{fit} - 0.007\frac{Y_t}{X_t}. \tag{D4}
$$

In equation (D4), $\left(\Delta\frac{X_t}{M_t}\right)^{fit}$represents the fitted value of $\Delta\frac{X_t}{M_t}$, which can be calculated by using the estimates in the paper. Note that, calculating $\left(\Delta\frac{X_t}{M_t}\right)^{fit}$ by using the estimates implies that we can decompose $\left(\Delta\frac{X_t}{M_t}\right)^{fit}$ into the following factors: the changes in the levels of comparative advantage, the unexpected changes in common technologies, the expected changes in common technologies, and the changes in real effective exchange rates. To calculate $\left(\Delta\frac{X_t}{M_t}\right)^{fit}$, we weight each sector according to the consumption goods share in total production to construct the aggregate import penetration ratio. Thus, $\left(\Delta\frac{X_t}{M_t}\right)^{fit}$ is given by:

$$\left(\Delta\frac{X_t}{M_t}\right)^{fit} = \sum_i \eta_i \; \Delta\left(\frac{X}{M}\right)^{fit}_{i,\,t} ,$$

where η_i is sector i 's consumption goods share in the total production. Substituting the above equation into equation (D4) yields:

$$\Delta IP_t = -0.044 \sum_i \eta_i \; \Delta\left(\frac{X}{M}\right)^{fit}_{i,\,t} , \tag{D5}$$

where $\Delta\left(\frac{X}{M}\right)^{fit}_{i,\,t}$ is the fitted value obtained from the regression estimates in the paper. We ignore the term $\Delta\frac{Y_t}{X_t}$ to decompose the change in the import penetration ratio since the weight on $\Delta\frac{Y_t}{X_t}$ is relatively small.

Table 1: Regression Estimates

Regression equation:			
$\Delta \ln(EXPORT / IMPORT)_{i,t} = cnt + \alpha_{1,i}\, \Delta \ln(A_i^{JPN} / A_i^{World})_{t-1} + \alpha_{2,i} \ln A_t^{UN} + \alpha_{3,i} \Delta \ln A_t^{E} + \alpha_{4,i} \Delta REXRT_t + e_{i,t}$			
	Estimate	Std. Err	p-value
$\hat{\alpha}_1$	0.4369	0.2067	0.035
$\hat{\alpha}_2$	-2.0148	0.4486	0.000
$\hat{\alpha}_3$	1.7508	0.9816	0.074
$\hat{\alpha}_4$	-0.0037	0.0014	0.009
No. obs: 342 Wald $\chi^2(4)$: 40.72 Swamy $\chi^2(85)$: 106.95 DW: 1.83			

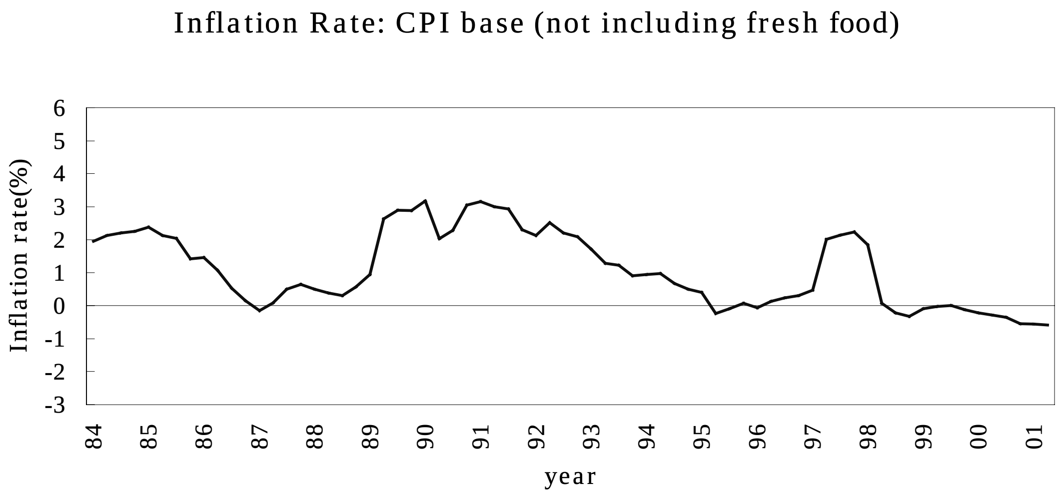
Table 2: Predicted Sectoral Coefficients

Regression equation:

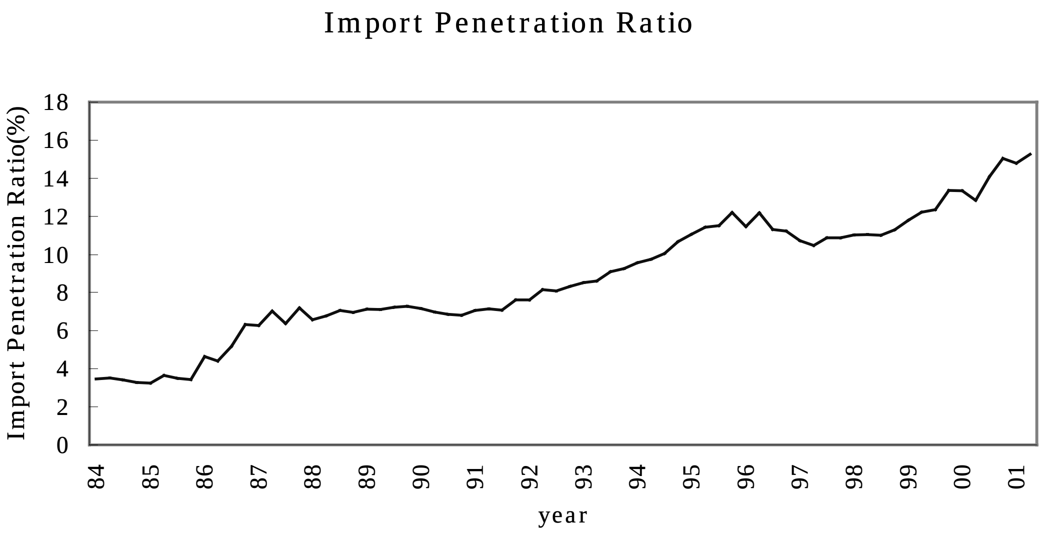
$$\Delta \ln(EXPORT / IMPORT)_{i,t} = cnt + \alpha_{1,i}\, \Delta \ln(A_i^{JPN} / A_i^{World})_{t-1} + \alpha_{2,i} \ln A_t^{UN} + \alpha_{3,i} \Delta \ln A_t^{E} + \alpha_{4,i} \Delta REXRT_t + e_{i,t}$$

