A New Growth Engine for Japan: Women in STEM Fields

Japan

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ABSTRACT: Despite recent improvements in female labor force participation, women remain under-represented in STEM fields in Japan. Given the close link between STEM workers and innovation, encouraging women to pursue STEM careers could boost growth potential. Using a calibrated endogenous growth model with STEM talent, this paper quantifies the potential gains from eliminating barriers to STEM fields among women. The findings suggest that bridging the gender gap in STEM fields can boost TFP growth by 20 percent and consumption-equivalent welfare by 4 percent in Japan.

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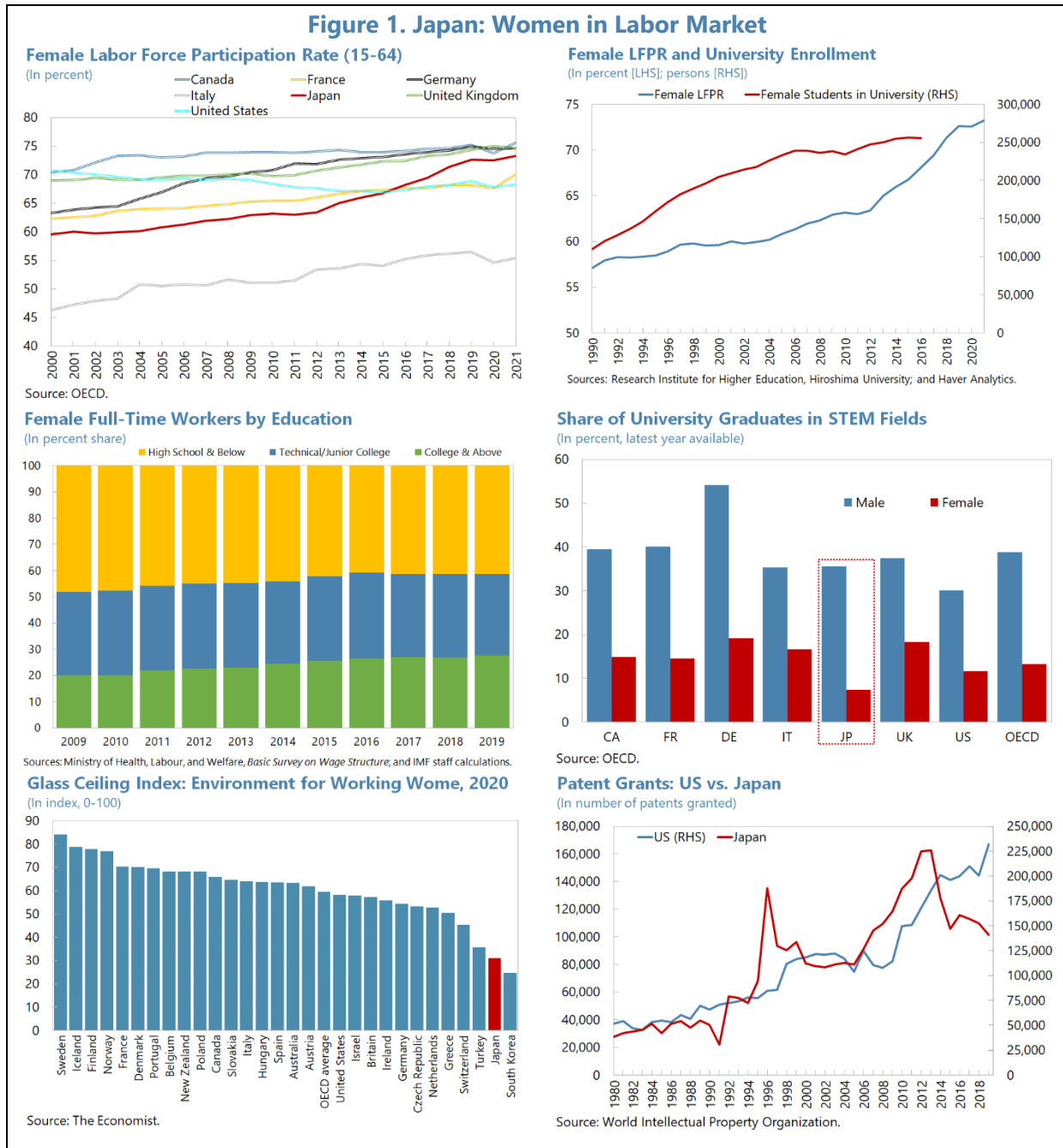| Approved By	Prepared By Rui Xu.
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A NEW GROWTH ENGINE FOR JAPAN: WOMEN IN STEM FIELDS[1]

