Trading Tasks: A Simple Theory of Offshoring

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Introduction

- The nature of international trade has changed
- For centuries, trade largely entailed an exchange of complete *goods*
  - Transportation and communication were exceedingly slow and costly
  - Specialization by task, as noted by Adam Smith, required proximity
- Paradigm of trade theory conceptualized the production process as generating finished goods from bundles of inputs combined at a single plant
- Now, trade increasingly involves bits of value being added in many different locations: *Trade in tasks*

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  - Revolutionary advances in transportation and (especially) communications technology
  - Weaker link between specialization and geographic concentration
    - Firms can take advantage of factor cost disparities in different countries without sacrificing the gains from specialization
- Need for a new paradigm, one that puts task trade at center stage
- We develop a simple and tractable model of offshoring that features such trade in tasks

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Some Evidence of Task Trade

- Hard evidence on the growing scale of task trade is hard to come by
  - Trade data are collected and reported as gross flows rather than as foreign value added (NRC, 2006)
  - Some of this trade leaves no paper trail
- But hints of the global disintegration of the production process abound:
  - Share of imported inputs in total inputs used by goods-producing sectors in the US rose from 7% in 1972 to 18% in 2000
  - Intra-firm trade accounted for 47% of U.S. total imports in 2005
  - In the US, imports of Business, Professional and Technical (BPT) services have increased by more than 66% in real terms from 1997 to 2004