	Predicted coefficients			
Sector	$\hat{\alpha}_{1,i}$	$\hat{\alpha}_{2,i}$	$\hat{\alpha}_{3,i}$	$\hat{\alpha}_{4,i}$
Food	0.88	-0.58	1.06	-0.0028
Beverages	0.16	-3.18	-0.97	-0.0070
Textiles	0.20	-2.51	1.23	-0.0048
Wearing Apparel	0.49	-2.10	2.38	-0.0047
Leather	0.24	-1.74	2.52	-0.0049
Footwear	0.14	-2.48	2.62	-0.0074
Wood Products	-0.29	-3.20	3.05	-0.0084
Furnitures & Fixtures	0.42	-1.20	4.71	-0.0020
Paper	0.49	-1.68	2.30	-0.0028
Printing & Publishing	0.01	-1.80	2.34	-0.0027
Iron & Steel	0.40	-3.15	-0.73	-0.0068
Non-Ferrous Metal	0.24	-3.13	-0.56	-0.0033
Fabricated Metal	1.25	-2.41	0.54	-0.0025
Non-Electrical Machinery	1.28	-0.50	2.10	0.0004
Electrical Machinery	0.92	-1.40	4.06	-0.0016
Transport Equipment	0.54	-1.74	1.18	-0.0030
Professional Goods	0.11	-1.19	2.05	0.0000
Other	0.37	-2.32	1.62	-0.0054

Figure 1: Import Penetration Ratio and Inflation Rate

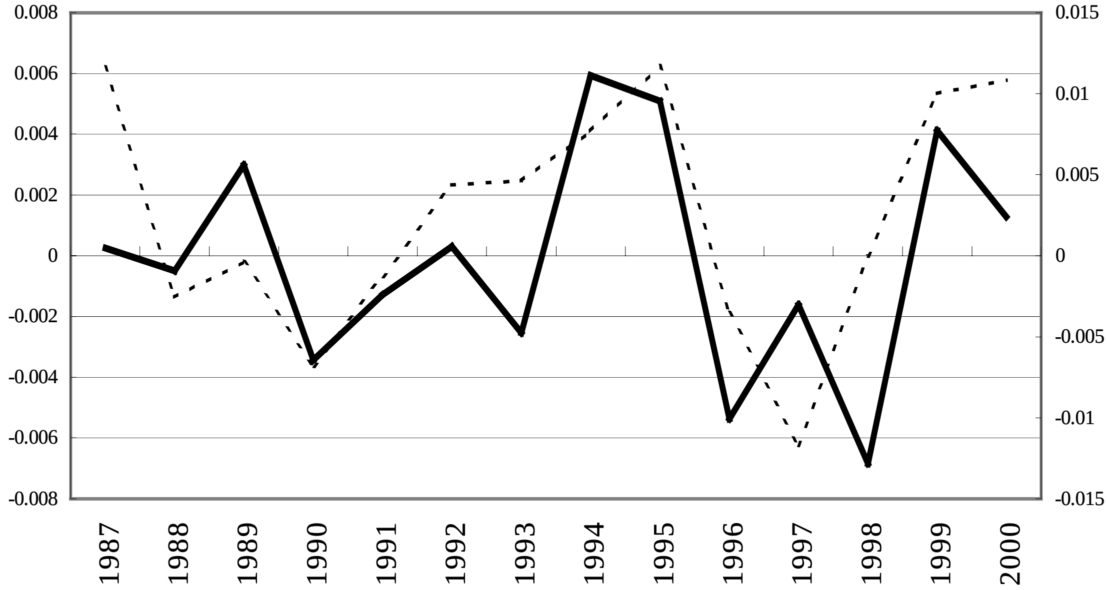


Source: Ministry of Public Management, Home Affairs, Posts and Telecommunications, “Consumer Price Index (various years).”



Source: Ministry of Economy, Trade and Industry, “Indices of Industrial Production (various years).”

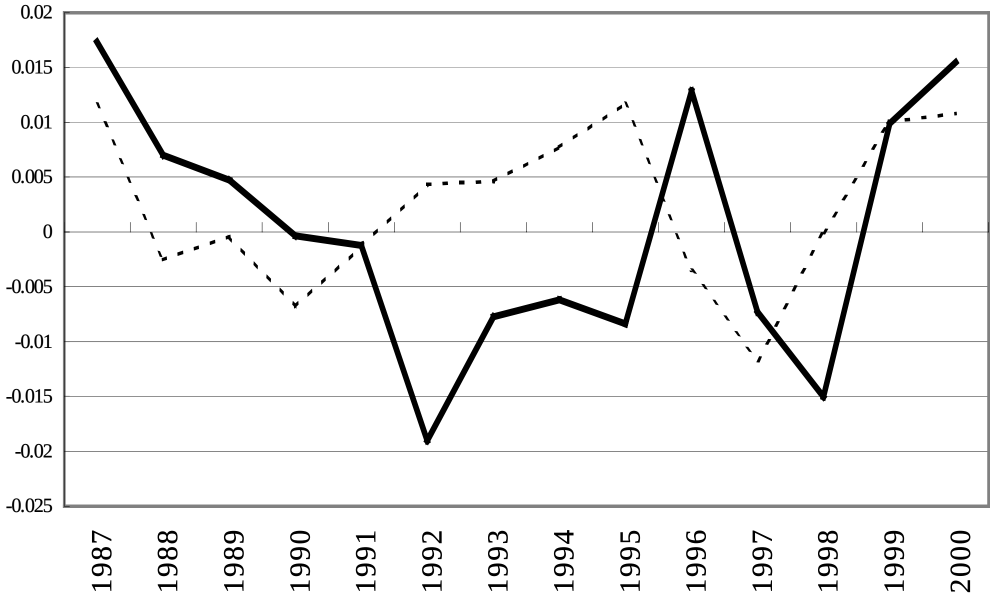
Figure 2: Individual Factor (comparative advantage changes)



Comparative advantage changes (negative effects): Left axis - 1st difference

Import penetration ratio changes (actual): Right axis - 1st difference

Figure 3: Individual Factor (unexpected common tech. changes)



Unexpected common tech. changes (positive effects): 1st difference

Import penetration ratio changes (actual): 1st difference

Figure 4: Individual Factor (Expected common tech. changes)

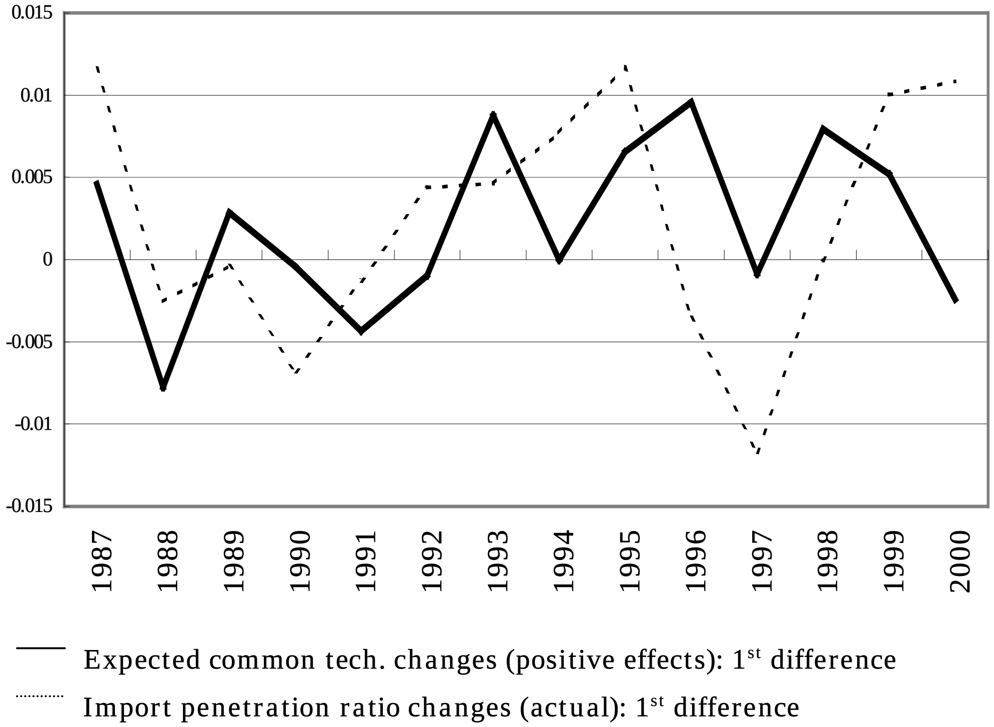


Figure 5: Individual Factor (real effective exch. rate changes)