A. Introduction

1.   Since Abenomics, more women have joined the labor force amid economic recovery and improved childcare support. The female labor force participation rate rose by 10 percentage points in the last 10 years, approaching the highest level among G7 countries. The education level among female workers has also improved significantly, suggesting that new female workers are better educated. This is in line with the sharp rise in female university students since 1990.

2.   However, women are still severely under-represented in STEM fields. Among G7 countries, the share of women enrolled in science, technology, engineering, and mathematics (STEM) fields in university is the lowest in Japan at around 7 percent. The share is likely lower among STEM professions as women tend to drop out throughout their professional career.

3.   In addition to explicit gender pay gaps, cultural biases and adverse working environments are discouraging women from pursuing STEM careers. Starting from junior school, science-related subjects are less popular among girls than among boys. The low proportions of women in STEM fields can be attributed to three factors according to Homma et al. (2013): 1) few role models for younger women; 2) unconscious bias among male researchers towards female colleagues; and 3) avoiding competition and underestimation of ability by women themselves. These factors are compounded by the social norm of long working hours and mandatory socializing after work in a male-dominated society. According to the Glass Ceiling index compiled by The Economist magazine, Japan is the second worst in terms of environment for working women. These gender biases discourage women from entering STEM fields and hurt economic growth due to talent misallocation (see Hsieh et al. for a related study on the United States).

4.   Encouraging more women to join STEM fields could help spark innovation and lift potential growth rates in an ageing society. The growth economics literature has established the key role of STEM workers as fundamental inputs for innovation and the main driver of productivity growth (see Griliches 1992 and Jones 1995). Innovation seems to be slowing in Japan, with patent grants declining since 2012. As the labor force continues to age and labor force participation of female and senior workers peaks, the only way to boost potential growth is to improve total factor productivity through technological progress. Tapping into the underutilized talent of female workers is one of the most promising growth engines for Japan.

5.   This paper quantifies the potential gains from eliminating barriers to STEM fields among women. Using an endogenous growth model with STEM talent, this paper finds that

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bridging the gender gap in STEM fields can encourage more women to join the STEM fields and boost the TFP growth by 20 percent.
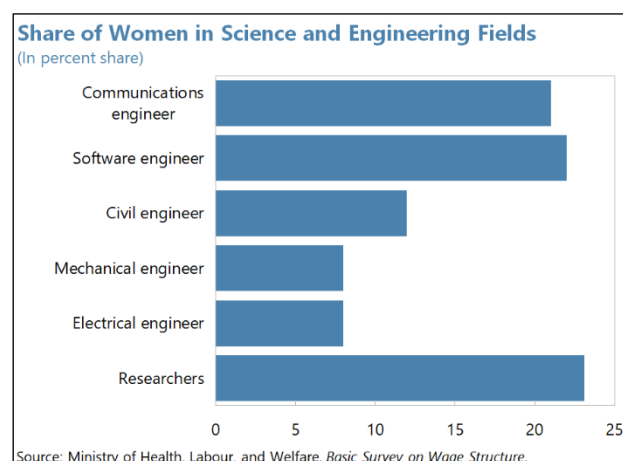
Figure 1. Japan: Women in Labor Market

Female Labor Force Participation Rate (15-64)
(In percent)

Canada, France, Germany, Italy, Japan, United Kingdom, United States

Source: OECD.

Female LFPR and University Enrollment
(In percent [LHS]; persons [RHS])

Female LFPR — Female Students in University (RHS)

Sources: Research Institute for Higher Education, Hiroshima University; and Haver Analytics.

Female Full-Time Workers by Education
(In percent share)

High School & Below | Technical/Junior College | College & Above

Sources: Ministry of Health, Labour, and Welfare, *Basic Survey on Wage Structure*; and IMF staff calculations.

Share of University Graduates in STEM Fields
(In percent, latest year available)

Male | Female

CA FR DE IT JP UK US OECD

Source: OECD.