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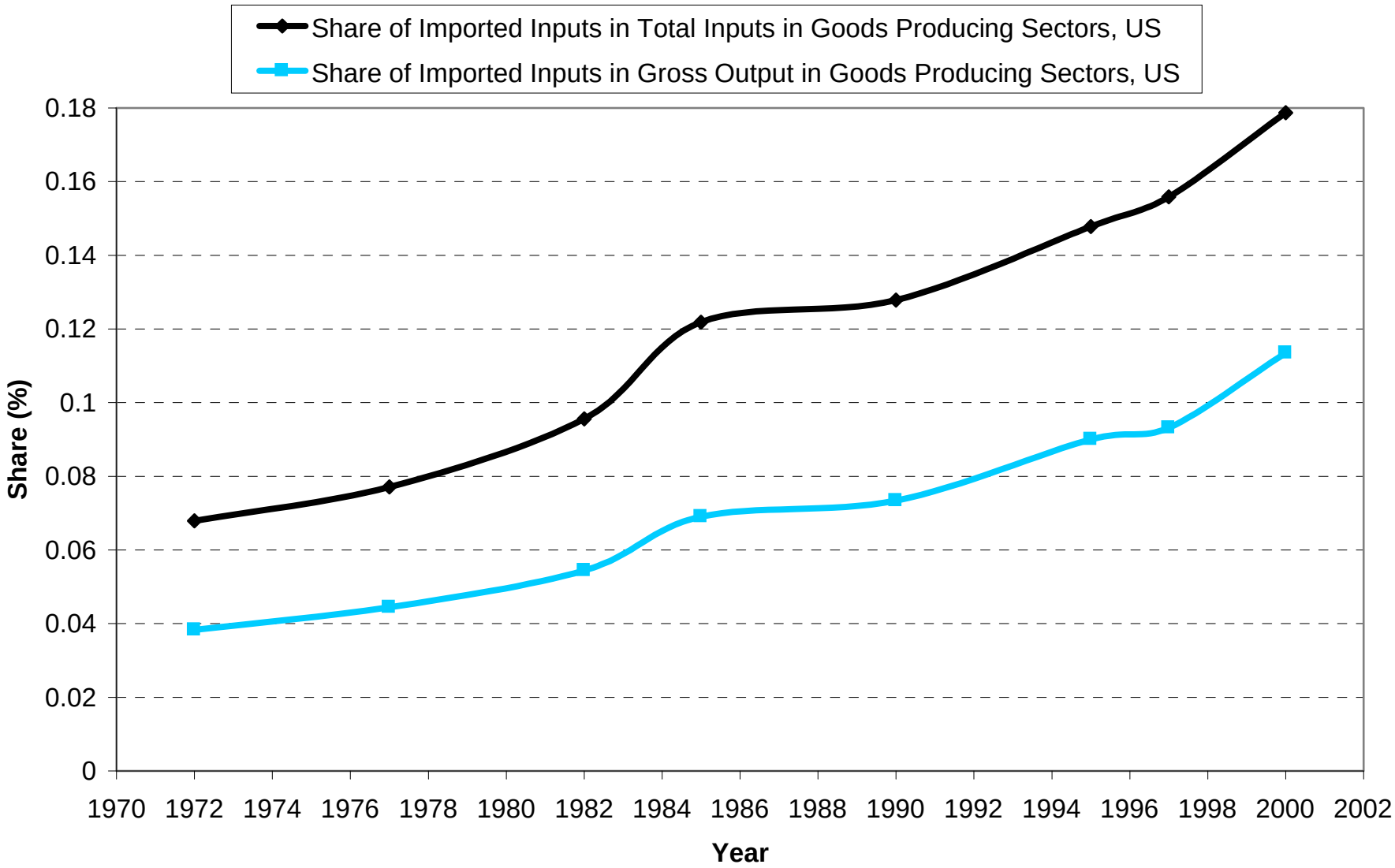