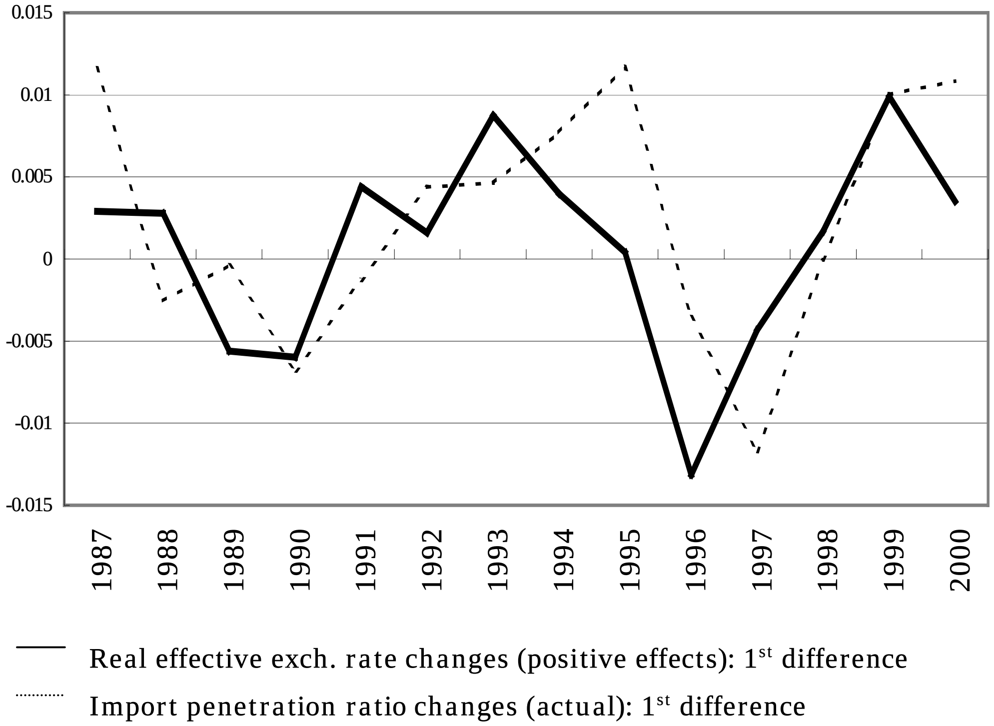


Figure 6: Factorization of the Fitted Values of Changes in the Aggregate Import Penetration Ratio

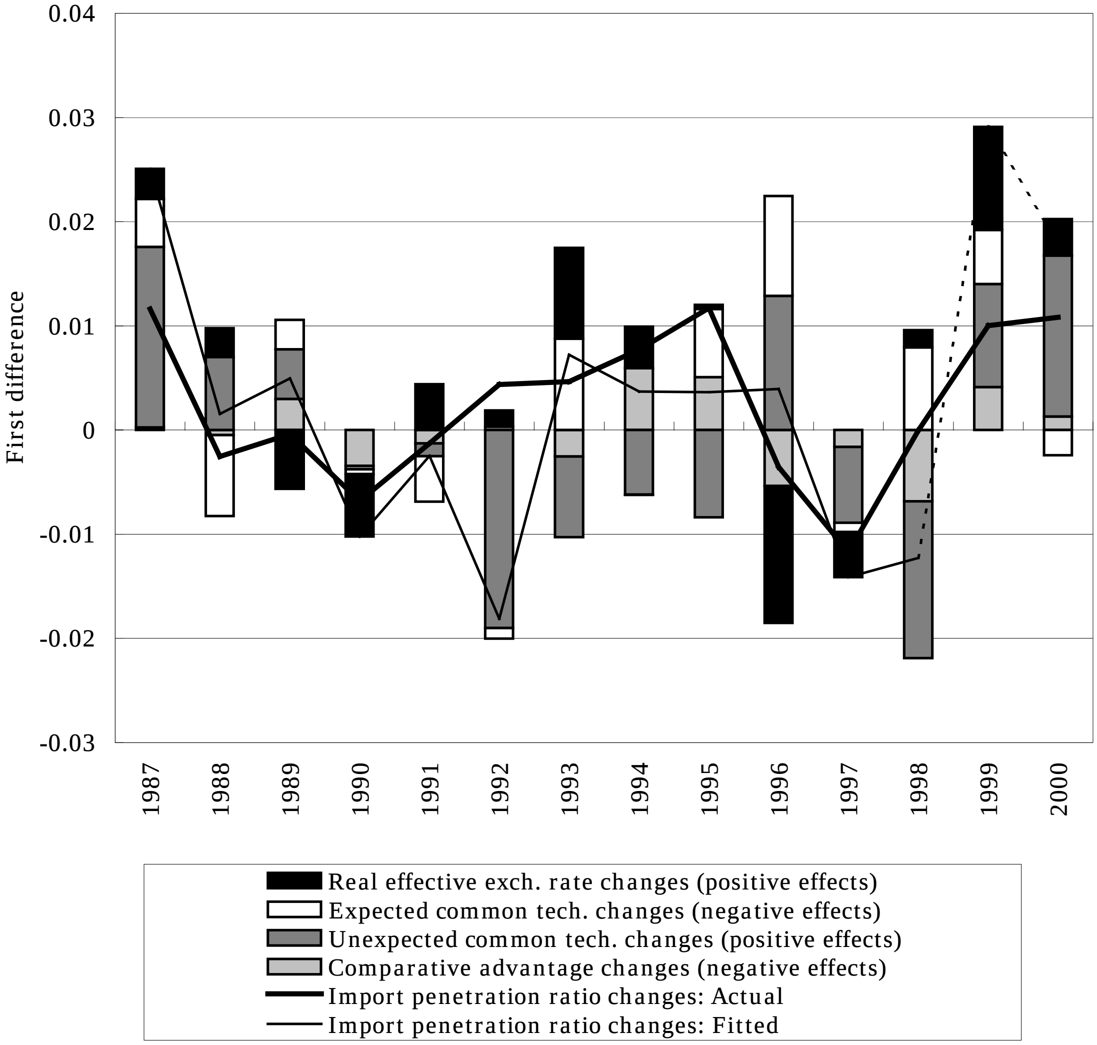


Figure 7: Factorization of Changes in Export-Import Ratio (food)