Glass Ceiling Index: Environment for Working Wome, 2020
(In index, 0-100)

Sweden, Iceland, Finland, Norway, France, Denmark, Portugal, Belgium, New Zealand, Poland, Canada, Slovakia, Italy, Hungary, Spain, Australia, Austria, OECD average, United States, Israel, Britain, Ireland, Germany, Czech Republic, Netherlands, Greece, Switzerland, Turkey, Japan, South Korea

Source: The Economist.

Patent Grants: US vs. Japan
(In number of patents granted)

US (RHS) — Japan

Source: World Intellectual Property Organization.

B. An Endogenous Growth Model with STEM Talent

6.   As in a standard endogenous growth model, growth is driven by research conducted by firms that are under monopolistic competition. While final goods producers make no profit under perfect competition, the intermediate goods producers make monopolistic profits as their products are imperfect substitutes. The profits provide incentives to

hire researchers to do R&D and invent better intermediate products. In this paper, we will treat STEM workers as researchers, and use these two terms interchangeably. In equilibrium, more R&D will lead to higher growth, but the amount of R&D depends on the country's efficiency in innovation. The detailed model setup is included in Box 1.

7.   Each person, regardless of gender, is endowed with a different level of talent for research activity but the same talent for final goods production. The research talent is assumed to follow Pareto distribution as in the literature. All workers in the final goods sector will be paid the same wage whereas researchers will be paid based on their specific research talent. This implies that only people who are very talented in research will choose to be researchers.

8.   Based on the model, discrimination against female researchers will raise the bar for women researchers and reduce the number of women in STEM fields. The discrimination could come from either schooling biases or labor market discrimination. Schooling bias is modelled as a uniform discount factor on women's research *talent*, whereas labor market discrimination is modelled as a uniform discount factor on female researchers' *wages* with no effect on productivity. Both types of discrimination will discourage women from entering STEM fields and thus reduce equilibrium growth rates. The schooling bias matters more for economic growth because it lowers female researchers' productivity.

Share of Women in Science and Engineering Fields
(In percent share)

Field	
Communications engineer	
Software engineer	
Civil engineer	
Mechanical engineer	
Electrical engineer	
Researchers	

Source: Ministry of Health, Labour, and Welfare, *Basic Survey on Wage Structure*.

9.   The discrimination against female researchers would lower long-term growth rates due to talent misallocation. To overcome the schooling bias and the gender pay gap, women need to be more talented than their male peers to pursue STEM careers. The higher talent cutoff leads to talent misallocation as fewer women will choose STEM fields. Such misallocation would reduce long-run growth, as it lowers total research talent devoted to R&D.

10.   Therefore, eliminating discrimination against women in STEM fields will boost long-run growth and increase the income of female researchers. Faster growth will benefit the workers as well. The effect on male researchers is ambiguous. On one hand, higher growth rates would put their consumption on a steeper trajectory. On the other hand, more women in STEM fields will drive down the unit wage for researchers and raise the bar for male researchers. The net effect on male researchers' welfare is a quantitative question. We will calculate consumption-equivalent welfare change (Lucas 1987) to evaluate the net effect on each agent (see Box 2).

11. **The model is calibrated to Japan by matching key moments in macro data.** One challenge is to separate schooling bias from labor market discrimination. With only wage and occupation data, the two biases are isomorphic and thus cannot be separately identified. To identify schooling bias, research efficiency data among women vs. men is needed, but such data are not typically unavailable. Naïve publication data would understate the productivity of female researchers due to gender discrimination, as shown in Bendels et al. (2018). For the baseline calibration, we assume all misallocation comes from labor market discrimination. This provides a more conservative estimate of the gains from removing the gender bias. As a robustness check, we consider an alternative scenario where half of the discrimination comes from schooling bias.

Table 1. Japan: Parameter Calibration

Parameters Set Externally		
Parameter	Explanation	Source, Value
α	1-labor share	PWT10, 0.4
ρ	Discount rate	0.02
γ	Risk Aversion (CRRA)	Hall (2009), 2.0

Parameter Set Independently		
Parameter	Explanation	Source, Value
θ	Pareto shape parameter	Basic Survey on Wage Structure, 3.5

Parameters Estimated Jointly		
Parameter	Targeted moments, Value	Source
$\eta=0.024$	TFP growth rate	PWT10
$\lambda=2.4$	% of STEM workers among male: 10%	Basic Survey on Wage Structure
$\delta=0.4$	% of STEM workers among female: 2%	Basic Survey on Wage Structure

Source: IMF staff estimates.