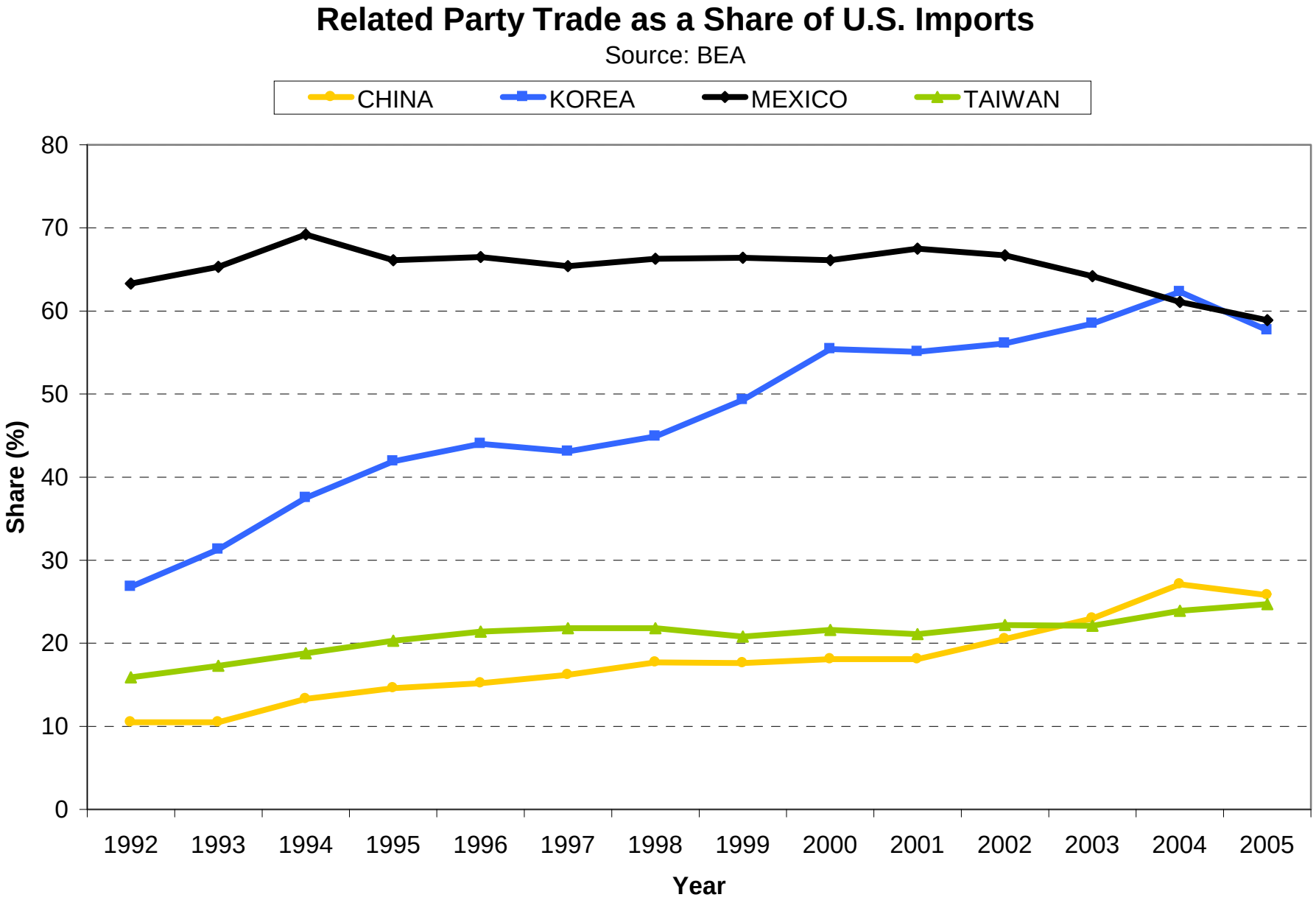
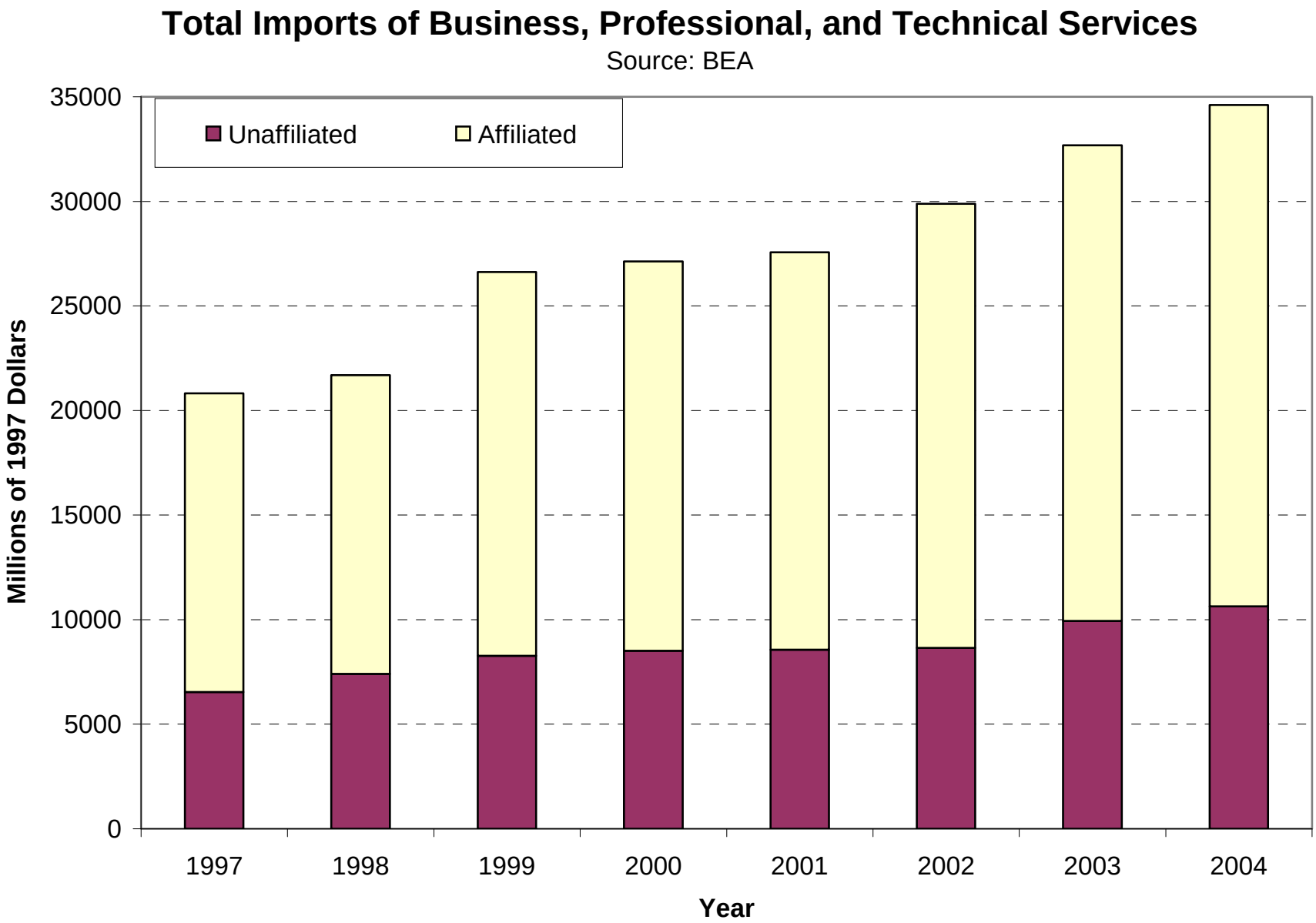
Imported Inputs