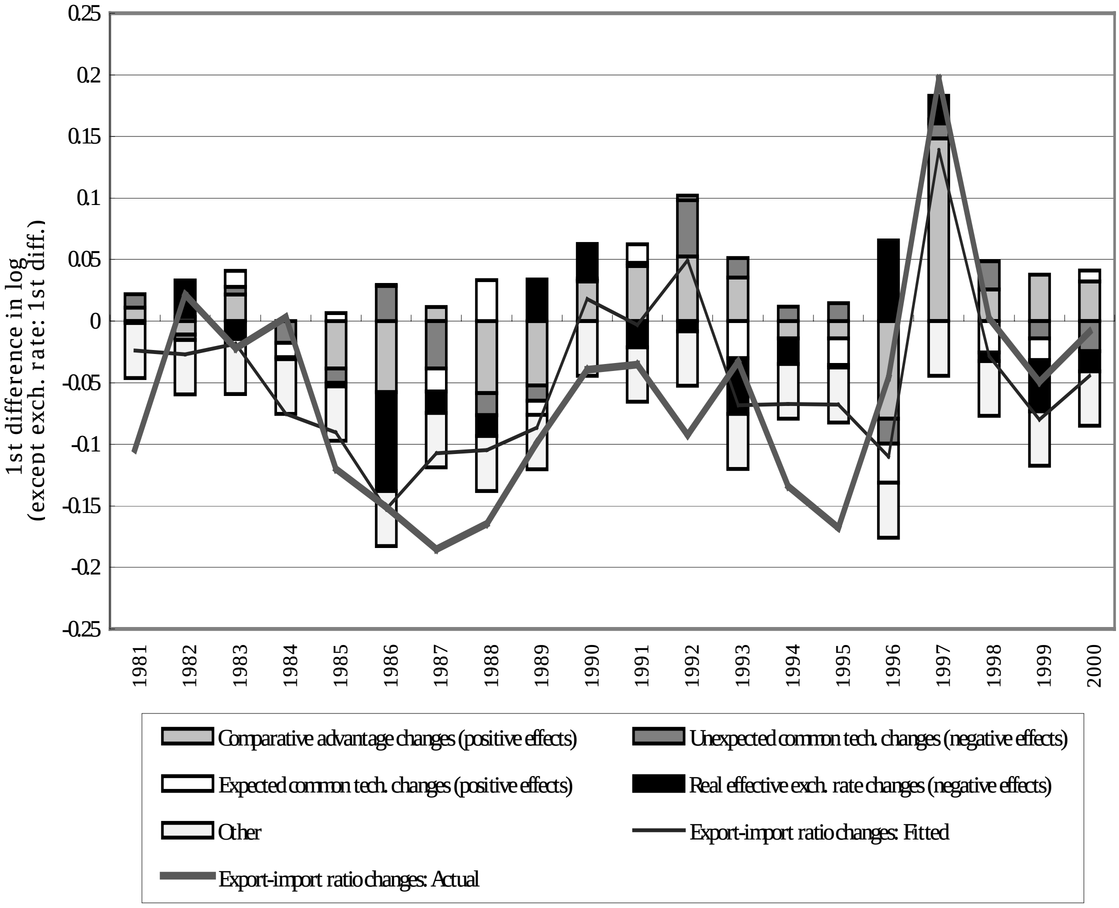


Figure 8: Factorization of Changes in Export-Import Ratio (beverages)

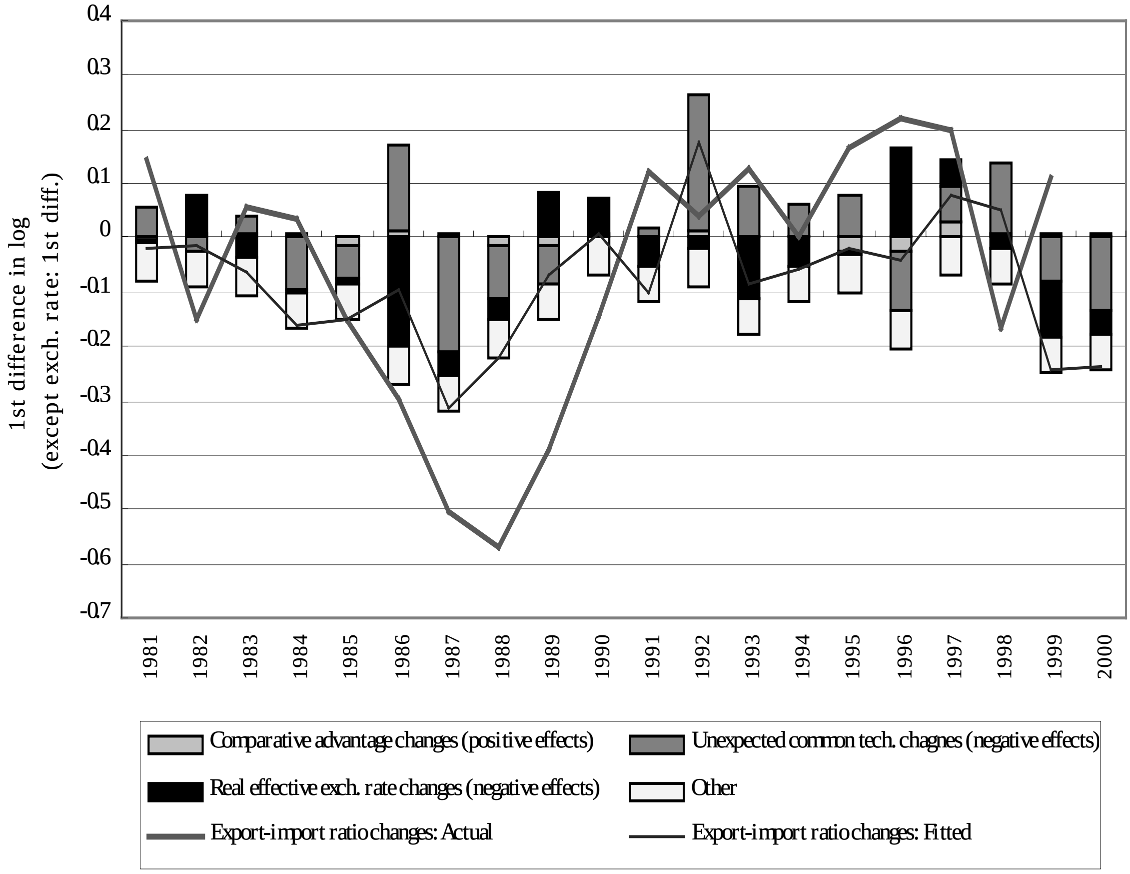


Figure 9: Factorization of Changes in Export-Import Ratio (textiles)