C. Results

12. **Bridging the gender gap in STEM fields could raise TFP growth by 20 percent.** The increase mainly reflects an increase in the number of researchers by correcting misallocation of talent. Removing discrimination against female researchers would increase their wages and incentivize more women to pursue a career in STEM fields. However, the additional supply of female researchers would push down the wage for each unit of research talent and drive out the marginal male researchers. The total number of

Illustration of the Effects of Gender Discrimination
(In units)

Source: IMF staff estimates.
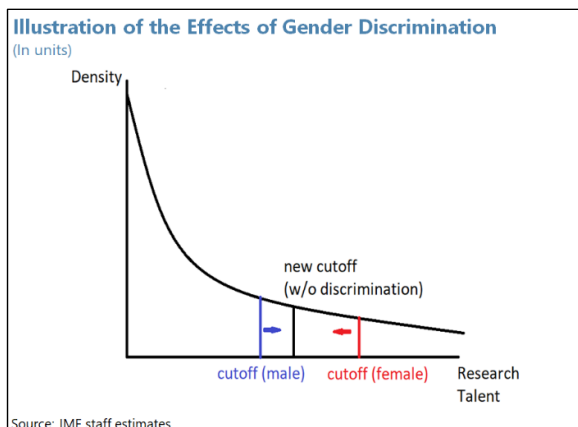
researchers would still increase by about 20 percent as the additional female researchers outnumber the replaced male ones.

13.   The welfare impact differs across agents, with the most gains among female scientists while male scientists would be worse off. Due to faster TFP growth, output and wages will grow along a steeper trajectory, benefiting all agents. However, the entry of new female scientists will push down the wage for all researchers in the near term. For male researchers, the crowding-out effect dominates the growth effect, leading to welfare loss of 5.3 percent. For female researchers, the income boost from removing gender discrimination is much stronger than the crowding out effect, leading to a welfare gain of up to 12.5 percent. For workers, their welfare will improve in line with faster TFP growth by about 4.2 percent. Some agents would change professions, i.e., the marginal male researchers would be crowded out due to entrance of new female researchers. Their welfare gains depend on the individual's research talent.

Table 2. Japan: Welfare Impact of Removing Barriers to Female STEM Workers					
% change	Old female researchers	New female researchers	Remaining male researchers	Male researchers who dropped out	Workers
CE Welfare	12.5	[4.2~12.5]	-5.3	[-5.3,4.2]	4.2
Source: IMF staff estimates.					

14.   Average consumption-equivalent welfare would rise by about 4 percent. The benefit is quantitatively significant considering the demographic headwinds in Japan. For reference, the welfare gains from a 10-percentage point increase in female labor force participation rate (LFPR) are only about 3.5 percent given the current labor market structure. As the participation rate plateaus, more emphasis should be on removing gender pay gaps and discrimination, which would incentivize women to undertake more productive and growth-enhancing jobs.

15.   The gains would be larger if we also consider potential schooling barriers for women in STEM fields. Schooling barriers capture the cultural and societal bias against girls in STEM fields. By discouraging girls from pursuing STEM education, women's effective research talent is discounted and their relative pay in STEM fields would drop. Removing such barriers will not only attract new female researchers, but also increase the effective research talent of the existing female researchers. Assuming that half of the distortion comes from schooling, removing the schooling barriers and the pay gap can boost TFP growth by 26 percent and average welfare by 4.5 percent.