Source: OECD Input-Output Matrices




Related Party Trade as a Share of U.S. Imports
Source: BEA
CHINA
KOREA
MEXICO
TAIWAN
80
70
60
50
40
30
20
10
0
Share (%)
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Year


Total Imports of Business, Professional, and Technical Services
Source: BEA
Unaffiliated
Affiliated
Millions of 1997 Dollars
35000
30000
25000
20000
15000
10000
5000
0
1997
1998
1999
2000
2001
2002
2003
2004
Year

But world is not (yet) flat

- Trade in tasks is still costly and varies widely across different tasks
  - "Routine" tasks vs. "Nonroutine" tasks (Autor, Levy and Murnane (ALM), 2003)
    - ALM document an increase in the number of "Nonroutine" tasks relative to "Routine" tasks in the US
  - Tasks that require "Codifiable" information and those that require "Tacit" information (Leamer and Storper, 2001)
  - Tasks that require physical contact and geographic proximity and those that generate outputs that can be delivered impersonally and from a distance (Blinder, 2006)
- There is a less than perfect relationship between the suitability of a task for offshoring and the level of skill required to perform the job

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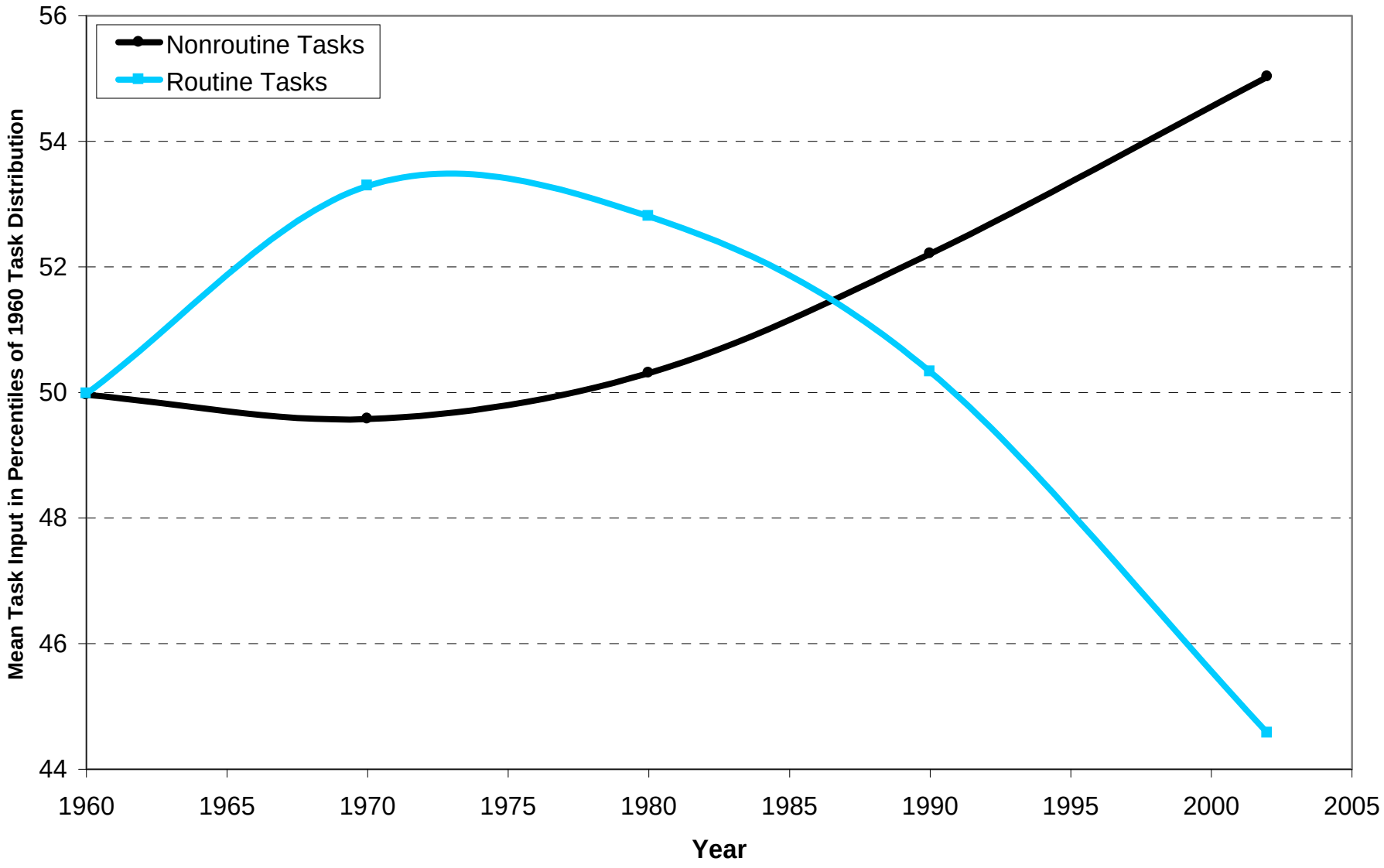
Trends in Nonroutine and Routine Tasks

Source: Autor, Levy and Murnane (2003)



Towards a New Paradigm

- Our approach begins with a different conceptualization of the production process
  - Production of every good requires the performance of a continuum of tasks by each of the factors of production
  - Tasks might be performed in different locations
  - Firms are motivated to offshore tasks by factor-cost savings, but trading tasks is costly
- More general, but here we develop a model with two industries, perfect competition, and an arbitrary number of factors greater than one
- We then study how decreases in offshoring costs affect the wages of different types of labor
- Perhaps surprisingly, we find that low-skilled workers may benefit from the production of low-skilled tasks abroad

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  - GE structure in these analyses has been kept to a bare minimum
  - Hard to study GE implications of offshoring
- 'Fragmentation': Jones and Kierzkowski (1990, 2001), Deardorff (2001a, 2001b) and Kohler (2004)
  - No marginal decisions about how to organize production
  - Many different configurations could characterize an equilibrium
- 'Intermediate Goods': Feenstra and Hanson (1996) and Yi (2003)
  - Uniform costs of trading intermediate goods
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The Model

- Model allows trade in tasks, as well as trade in goods
- Production involves a continuum of L tasks, continuum of H tasks, etc., possibly with substitution
- Industries differ in factor intensity, as usual
- Normalize measure of tasks of each type to one, and model factor intensity differences as different required amounts of factors per task
    - Equivalently: different measures of tasks, with one unit of factor per task
- Cost of offshoring task i is given by $\beta t(i) \geq 1$
- Order tasks so $t'(i) \geq 0$ and assume $t(i)$ continuously differentiable
- For the moment only L-tasks can be offshored and same $t(i)$ schedule in each industry

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- Normalize measure of tasks of each type to one, and model factor intensity differences as different required amounts of factors per task
    - Equivalently: different measures of tasks, with one unit of factor per task
- Cost of offshoring task i is given by $\beta t(i) \geq 1$
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Firm's Problem

- Consider production in sector j
- Assume firms, or industry, produces using a Constant Returns to Scale technology
- Firms maximize profits

$$\max_{Y_j, I_j} p_j Y_j - c_j Y_j$$

where

$$c_j = w a_{Lj}(\cdot)(1 - I) + w^* a_{Lj}(\cdot) \int_0^I \beta t(i) di + s a_{Hj}(\cdot) + \ldots$$