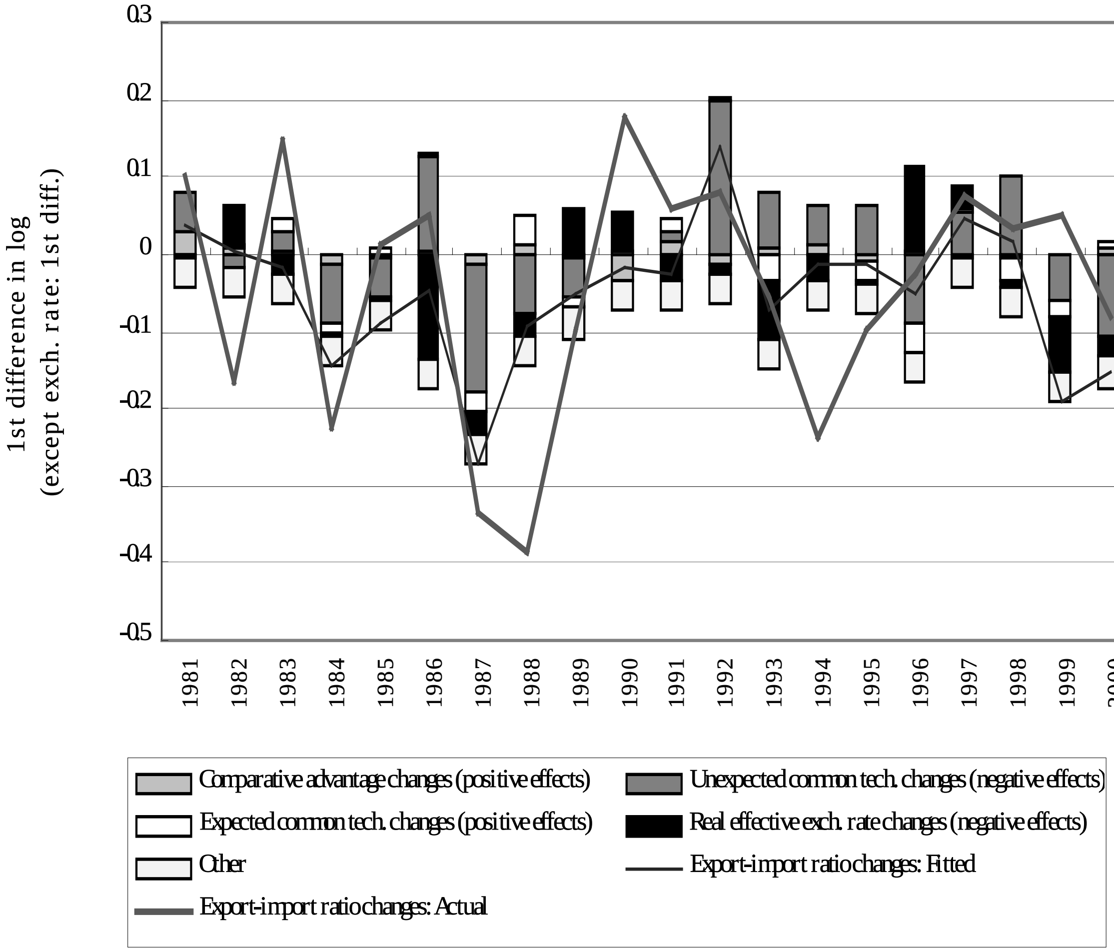


Figure 10: Factorization of Changes in Export-Import Ratio (wood products)

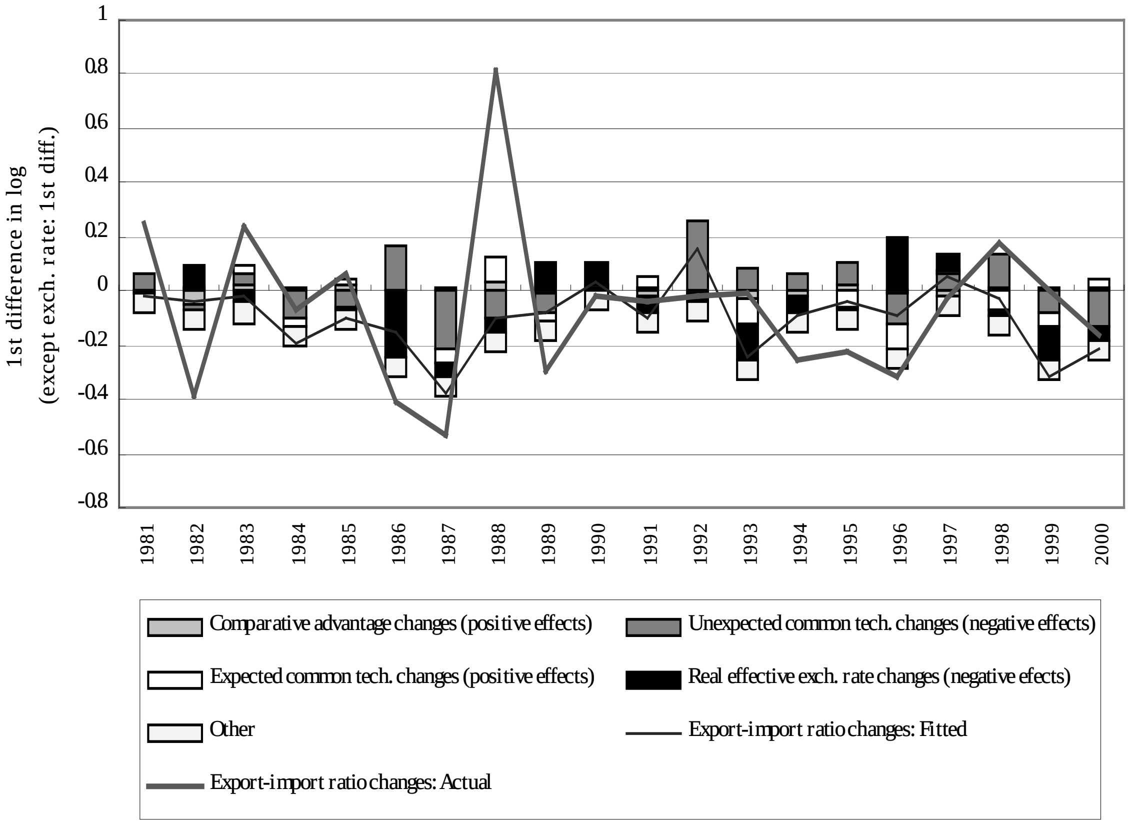


Figure 11: Factorization of Changes in Export-Import Ratio (paper and products)