D. Policy Implications

16.   Policies that promote female STEM workers should remove both financial and non-financial barriers. First, Japanese women face explicit pay gaps in nominal income. Among OECD countries, Japan's gender pay gap is the third highest. Second, female workers face
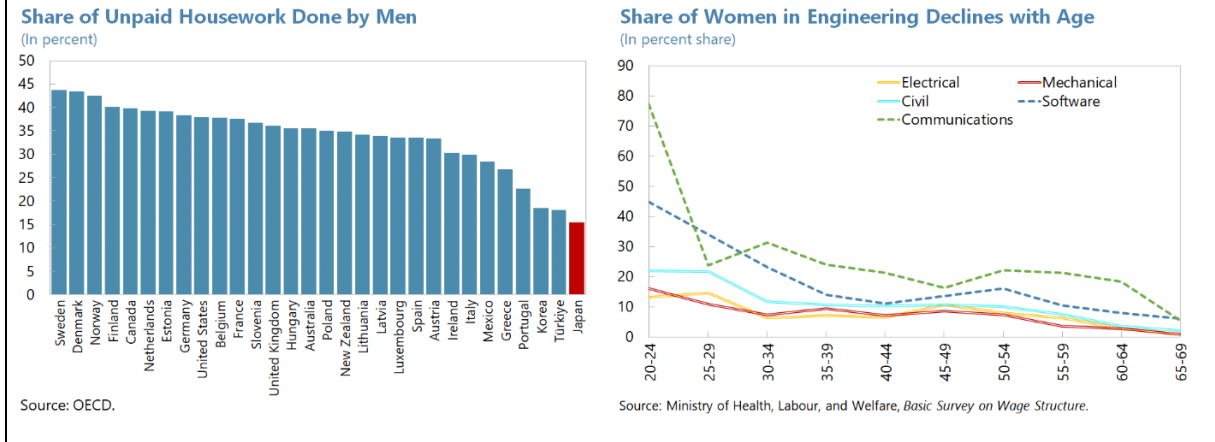
implicit pay gaps due to disproportionate family care burdens and work-place discrimination. Compared to other OECD countries, Japanese men do the least amount of housework, making it difficult for working moms to keep their full-time jobs. 30 percent of women quit their jobs when they give birth, and many do not come back as full-time workers under the rigid labor market structure. In addition, many managers are hostile towards working moms—one out of every five pregnant full-time working women have experienced maternity harassment according to the Japan Institute for Labour Policy and Training. Although the maternity leave policy is generous in Japan, the harassment may discourage women from returning to their full-time positions after childbirth given no legal consequences for maternity harassment. And third, cultural bias and social stereotypes are preventing young girls from exploring the STEM fields in schools.

17.   The government can help reduce the explicit gender pay gap through policies and leading by example. The recent "framework policies" that require companies to increase the transparency of their gender wage gap is a welcome step. In addition, public agencies should promote female leaders to set an example for the private sector. Public universities can consider using female-specific quotas to improve diversity and representation of women in STEM fields.

18.   Work style reforms and a more flexible labor market can help address the implicit gender pay gap. Despite the generous parental leave policy on paper, very few men take childcare leave lest they disappoint their managers and coworkers. The government is trying to double the number of men taking paternity leave by 2025, but mandatory leave policies may be needed to achieve that. Reducing working hours and adopting flexible work arrangements (such as teleworking) are needed to allow men to contribute more to housework so that women can retain their full-time jobs. To help women reenter the labor market as full-time workers, the labor market in STEM fields needs to be more flexible, with hiring and promotion based on merit instead of seniority. As an example, more flexible hiring policies in medical and legal fields (likely due to the certificate requirement) have allowed women to reenter the labor force as full-time workers after childbirth.

19.   Parents, schools, and the society at large should eliminate gender stereotyping and explore the use of quotas to correct for gender biases. The gender stereotype that boys are better at math and science fields has been prevalent everywhere but is now gradually improving in the United States, China, and some other countries. A few factors have proved helpful. First, more training and workshops should take place to counter gender bias for teachers and parents. Second, the government and public universities should support female scientists through targeted research grants and special quotas. In the presence of gender bias in STEM fields, quotas are needed to correct for such biases and improve diversity. The recent decision by Tokyo Tech to introduce special quotas for female students is a welcome step. And third, role models and mentoring are essential for women in STEM given all the biases. Schools could invite successful female scientists to share their experiences. Women in senior positions can also mentor young colleagues on how to deal with conflicts between work and family.

Figure 2. Japan: Barriers to Female STEM Workers

Share of Unpaid Housework Done by Men
(In percent)

Share of Women in Engineering Declines with Age
(In percent share)

Source: OECD.