- Firm will offshore tasks $[0, I]$ where

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and if the firm produces a positive amount

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Marginal Costs

- Cost of producing good j using home technology are given by

$$\begin{aligned} c_j &= wa_{Lj}(\cdot)(1-I) + w^* a_{Lj}(\cdot)\int_0^I \beta t(i)di + sa_{Hj}(\cdot) + \ldots \\ &= wa_{Lj}(\cdot)(1-I) + wa_{Lj}(\cdot)\frac{\int_0^I t(i)di}{t(I)} + sa_{Hj}(\cdot) + \ldots \\ &= wa_{Lj}(\cdot)\,\Omega(I) + sa_{Hj}(\cdot) + \ldots \end{aligned}$$

where

$$\Omega(I) = 1 - I + \frac{\int_0^I t(i)di}{t(I)} \qquad \text{and} \qquad \Omega'(I) = -\frac{\int_0^I t(i)di}{t^2(I)}t'(I) \leq 0$$

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The Three Effects of Offshoring

- To allow for all the potential effects of offshoring, we need a model with (at least) three factors and (at least) two goods
- Price less or equal than unit cost implies

$$\begin{aligned} 1 &= w\Omega a_{Lx}\left(s/w\Omega,\cdot\right) + s a_{Hx}\left(s/w\Omega,\cdot\right) + \ldots \\ p &\leq w\Omega a_{Ly}\left(s/w\Omega,\cdot\right) + s a_{Hy}\left(s/w\Omega,\cdot\right) + \ldots \end{aligned}$$

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$$\begin{aligned} a_{Lx}x(1-I) + a_{Ly}y(1-I) &= L \\ \Leftrightarrow a_{Lx}x + a_{Ly}y &= \frac{L}{1-I} \\ a_{Fx}x + a_{Fy}y &= F \text{ for } F = H, \ldots \end{aligned}$$

- These $2+v$ equations determine $x, y, \Omega w, s$ as functions of p, I and $L, H, \ldots$

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Small Heckscher-Ohlin Economy

- Consider a small economy (p and w^* fixed) with two factors, L and H and two goods. Then

$$\begin{aligned} \theta_{Lx}\left(\hat{w}+\hat{\Omega}\right)+\theta_{Hx}\hat{s} &= 0 \\ \theta_{Ly}\left(\hat{w}+\hat{\Omega}\right)+\theta_{Hy}\hat{s} &= \hat{p}=0 \end{aligned}$$

  which implies that

$$\hat{w}=-\hat{\Omega} \qquad \text{and} \qquad \hat{s}=0$$

- Since $w=\beta t(I)w^*$ and w^* is fixed, $\hat{w}=\hat{\beta}+\hat{t}(I)$, so

$$\frac{dI}{d\beta}=-\frac{(1-I)\,t(I)+\int_0^I t(i)di}{\beta t'(I)(1-I)}<0$$

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Why Does Unskilled Labor Benefit?

- Offshoring increases productivity of workers that remain employed at home
  - Lower β implies a lower cost of offshoring the marginal tasks and lower cost of offshoring all the infra-marginal tasks
  - Benefits from improved offshoring in proportion to the share of low-skilled labor
- Compare: Offshoring vs. Immigration
  - For marginal immigrant, $w = w^* \beta \tau(I)$
  - But domestic firms may pay w to all immigrants, unless they can price discriminate. Then rents may go to immigrants
- Why no Labor-Supply Effect?
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Characterization

- The effect of changes in β on wages is given by

$$\hat{w} = -\hat{\Omega} = -\hat{\beta}\frac{1}{(1-I)}\int_0^I \frac{t(i)}{t(I)}di$$

  - If $I = 0$, $\hat{w} = -\hat{\Omega} = 0$, and so there is no productivity effect
  - If $I > 0$, $\hat{w} = -\hat{\Omega} > 0$. Moreover, if $\eta(i) = t'(i)(1-i)/t(i)$ constant or $\eta(i) < 1$ for all i, the productivity effect increases with I everywhere

- What if easier to offshore in L-intensive industry relative to H-intensive industry?
  - This strengthens effect. If offshoring only possible in L-intensive industry y,

$$\hat{w} = -\hat{\Omega}\left(\frac{\theta_{Hx}\theta_{Ly}}{\theta_{Hx}\theta_{Ly} - \theta_{Lx}\theta_{Hy}}\right) > -\hat{\Omega} > 0 \qquad \text{and} \qquad \hat{s} = -\frac{\theta_{Lx}}{\theta_{Hx}}\hat{w} < 0$$

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  where Ω_x is defined analogously to Ω_y.
- The factor-share ratios are such that $\theta_{Hx}/\theta_{Lx} > \theta_{Hy}/\theta_{Ly}$ so $\hat{w} > 0$ and $\hat{s} < 0$ if $-\hat{\Omega}_y > -\hat{\Omega}_x$.
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- Take, for example, the case in which $t_x(i) = \alpha t_y(i)$ with common factor β.
  - Define $\eta_j(i) \equiv t_j'(i)(1-i)/t_j(i)$ for $i = x, y$
  - Then, if η_x and η_y are constants, or if $\eta_x(I_x) < 1$ and $\eta_y(I_y) < 1$, $\alpha < 1$ implies $I_x > I_y$ and $-\hat{\Omega}_y > -\hat{\Omega}_x$