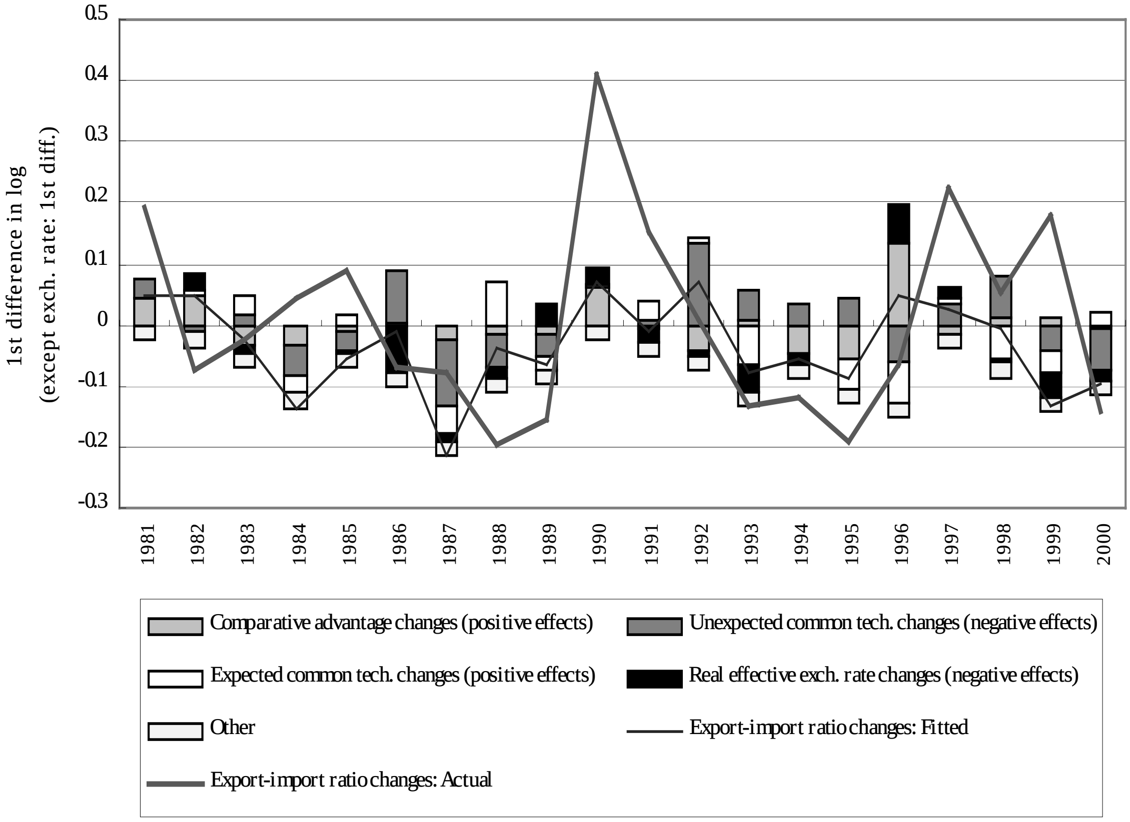


Figure 12: Factorization of Changes in Export-Import Ratio (iron and steel)

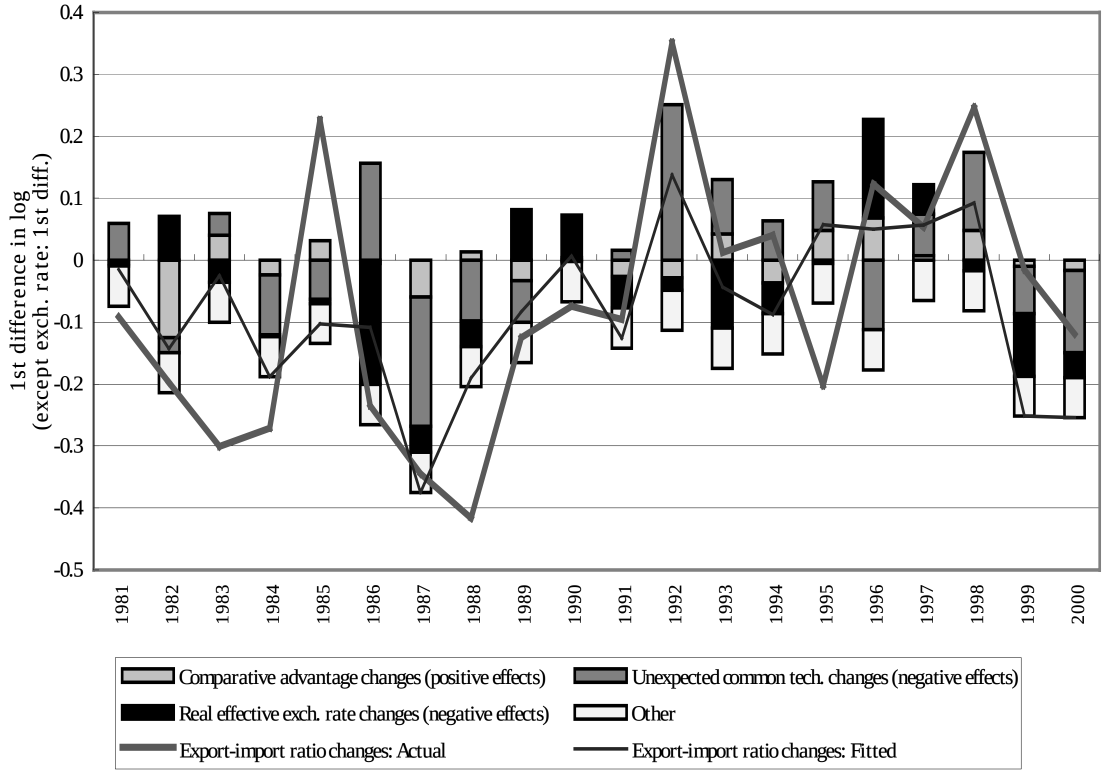


Figure 13: Factorization of Changes in Export-Import Ratio (non-ferrous metals)

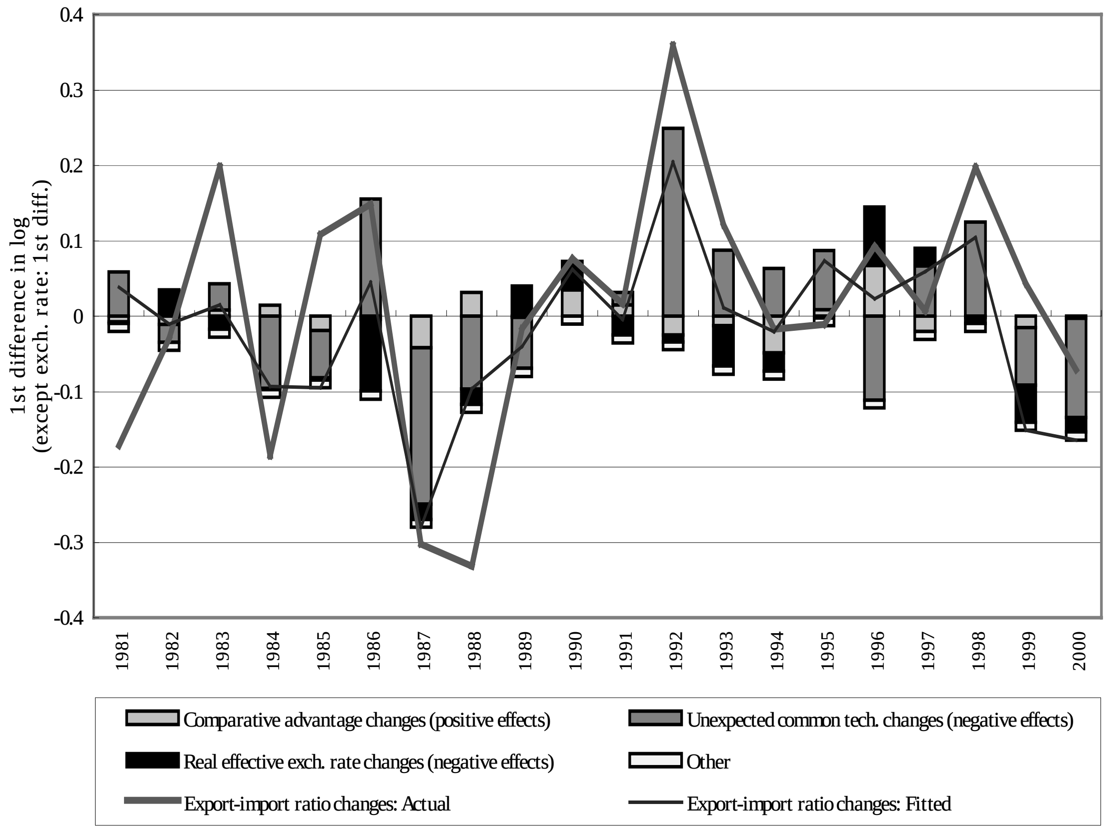


Figure 14: Factorization of Changes in Export-Import Ratio (fabricated metal products)