Source: Ministry of Health, Labour, and Welfare, *Basic Survey on Wage Structure.*

Box 1. Japan: Model Setup

The model is built on the endogenous growth model with quality ladders, adding agents with heterogeneous STEM talent. The agents maximize present discounted utility: $U(\epsilon, t) = \int_t^\infty e^{-\rho(\tau-t)} \cdot \frac{c(\epsilon,\tau)^{1-\gamma}-1}{1-\gamma} d\tau$. Each person is born with talent ϵ for STEM (i.e., research talent) drawn from a Pareto distribution. Agents choose to be a worker or a researcher given the prevailing wages and their research talent ϵ.

As in a standard endogenous growth model with quality ladders, there are two types of production activity. Final goods are produced using labor L_Y and all available intermediate goods (i.e., machines) $x(i, t)$: $Y(t) = \int_0^1 A(i, t)x(i, t)^\alpha di \cdot L_Y(t)^{1-\alpha}$. The machines have quality $A(i, t)$ and are imperfect substitutes. The machine producers can make monopolistic profits, which are used to innovate and improve the quality $A(i, t)$. Growth in the economy is driven by the rising quality of the machines.

The R&D process is a key aspect of the model. Researchers try to innovate, and they can succeed with a flow rate of η to come up with a new machine of quality $\lambda A(i, t)$. The aggregate arrival rate of ideas is then given by the success rate multiplier by the total human capital involved in research: $z(t) = \eta \cdot H_R(t)$. The researchers are paid based on the expected profits from inventing the new machines.

A decentralized equilibrium of the model consists of time paths of individual choices $\{c(\epsilon, t), a(\epsilon, t)\}_{t=0}^\infty$, average technology $\{A(t)\}_{t=0}^\infty$, efficiency wage of each occupation $\{w_Y(t), w_R(\epsilon, t)\}_{t=0}^\infty$, labor demand in final goods sector $\{L_Y(t)\}_{t=0}^\infty$, aggregate quantities $\{Y(t), X(t), C(t)\}_{t=0}^\infty$, interest rate $\{r(t)\}_{t=0}^\infty$ and talent cutoff of researchers $\{\epsilon^*(t)\}_{t=0}^\infty$ such that

- Agents maximize utility;

- Demand of labor and intermediate goods is given by the final goods sector;

- Each monopolist of intermediate goods maximizes profits;

- There is free entry of intermediate firms, requiring $w_R(t)$ to equal to the value of innovation;

- An individual chooses to be a STEM worker if her talent ϵ is greater than the cutoff ϵ^*, where ϵ^* is pinned down by $w_Y(t) = \epsilon^*(t)w_R(t)$; and

- Growth is pinned down by the amount of total STEM talent among researchers.

Gender discrimination in STEM fields incorporates both explicit pay gaps and implicit barriers. For simplicity, the discrimination is captured by a discount factor (i.e., δ) on female researcher's wages in the model. The talent cutoff for female researchers $\epsilon_F^*(t)$ is pinned down by $w_Y(t) = \epsilon_F^*(t)(1 - \delta) \cdot w_R^F(t)$.

Box 2. Japan: Consumption-Equivalent Welfare

As in Lucas (1987), an individual's welfare change is defined as the amount of extra consumption $\omega(\epsilon)$ that a rational consumer would require in order to be indifferent between the new equilibrium (after removing the barriers to women in STEM) and the old equilibrium. $\omega(\epsilon)$ would differ across individuals depending on their research talent ϵ and gender.

$$\int_0^\infty e^{-\rho t} \cdot \frac{\left[(1 + \omega(\epsilon)) \cdot c_t^{old}(\epsilon)\right]^{1-\gamma}}{1-\gamma} dt = \int_0^\infty e^{-\rho t} \cdot \frac{[c_t^{new}(\epsilon)]^{1-\gamma}}{1-\gamma} dt$$

The average welfare change ω is calculated using the total welfare of all individuals, as shown below.

$$\int_0^\infty e^{-\rho t} \cdot \int_1^\infty \frac{[(1 + \omega) \cdot c_t^{old}(\epsilon)]^{1-\gamma}}{1-\gamma} f(\epsilon) d\epsilon \cdot dt = \int_0^\infty e^{-\rho t} \cdot \int_1^\infty \frac{[c_t^{new}(\epsilon)]^{1-\gamma}}{1-\gamma} f(\epsilon) d\epsilon \cdot dt$$

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