Characterization

- In general

$$\hat{w} = \frac{\frac{\theta_{Hx}}{\theta_{Lx}}\left(-\hat{\Omega}_y\right) - \frac{\theta_{Hy}}{\theta_{Ly}}\left(-\hat{\Omega}_x\right)}{\frac{\theta_{Hx}}{\theta_{Lx}} - \frac{\theta_{Hy}}{\theta_{Ly}}}$$

$$\hat{s} = \frac{\theta_{Ly}\theta_{Lx}}{\theta_{Ly} - \theta_{Lx}}\left[\left(-\hat{\Omega}_x\right) - \left(-\hat{\Omega}_y\right)\right]$$

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Large Heckscher-Ohlin Economy

- Need a reason for differences in factor prices across countries
  - Assume foreign country has inferior technology so that offshoring flows in one direction (with $\beta t(i) \geq 1$ all i)
  - Let A^* measure Hicks-neutral technological inferiority in both industries, then with incomplete specialization

$$A^* a_{Lx}^* w^* + A^* a_{Hx}^* s^* = 1$$

$$A^* a_{Ly}^* w^* + A^* a_{Hy}^* s^* = p$$

- Incomplete specialization implies that in equilibrium there is adjusted Factor Price Equalization:

$$\begin{aligned} w\Omega &= w^* A^* \\ s &= s^* A^* \end{aligned}$$

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- This implies that both countries have similar a_{Fj}'s, so factor clearing conditions are given by

$$A^* a_{Lx} x^* + A^* a_{Ly} y^* + \beta \int_0^I t(i)di \left(a_{Lx} x + a_{Ly} y\right) = L^*$$

$$A^* a_{Hx} x^* + A^* a_{Hy} y^* = H^*$$

or

$$\begin{aligned} a_{Lx} x^* + a_{Ly} y^* &= \frac{L^*}{A^*} - \frac{\beta}{(1-I)\,A^*} \left[\int_0^I t(i)di\right] L \\ a_{Hx} x^* + a_{Hy} y^* &= \frac{H^*}{A^*} \end{aligned}$$

Large Heckscher-Ohlin Economy

- After some algebra we obtain

$$x + x^* = \frac{a_{Ly}\left(H + \frac{H^*}{A^*}\right) - a_{Hy}\left(\frac{L^*}{A^*} + \frac{L}{\Omega}\right)}{\Delta_a}$$

$$y + y^* = \frac{a_{Hx}\left(\frac{L^*}{A^*} + \frac{L}{\Omega}\right) - a_{Lx}\left(H + \frac{H^*}{A^*}\right)}{\Delta_a}$$

where

$$\Delta_a = a_{Hx}a_{Ly} - a_{Lx}a_{Hy} > 0$$

- So $\beta \downarrow \Rightarrow I \uparrow \Rightarrow \Omega \downarrow \Rightarrow \frac{x+x^*}{y+y^*} \downarrow \Rightarrow p \downarrow$ (with standard preferences)
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- Hence, $p \downarrow$ implies Relative Price Effect favors H and harms L
- Overall:

$$\hat{w} = -\hat{\Omega} + \mu_1 \hat{p}$$

and

$$\hat{s} = -\mu_3 \hat{p}$$

  - H must gain, L may gain or lose
  - Possible Pareto gains for home country if productivity effect large enough

- Note complete analogy with labor-augmenting technological progress in home country

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The Labor-Supply Effect

- Present as long as there are more factors than goods
  - Short term effect if factors are specific because of frictions on factor mobility across industries
- Simplest setting to illustrate the effect is small country specialized in producing one good with two factors
- Then, if price of good normalized to one, equilibrium is given by

$$\Omega w a_L + s a_H = 1$$

$$a_L x = \frac{L}{1 - I}$$

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- Differentiate to obtain

$$\theta_L \left(\hat{w} + \hat{\Omega}\right) + (1 - \theta_L)\,\hat{s} = 0$$

and since

$$\frac{a_L}{a_H} H = \frac{L}{1 - I}$$

if σ is the elasticity of substitution between low and high-skilled labor

$$\sigma(\hat{s} - \hat{w} - \hat{\Omega}) = \frac{dI}{1 - I}$$

- So

$$\begin{aligned} \hat{w} &= -\hat{\Omega} - \frac{1 - \theta_L}{\sigma} \frac{dI}{1 - I} \\ \hat{s} &= \frac{1 - \theta_L}{\sigma} \frac{dI}{1 - I} > 0 \end{aligned}$$

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- From the definition of $\Omega = 1 - I + \int_0^I t(i)/t(I)\,di$ we know that

$$\hat{\Omega} = -\eta\gamma\frac{dI}{1-I}$$

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$$\begin{aligned}\eta(I) &= \frac{t'(I)(1-I)}{t(I)},\\ \gamma(I) &= \frac{\int_0^I t(i)di}{(1-I)t(I)+\int_0^I t(i)di} \in [0,1]\end{aligned}$$