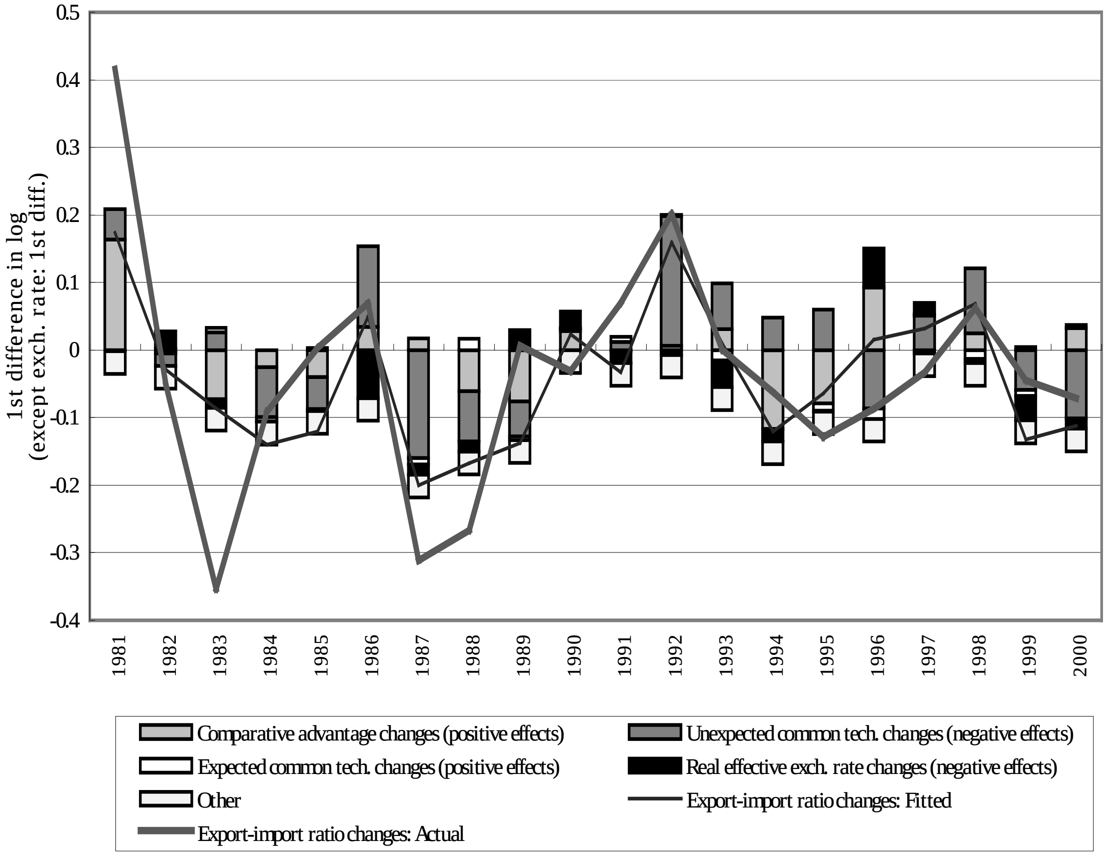


Figure 15: Factorization of Changes in Export-Import Ratio (non-electrical machinery)

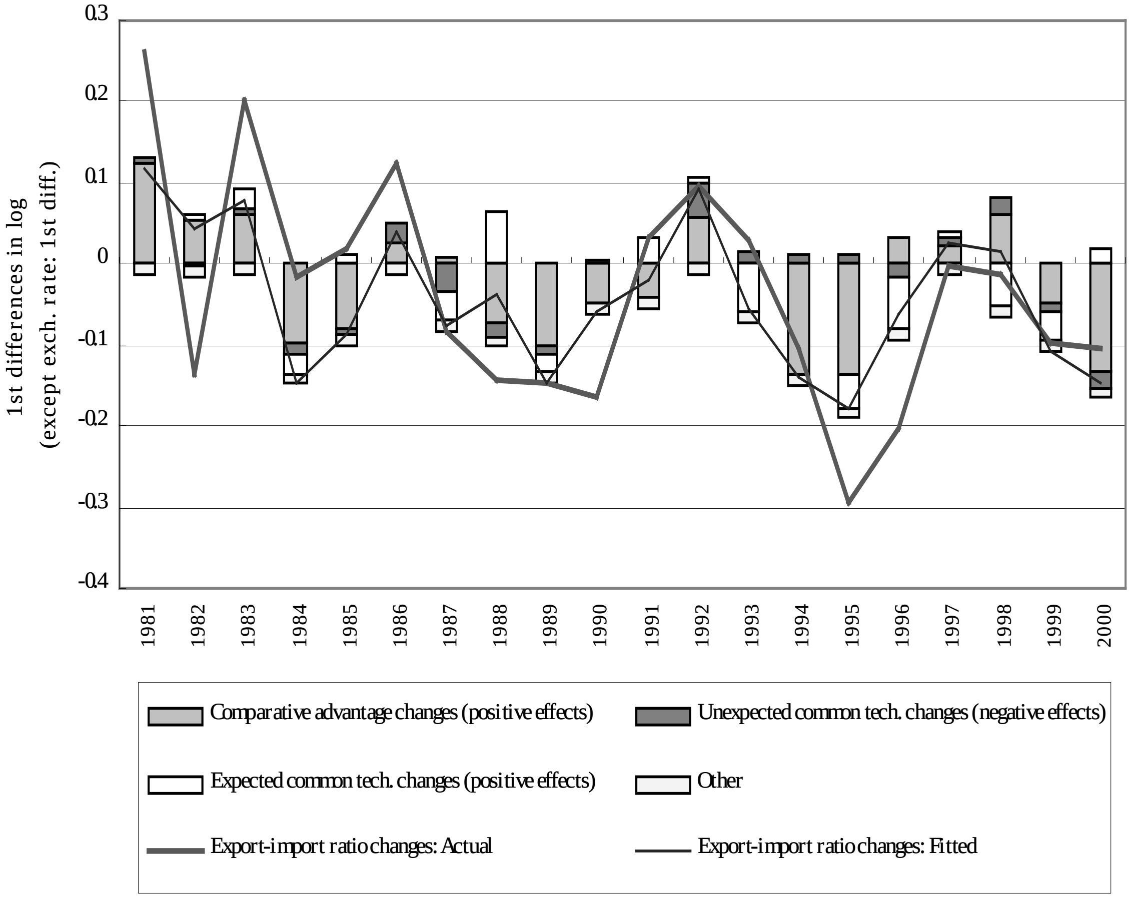


Figure 16: Factorization of Changes in Export-Import Ratio (electrical machinery)

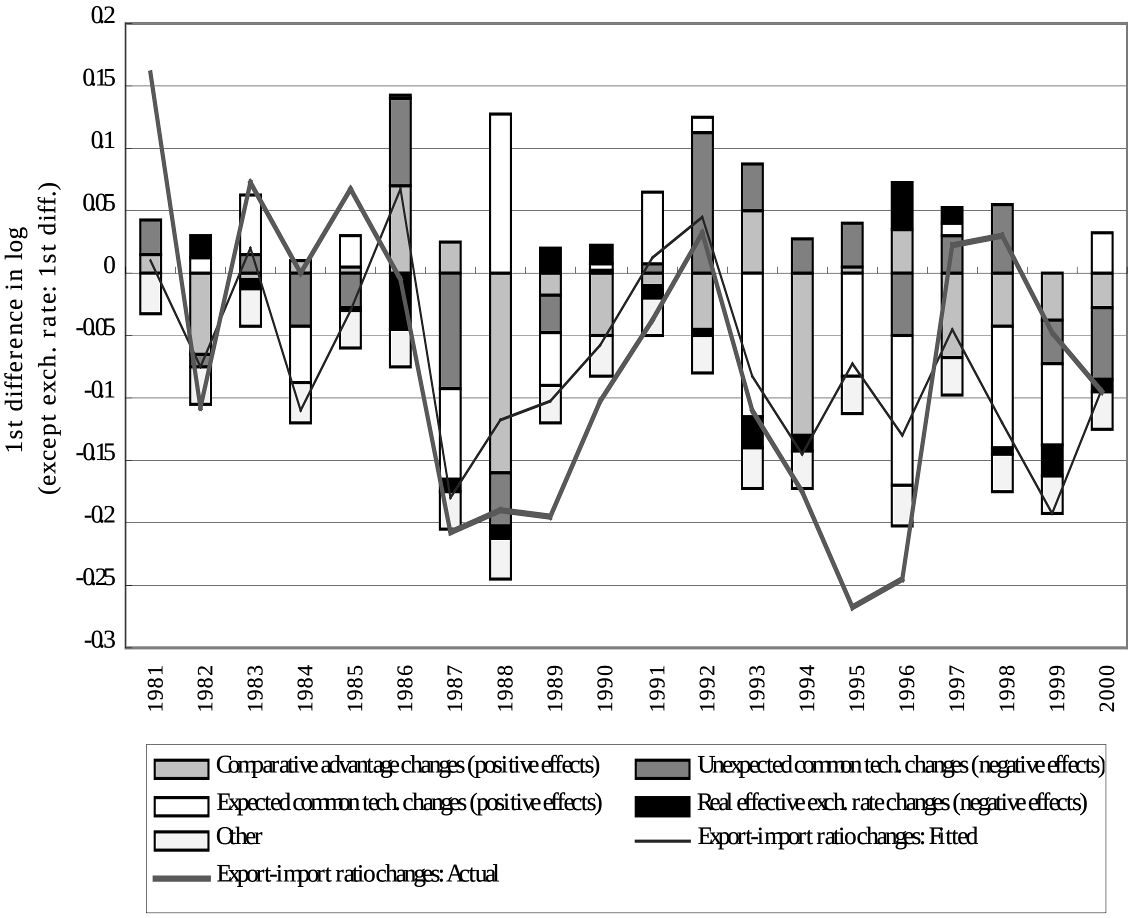


Figure 17: Factorization of Changes in Export-Import Ratio (transport equipment)

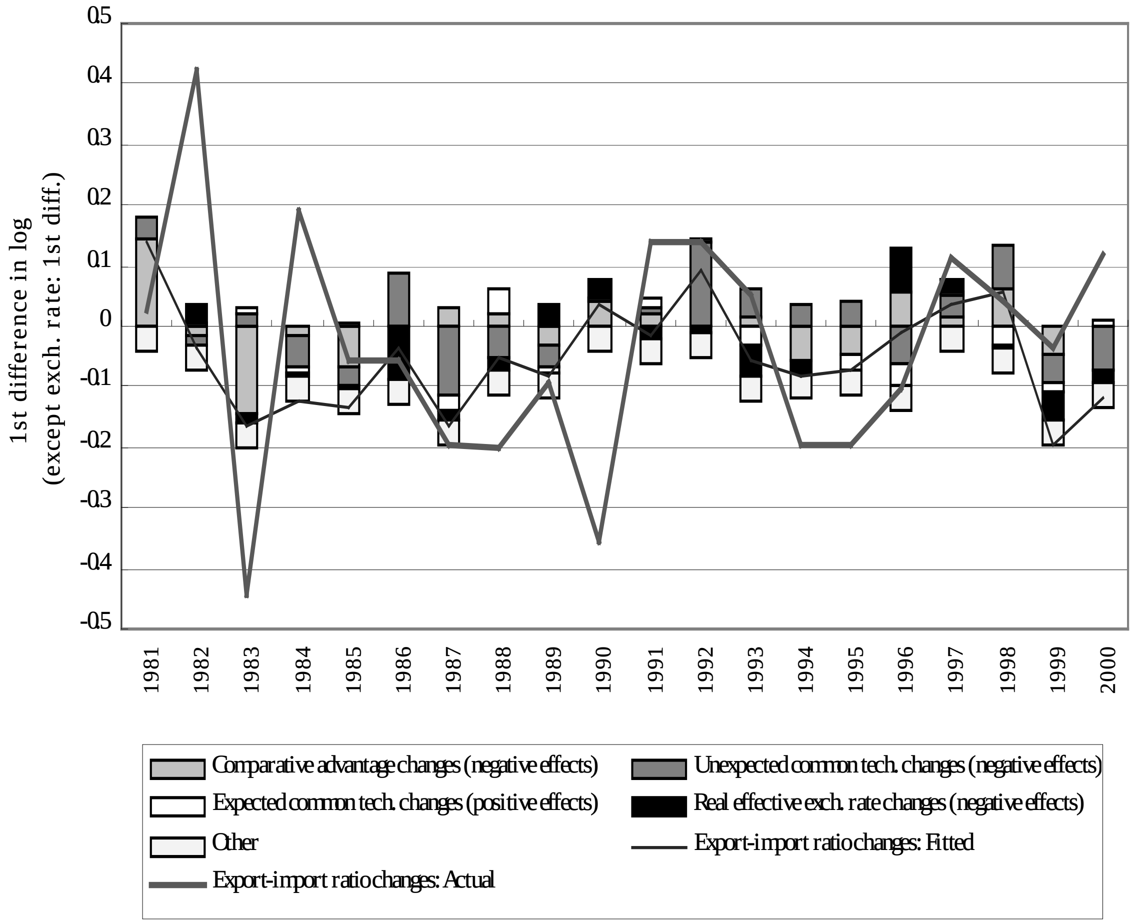


Figure 18: Factorization of Changes in Export-Import Ratio (professional goods)