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Offshoring Skill-Intensive Tasks

- Recent policy debate has focused on offshoring of white collar jobs
- May interpret this as offshoring of H-tasks
- Offshoring of H-tasks can be easily incorporated, for example, in small HO economy. Then

$$w = w^* \beta_L t_L(I_L) \qquad \text{and} \qquad s = s^* \beta_H t_H(I_H)$$

and

$$a_{Lx} w \Omega_L + a_{Hx} s \Omega_H = 1$$
$$a_{Ly} w \Omega_L + a_{Hy} s \Omega_H = p$$

determine $I_L(\beta_L)$ and $I_H(\beta_H)$ and

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- Thus, $\beta_H \downarrow$ implies $s \uparrow$, w unchanged

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Back-of-the-Envelope Calculation

- US wages for blue collar workers roughly flat over last 10 years
- Assume A has been rising in US at rate of TFP growth
- Look at TOT in manufactured goods vis-a-vis non-industrialized countries
  - TOT have been improving dramatically for US
- Take plausible values for Stolper-Samuelson coefficient, using labor shares in various import and export industries. These imply that low-skill wages should be falling, despite TFP improvement
- Thus, positive residual
  - A bit heroic to associate this with net positive productivity plus labor supply effects of offshoring
  - But, at least data leaves room for this interpretation

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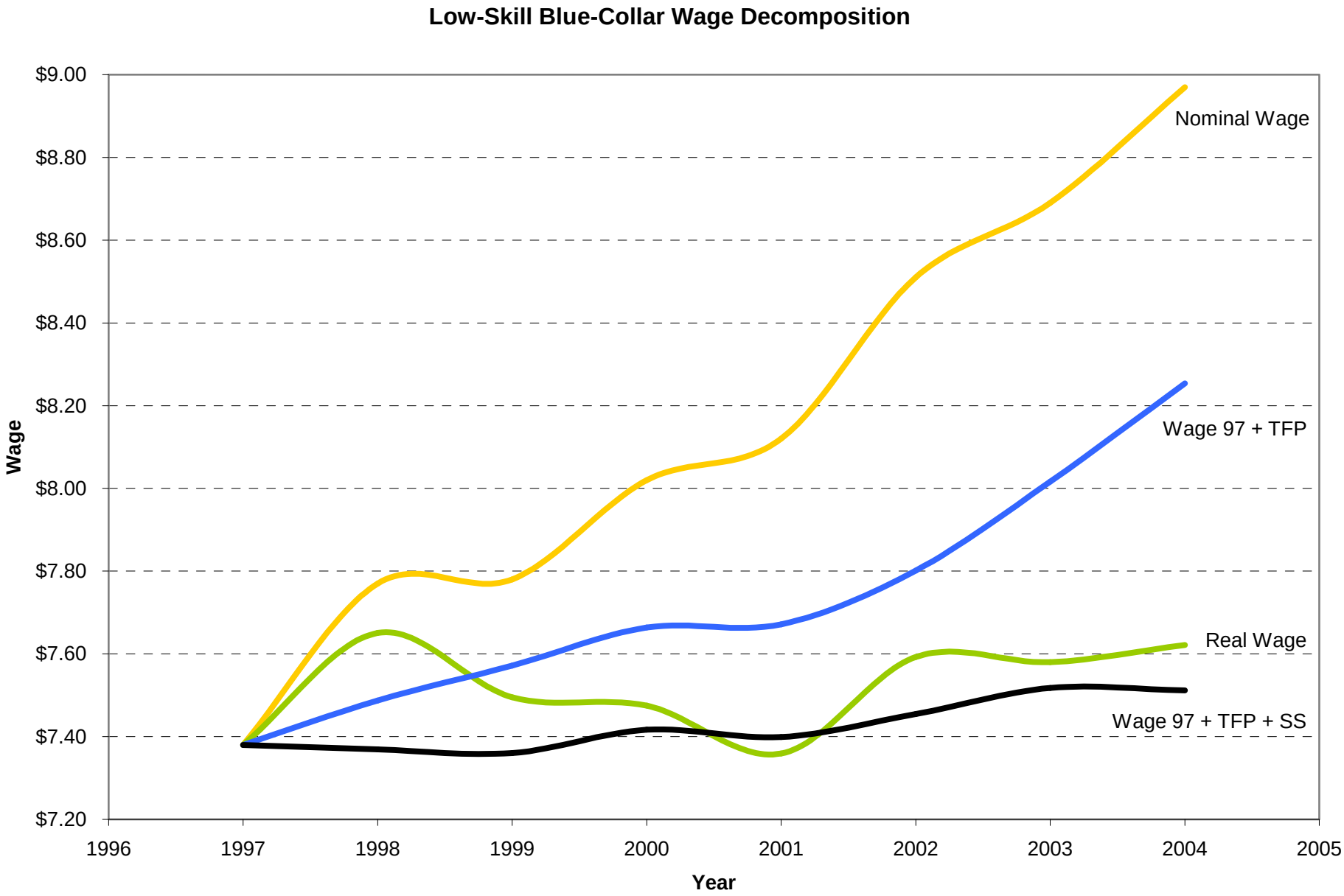
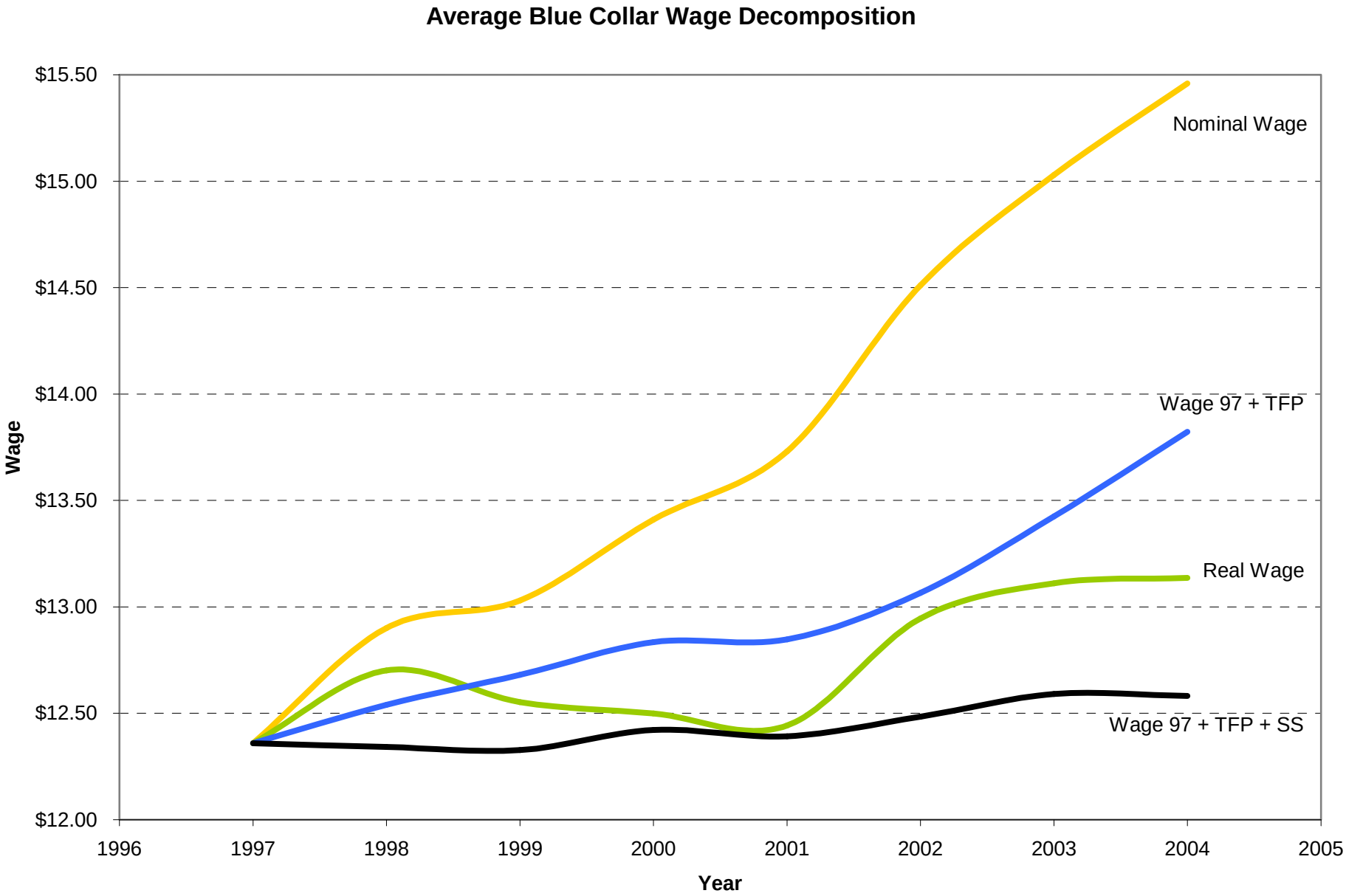

Low-Skill Blue-Collar Wage Decomposition
$9.00
$8.80
$8.60
$8.40
$8.20
$8.00
$7.80
$7.60
$7.40
$7.20
Wage
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Year
Nominal Wage
Wage 97 + TFP
Real Wage
Wage 97 + TFP + SS


Average Blue Collar Wage Decomposition
$15.50
$15.00
$14.50
$14.00
$13.50
$13.00
$12.50
$12.00
Wage
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Year
Nominal Wage
Wage 97 + TFP
Real Wage
Wage 97 + TFP + SS

Conclusion

- In the past:
  - Countries produced mostly complete products that they consumed and traded with other nations
  - Gains from worker specialization by dividing the production process into a variety of tasks required proximity: Industrial factory
- Today:
  - Drastic reductions in transport and communication costs have facilitated direct trade in tasks
  - Traditional benefits from worker specialization plus gains generated when tasks are performed at the lowest cost location
- Proposed a new paradigm where task trade takes center stage and:

  Offshoring of a particular factor's tasks is equivalent to factor-augmenting technological progress

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